Analysis and Projection of Multiregional Population Dynamics in China: 1950-2087

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Abstract

This research focuses on an analysis of multiregional population dynamics of China at two spatial levels. The first part of the thesis is about urban-rural population dynamics in China. The forces determining urbanization process are discussed. The concepts of multiregional population accounts and forward demographic rates are used to analyze the urban-rural population change. Urban-rural life tables and an urban-rural population projection model are developed. A demo-economic model is used to drive the urban-rural population migration and transition in the population projection model. Three urban-rural population projections are made for the period 1987-2087 assuming various fertility trends in urban and rural populations. A growth stage (before the late 2030s) and a stable stage (after the late 2030s) of population development in China are identified on the basis of these projection results.

The second part of the thesis is about multiregional (provincial level) population dynamics in China. The main features of the spatial distribution of China's population and regional trends in population change since the 1950s are examined. Fertility, mortality and migration analyses are carried out to reveal the major factors affecting regional disparities. Finally, a more precise and straightforward multiregional population projection model based on forward demographic rates is developed by introducing extended multiregional population accounts. The model is calibrated using 1982 census data and 1987 one-percent population sampling data to produce a multiregional population projection of China. Future provincial population trends are revealed.

The implications of the future long-term population trends both at the urban-rural and provincial levels are discussed in the concluding chapter of the thesis. Population growth will continue to be a major problem facing China in the next 40 years. Economic reform and development may have both negative and positive effects on population development. Smooth transition to a market economy, continued steady growth of China's economy and a slowdown of population growth will augur well for the future in China.

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1
Introduction

1.1 Population growth in China

China is a developing country with a population over 1100 millions which accounts for about one-fifth of the total population in the world. Several distinctive features about China's population can be identified. First, China's population has experienced rapid growth since the foundation of the People's Republic in October 1949. According to the State Statistical Bureau of China (SSB, 1991), China's population was 542 million by the end of 1949. It's population reached 600 million in 1954. Then China's population increased by 100 million in ten years and reached 700 million in 1964. In the next ten years, China's population increased by 200 million and reached 800 million in 1969 and 900 million in 1974 as China recovered from a socio-economic crisis in early 1960s. The population growth in China was slowed down in 1970s and 1980s due to the implementation of a series of large-scale birth control campaigns (Peng, 1991). However, the size of population growth was still immense. In the period of fourteen years from 1974 to 1988, another 200 million people were added to China's population. China's population reached 1000 million in 1981 and 1100 million in 1988. It can be realistically expected that China's population will pass the mark of 1200 million before the end of this century.

Second as already has been mentioned, dramatic fertility decline has been achieved in China since 1970 due to a series of birth control campaigns. The total fertility rate of China declined from 5.75 in 1970 to 2.62 in 1982 (Coale and Chen, 1987). The recent census showed that the total fertility rate further declined to 2.25 by 1990. This dramatic decline in fertility has resulted in a lower population growth rate in China in the 1980s than in many other populous developing countries such as India, Indonesia, Brazil, Pakistan, Bangladesh and Nigeria (SSB, 1991). However, the absolute size of population growth in China is still immense due to its huge population base and high proportion of childbearing-cohorts as mentioned above. According to this research, China' population may be expected to continue to grow in the next forty to fifty years and may reach a peak population around 1500 million.

Third, the distribution of China's population is extremely uneven over its huge territories. If a line was drawn roughly dividing China into south-east and north-west areas, over 94.4% of China's population reside in the south-east of China which accounts for only 42.9% of the total land area. Conversely, only 5.6% of China's population reside in the north-west of China, an area which accounts for 57.1% of the total land (Hu, 1986).

Fourth, regional population change is also uneven in China. The total fertility rate in urban areas is much lower than in rural areas. Population growth rates in provincial regions also vary significantly. According to two censuses in 1982 and 1992, Beijing, Ningxia and Guangdong have a growth rate over 17% between two censuses while Heilongjiang, Zhejiang and Sichuan have a growth rate under 9% in the same period. These features will be recurrent themes throughout the whole of this research.

1.2 Objectives of the research

There is much interest about China's population. Considerably detailed information has been made available about China's population since 1978. Precise description and analysis of China's population dynamics since 1950s have been made possible with the release of a series of censuses and survey data. With the fertility decline in China, there are also growing concerns about population ageing in China (Zeng, Zhang and Peng, 1990). However, most Chinese and foreign researchers have focused on the description and analysis of China's population in the past. Most of these studies treat China's population as a whole (Coale, 1984). Some research does take the spatial dimension into consideration (Hu and Zhang, 1984; Pannell and Torguson, 1991, Yang, 1991; Peng, 1991). For example, Peng (1991) documented and analyzed fertility transitions in China's urban-rural and provincial regions since the 1950s. Various regional fertility trends may have significant implications for future regional populations. For example, a region experiencing a low fertility rate for a long time is likely to face rapid population ageing in the future. Due to significant regional differentials in fertility rates, the population trend and population problems in one region may be different from another. Several national population projections for China have been made by Song et al. (1981) before the 1982 census, and by Jiang and Lan (1987) and Zhang (1987) using the 1982 census data. These national population projections only show an average trend in China's population as a whole. Population projections for various regions have also been carried out respectively to show their future population trends. The United Nations (1989; 1991) has also produced urban and rural population projections for China. However, these projections of urban and rural populations are calculated from the projected proportion of urban population and the total population, and vital age compositions of urban and rural populations are not available. These population projections are useful in the formation of family planning policies and planning of socio-economic developments for China as a whole and in various regions. For example, the launching of the " one-child campaign " in 1978 was based on the projection that population growth will continue to soar in China if each couple were allowed to have two children.

However, the various regional population projections may not be consistent with national projections if they are carried out independently. A multiregional population model is needed to make consistent regional and national population projections in the sense that interregional migrations can be projected systematically and consistent projections assumptions can be made. One major aim of this research is to develop multiregional population models at urban-rural and provincial levels so that consistent population projections can be made. At the first spatial level, China is divided into an urban region and a rural region. At the provincial level, the spatial population system of interest consists of twenty-nine provincial regions in China. Currently, there are thirty provincial regions under the administration of the People's Republic. The new province of Hainan, founded in 1988, is included in Guangdong province in this research. A systematic study of the multiregional population dynamics of China will be made to examine the regional differentials in population growth and the effects of various factors on these differentials. Consistent long-term multiregional population projections at two spatial levels of China will be made.

1.3 Methodology

This research will develop an alternative approach to multiregional population projection on the basis of forward demographic rates. Significant progress has already been made in the dynamic analysis and projection of spatial population systems (Rees, 1989; 1993). It has been recognized that two different approaches may need to be used to derive demographic rates on the basis of different types of migration measures (Rees, 1986). These are called transition and movement approaches. The transition approach uses the number of migrants who migrated within a fixed period or variable periods to measure migration. Each migrant is counted only once in the transition approach. The movement appoach uses the number of movement events made by migrants in a period to measure migration. Each movement event is counted once but a migrant may make multiple movements in a period and be counted more than once. It seems that earlier studies are mainly about the transition approach. Multiregional population models were developed to link populations at the begining and end of a period by survival rates and a growth matrix (Rogers, 1966, 1973; 1975). A major problem here is how to calculate survival rates or a growth matrix more precisely. A major improvement was the introduction of population accounts and occurrence-exposure rates which can be correctly and precisely defined (Rees and Wilson, 1977). Similar approaches were also developed for movement data (Rees, 1986; 1989). However, an iterative procedure is needed for population projections. In the case of movement data, a transition probabilities matrix can be usefully calculated by matrix inversion (Willekens and Drewe, 1984; Rogers and Willekens, 1986; Rees, 1989). An approximate version of occurrence-exposure rate definitions needs to be used if the matrix inversion approach is applied in the case of transition data. It has been found that forward demographic rates can be defined as well and they have unique relations with occurrence-exposure rates (Shen, 1994). Different population projection models can be developed on the basis of occurrence-exposure rates and forward rates respectively and both are correct if corresponding demographic rates are used. However, a forward demographic rates-based model does have the advantage that population projections can be carried out straightforwardly while an iterative procedure is needed for the occurrence-exposure rates-based population model. In this research, an approximate version of forward rates-based model will be developed for the analysis and projection of urban-rural population systems. A more precise multiregional population model will be developed using a set of extended population accounts for the analysis and projection of multiregional population systems at a provincial level.

1.4 Data

Four population censuses have been carried out in China since the foundation of the People's Republic. The first and second censuses were undertaken in 1953 and 1964 respectively. These two censuses probably aimed to examine the population situations facing the People's Republic after its foundation and the socio-economic crisis in early 1960s respectively. The data on these two censuses were kept secret and were not released until recently. The third census was conducted in 1982 with assistance from the United Nations after economic reform and open-door policies were introduced in 1978. The results of the 1982 census were released to the outside world immediately after its completion. In 1982, a national one per thousand population fertility sample survey was conducted by the State Family Planning Commission. In 1985, the first stage of an in-depth fertility survey was carried out in Shaanxi, Hebei and Shanghai. In 1987, the second stage was carried out in Beijing, Liaoning, Shandong, Guangdong, Guizhou and Gansu. A major one percent population sample survey was also carried out in 1987. The information on internal migration in China was made available from this survey. The fourth census was undertaken in 1990. Some data from this recent census have already been released. It can be expected that the next census will be carried out in 2000 which is the target year of the original modernization program in China.

The State Statistical Bureau (SSB) of China and its Department of Population Statistics (DPS) are responsible for the compilation and publishing of these population data. They also publish annually the Statistical Yearbook of China and the China Population Statistics Yearbook respectively. These yearbooks also include population data collected via the residence registration system administrated by the State Public Security Bureau.

According to the results of data quality control measures and related research, these census and survey data may be regarded as reliable and not subject to significant errors (Li, 1987; DPS, 1990). Some foreign researchers also concluded that these census data are of high quality (Banister, 1987).

The main data sources for this research are the 1987 one percent population sample survey (DPS, 1988a), the 1982 census (DPS, 1988b), the 1982 one per thousand fertility survey (Coale and Chen, 1987), the 1985 China in-depth fertility survey (DPS, 1986a, 1986b), the 1990 census (SSB, 1990a, 1990b, 1990c, 1990d), and the annual Statistical Yearbook of China and China Population Statistics Yearbook in various years.

1.5 Organization of the thesis

This research focuses on an analysis of multiregional population dynamics of China at two spatial levels. This introductory chapter discusses the objectives and methodology of the research. This chapter also discusses major data sources used in this study. The first part of the thesis is about the urban-rural population dynamics in China. The forces determining the urbanization process are discussed in chapter two. The concepts of multiregional population accounts and forward demographic rates are used to analyze urban-rural population change in chapter three. Urban-rural life tables are also constructed in chapter three. In chapter four, an urban-rural population projection model is developed. A demo-economic model is used to drive the urban-rural population migration and transition in the population projection model. Three urban-rural population projections are made for the period 1987-2087 assuming various fertility trends in urban and rural populations.

The second part of the thesis is about multiregional (provincial level) population dynamics in China. The main features of the spatial distribution of China's population and regional trends in population change since the 1950s are examined in chapter five. Fertility, mortality and migration analyses are carried out to reveal the major factors affecting regional disparities in chapters six and seven. In chapter eight, a more precise and straightforward multiregional population projection model based on forward demographic rates is developed by introducing extended multiregional population accounts. The model is calibrated using 1982 census data and 1987 one-percent population sampling data to produce a multiregional population projection for China.

The concluding chapter sums up the major findings and the implications of the future long-term population trends on socio-economic development in China are also discussed.

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2
Urbanization processes

2.1 Introduction

The first part of this thesis mainly concerns the urban-rural population dynamics of China. There is no doubt that urban-rural population change is a natural result of the urbanization process. Thus it is meaningful in this chapter to overview the forces driving the world-wide urbanization process in general and in particular produce an indication of the urbanization process in China. Section 2.2 will discuss the forces behind urbanization in general. Section 2.3 will discuss the urbanization trends and problems in China. Section 2.4 concludes this chapter.

2.2 Forces behind urbanization

About a century ago in 1899, Weber showed in his thesis *The Growth of Cities in the Nineteenth Century* that urbanization was the most remarkable social phenomenon in the nineteenth century (Weber, 1899). Today in 1994, when looking into the continuing urbanization of this century, it still can be said that urbanization is a remarkable phenomenon. While some developed countries had achieved high levels of urbanization in the last century, most urban growth worldwide has occurred in this century. In England, the urban population percentage of the total population had risen from 16.9 in 1801 to 53.7 by 1891 and in France from 24.4 in 1846 to 37.4 by 1891. In Japan, the urban population percentage rose from 18 in 1920 to 75 by 1975 (Hall, 1984); in Mexico from 50.7 in 1960 to 66.3 by 1980; in Brazil from 45.1 in 1960 to 74.4 by 1989; and in the former USSR from 47.9 in 1959 to 65.8 by 1989 (United Nations, 1962; 1991). In the world as a whole, the urban population percentage increased from 14.3 in 1920 to 41.2 by 1985. It is reliably predicted by some that by the year 2010, the entire world population will be more than 50 percent urbanized (Renaud,1981; United Nations, 1989).

One distinct feature of the urbanization of this century is its rapid increase in developing countries. According to the United Nations, between 1970 and 1975, the urban population of the less developed regions overtook that of the more developed regions. In 1985, 58 percent of the world's urban population was in the less developed regions (United Nations, 1989). Another feature of the urbanization in developing countries is that most market economy countries are believed to be overurbanized while most planned economy countries are considered underurbanized (Ofer, 1977; Ran and Berry, 1989). Chung Hyun Ro (1976) argued that the headlong rush to the capitals and metropolitan cities of Africa, Asia and Latin America is most intensive, massive and rapid in those very countries whose natural resources are underdeveloped. In planned economy countries, it is argued by some scholars that underurbanization is an explicit policy objective of socialist government (Ofer, 1977). It is expected that with economic reform in these countries, the underurbanization phenomenon may soon disappear and may even be replaced by overurbanization. For example, Ran and Berry (1989) suggest that China now appears to be overurbanizing.

From the above discussion about the urbanization trends in the world, it is clear that the urban population percentage has been increasing with time in both developed and developing countries in the last two centuries. It is most likely that this trend will continue especially in developing countries. Most developed countries on the other hand do not have much room for further urbanization and there the focus may be on the difficulties caused by inter-urban population dynamics.

It seems then that urbanization is an inevitable fate of the world's population. But why ? Many studies have been made to explore the forces driving the urbanization process (Weber, 1899; Renaud, 1981; Miyao, 1983; Hall, 1984; Lee, 1984; Timberlake and Lunday, 1985; Firebaugh, 1985).

The fundamental force of urbanization is industrialization with its associated economies of scale and agglomeration (see Davis, 1977). Industrialization has brought about the increase of productivity in both the urban and rural sectors but notably the former and the increase of income of the whole population. The increase of income changes the consumption structure of the economy as the income elasticity of the consumption of the industrial product is greater than that of the agricultural product. The result is the expansion of the industrial sector which normally concentrates in cities as a result of the economies of scale and agglomeration. Subsequently, the concentration of industrial sector and its population brings about the concentration of the tertiary sector serving the economy and its population further expanding the urban population. Meanwhile, the increase of productivity in the rural sector reduces the demand for labour thus releases the rural population to urban areas. Consequently, it is straightforward to find that urbanization is closely associated with industrialization and development.

In his study of the urban growth of the last century, Weber identified several causes of the concentration of population in cities (Weber, 1899). Firstly, he emphasized the role of Agrarian Revolution which occurred with the Industrial Revolution and greatly improved agricultural productivity thereby releasing population from the agriculture sector. Secondly, he emphasized the role of trade as a economic force working for the concentration of the released agricultural population as trade facilitates the supply of food to the non-agricultural population. Thirdly, he pointed out that the enlargement of the market had brought the concentration of population in industrial and commercial cities.

More recently, Lee (1984) proposed a dynamic general equilibrium model which is able to show the dynamics of urban-rural migration and urbanization levels under the operation of various factors, namely, productivity changes in urban and rural sectors, natural population increases in urban and rural populations, and income elasticity of the consumption of the products of urban and rural sectors. A clear picture of the urbanization process can be produced by the model. The following discussion is mainly based on the implications of this dynamic general equilibrium model.

Urban populations can be divided into five parts according to their functions. These are the administrative personnel, the industrial personnel, the services personnel, the agricultural work force and finally all of their dependents. Generally speaking, the administrative personnel accounts for a small proportion of the total population though in some places it may be a relatively high fraction. The proportion of the administrative personnel in the total population may be relatively stable. The dependent population has some relation with the level of urban employment. The ratio of the dependents is determined by the population age composition and the employment level and may be regular and relatively stable. The agricultural work force is another relatively minor proportion of the urban population. The industrial personnel and services personnel constitute the major proportions of the urban population and their major function is to provide consumption goods and services to both the urban and the rural populations. At the early stage of economic development, industry and services will increase their shares of employment at the expense of agriculture. After economic development reaches the stage of "maturity" services of various types such as communication and consultation will continue to increase their share of employment but mainly at the expense of industry so that industry may decrease its share of employment (Rowthorn, 1986). In summary, it seems clear that the scale of the urban population depends mainly on the number of the industrial and services personnel and thus the demands for consumption goods and services by the urban and rural populations.

Rural populations can be divided into the same five parts according to their functions too. According to the location and spatial economic theories, most of the administrative personnel, the industrial personnel and the services personnel are residents of cities and towns, only a minor part of them live in rural areas. The agricultural work force constitutes a major part of the rural population and its principal function is to provide agricultural goods to the urban and rural populations. The number of dependents is determined by the level of rural employment. Therefore, the scale of the rural population depends mainly on the demands for agricultural goods by the urban and rural populations.

It is well known that effective demand depends on income and that the increase of income depends on the increase of labour productivity. If there was no technical progress and labour productivity not increased, income and effective demand would also not increase. The result would be that the ratio of the urban population and the rural population would not be subjected to significant change over time. Therefore, increase of the labour productivity is a necessary condition of urbanization.

If there is a change in labour productivity, but the demands for agricultural and industrial goods and services increased at the same rate, the ratio of the urban population and the rural population also would not change. In fact, the population consumption structure changes with increase of income. The ratio of the expenditure on industrial goods and services increases while the ratio of the expenditure on agricultural goods decreases with increase of income. The increase of the demand for industrial goods and services is greater than that for agricultural goods. As a result, the proportion of the urban population in total population increases. Therefore, a change in consumption structure towards more consumption of industrial goods and services is the second necessary condition of urbanization.

If there is a change in consumption structure toward greater consumption of industrial goods and services and thus increased demand is greater than that for agricultural goods, and if the increase in the labour productivity of industrial goods and services is much greater than the increase in the labour productivity of agricultural goods, then the ratio of the urban population and the rural population would not change. Therefore, the third necessary condition of urbanization is reached as follows: the difference of the labour productivity change between urban and rural sectors is not great enough to meet the needs of the consumption structure change. Thus it is necessary to increase the proportion of urban population.

According to the arguments above, change of labour productivity and change of consumption structure are major determinants of urbanization. It is also an important feature of urbanization that the natural increase rate of the urban population is less than that of the rural population. In this case, rural to urban migrations are needed to keep the balance of the urbanization level even if there were no changes of other factors.

The discussion above concerns the fundamental forces which determine the general trend of urbanization in the world. It seems that there are also additional secondary forces or factors which may condition the level and pace of the urbanization process in a particular period and/or a particular country or region. These factors may include population growth, urban-rural differences and government policy.

Rapid population growth is often regarded as a major force of the rapid urban growth in developing countries (Hall, 1984). High natural increase rates in rural populations will result in a labour surplus and strengthen the " push " factor working towards urban areas. High natural increase rates in urban populations will rapidly expand the urban populations themselves. In calculations by the United Nations of the basic components of urban change on the basis of 1960 data, it has been found that natural increase has been playing a significant role in urban population growth in developing countries, though it should be noted that net migration was also high (Renaud, 1981).

There are great urban-rural differences in terms of income, living standards, education and the like, especially in developing countries. It is often expected that individuals may have a better standard of living in urban than in rural areas. In other words, the urban-rural system is in a state of disequilibrium. The so called urban-rural gap will inevitably lead to a flow of population from rural to urban areas even if the modern industrial and services sectors in the urban area cannot accommodate all these immigrants. The consequence is the mushrooming of the informal sector, squatter settlements and shantytowns in cities worldwide (Chung Hyan Ro, 1976). High unemployment rates may also be a natural result acting as an equilibrating force on urban-rural migration (Harris and Todaro, 1970). This problem is often called overurbanization which results in many political, social and economic problems. The basic solution to this problem may be a more balanced development of urban and rural sectors. However, this is by no means an easy task. Even in China which has been deliberately trying to eliminate the economic and welfare differences between the urban and rural areas, the urban-rural gap has widened since the 1950s (Murphey, 1980). Strong government policies are introduced in planned economy countries to control undesirable urban-rural migration but these policies are not likely to be acceptable in most market economies.

Government policy also may well have powerful effects on the urbanization process. In planned economy countries, the government has a number of instruments to condition or even control the pace of urbanization. For example, underinvestment in urban housing, infrastructure and social services aimed at maximizing industrial growth, and indeed even direct control of population migration (Ran and Berry, 1989). Wu and David (1980) discussed a set of government policies designed to constrain the migration of rural population to the urban areas in China. Theses policies include resident registration, restrictions on employment opportunities, etc.

Many cross-sectional and time-series data-based analyses of various countries and regions in the world show that there is a significant relation between urbanization levels and labour productivity, development levels, economic and employment structures, and the structure of consumption. In a general overview on the world pattern of urban growth (Hall, 1984), it is noted that the most highly developed industrial nations are the most highly urbanized and that the countries which undergo the most rapid economic development also record a rapid increase in urbanization. In this century, the world population has been increasingly employed in non-agricultural occupations. The world's labour force engaged in these activities rose from 28% in 1900 to 50% in 1970 (Timberlake and Lunday, 1985). Firebaugh (1985) in a cross-sectional analysis of GNP per capita and urbanization found that GNP per capita has significant effect on urbanization among developing countries having market economies. But he also found no significant relation of GNP per capita with urbanization among developed nations.

It appears that developing and developed countries are at different stages of urbanization. The urbanization processes in developing and developed countries are described as expanding urbanization and mature urbanization respectively by Renaud (1981). The distinctive features of mature urbanization processes in developed countries are the dominant roles of urban-urban migration and population deconcentration. The suburbanization phenomenon and the rural-to-urban migration turnaround has already appeared in many developed countries. These trends are crucial in understanding the regional and urban economic dynamics in developed countries. Many studies have been made in this area (Wood, 1988; Greenwood, 1985; Greenwood et al, 1989; Fielding; 1989). According to Greenwood (1985), in the USA during the 1970s, the percentage of USA population residing in metropolitan areas declined for the first time this century. This population shift was partly due to a change in the direction of net migration between metropolitan and non-metropolitan areas. Five causes of the rural-to-urban turnaround are summarized by Greenwood (1985). First, the relative increase in the costs of doing business in older urban centers. Second, the growth of resource-based industries in non-metropolitan areas. Third, the rise of income and wealth and the increase of demands for location-specific amenities. Fourth, the change of demographic structure and the labour force. Fifth, government policy. Sternlieb and Hughes (1977) conclude that the endpoint of industrialization-based urbanization may have been reached.

It would appear that this deconcentration trend in developed countries moderated in the 1980s. The employment performance of British cities for example was considerably better in the 1980s than the previous decade (Frost and Spence, 1991). In the USA, the strong counterurbanization trends of the 1970s subsided in the early 1980s (Frey, 1989). Bourne (1991) actually argued for a more balanced form of development between the existing built-up and new suburban areas. It seems that, the focus of urbanization process in developed countries may be on the re-adjustment of the urban systems, i.e, balanced development for various urban areas.

Nevertheless, the developing countries are still at the stage of expanding urbanization for the reasons discussed before. It is likely that urbanization will continue to be a major trend of the socio-economic development and population redistribution in these countries for the foreseeable future.

2.3 The urbanization process in China since the 1950s

2.3.1 The institutional context of urbanization

As a vast country with a large population China reached a relatively high urban population proportion even in ancient times. Weber cited in his study on urban growth in the nineteenth century that 22% of Chinese population lived in cities with a population over 100,000 (Weber, 1899). Various scholars have estimated that the urban population proportion of China ranged from 28% to 33% around 1936 (Hu and Zhang, 1984). The urbanization process was disrupted during the war against the invasion from Japan (1937-1945) and the internal war between the Communist party and Guo Min Dang party (1945-1949). However, it is interesting to note that the urban proportion fell well below 20% for several decades since the foundation of the People's Republic of China in 1949. From 1950 to 1977, the urbanization level rose slowly from 10.6% in 1949 year-end to 17.6% in 1977 year-end. The urbanization level at this time was well behind the world urbanization level and that of many developing countries. This phenomenon made China somewhat distinctive or viewed by some, a success in terms of levels of its urbanization and development (Chen, 1973; Murphey, 1980; Wu and David, 1980; Buch, 1981). Others have pointed out that China is more simply just a case of systematic underurbanization in planned economy countries (Ran and Berry, 1989). To achieve maximum capital accumulation and industrial growth, the government used a series of measures to control urban population growth and associated non-productive construction including housing. Kirkby has provided an excellent coverage of the variety of measures used to restrain urban growth in China (Kirkby, 1985). It is essential to have some knowledge of the institutional context of the China's society to understand the urbanization process in the country since the 1950s.

China is a well organized society. People are organized in basic units called residents committees. These basic units are further grouped into a number of higher levels of local and provincial governments. The central government - the State Council - is on the top of this hierarchical network. The local governments include xiang (rural people's commune before 1983) government, town government, county government, provincial government and municipal government. Xiang and town governments are in the same lowest level of local government. Generally, at the prefectural level between county and provincial levels there is no government but a representative organization from the provincial government. But if the prefectural level is a designated city, there will be a municipal government at the prefectural level. A municipal government may belong to one of the three different levels - county, prefectural or provincial. A municipal government in the last two cases may control several counties in addition to its core urban area. In this thesis, the urban areas refer to town areas and core urban areas of cities excluding counties. The rural areas refer to county areas excluding towns.

There is a parallel network of the communist party organizations which undoubtedly has some strong impacts on the operations of the various levels of government.

In China, people's residence registrations are classified either as agricultural population or non-agricultural population. This distinction is important for person's standards of living. As non-agricultural population, they are eligible for a food ration and a number of subsidies from the government. The government assumes the responsibility to provide jobs, housing, food etc., for the non-agricultural population. The government is keen to keep the non-agricultural population at a minimum level, just enough to meet the labour demands of industrial growth. A most important condition is that the government controls enough grain to feed the non-agricultural population.

The government strictly and effectively constraints the transition of people from agricultural population status to non-agricultural population status. There are only a few ways in which individuals can change status. For example, enrolled undergraduate students automatically become non-agricultural population if they were not already before. In recent years, there has appeared some slight flexibility in regulating the non-agricultural population status. For example, the wife and children of a professional may obtain the non-agricultural population status to ease their life-style. The percentage of the non-agricultural population increased from 15.8 in 1978 to 19.9 in 1987 (DPS, 1988b). But generally speaking, the control of the non-agricultural population growth is still largely in tact.

Of course non-agricultural population growth is closely related to the urbanization process in China. Actually, only the non-agricultural population in the urban areas are counted as urban population before 1982. In 1982, the statistics of the urban population was changed to include the agricultural and non-agricultural populations in urban areas. This change was introduced to take account of the fact that non-agricultural population growth is still strictly controlled while much of the so called agricultural population is engaged in non-agricultural activities especially in urban and more developed areas. Another reason to abolish the urban non-agricultural population statistics as urban population is the fact that the distinction of agricultural population and non-agricultural population is not place-oriented. Many of the agricultural population are in fact living in the same cities and towns as the non-agricultural population and these people should sensibly be counted in the urban population. Because of this change in the definition, the urban population proportion of China changed from 14.5% to 21.1% at the end of 1982. Fortunately, statistics of the urban population based on the 1982 definition are available from the 1950s to 1988. Appendix A gives the urban population definition and the evolution of the criteria for the designation of cities and towns in China.

Table 2-1 shows the relationship between the distinction of the agricultural population and the non-agricultural population, and the distinction of the rural population and the urban population in 1982. Table 2-2 shows the employment structures of the non-agricultural population and the agricultural population in 1987.

The statistics of the urban population based on the 1982 definition are still strongly affected by institutional and administrative factors. The urban population statistics are

Table 2-1 The urban-rural, agricultural-non-agricultural population division of China in 1982 (millions)

	Non-agricultural population	Agricultural population	Total	Percentage(%)
Urban population	147	69	215	21.1
Rural population	32	770	802	78.9
Total	179	838	1017	100
Percentage(%)	17.6	82.4	100	

Data source: SSB (1991); DPS (1988b)

Table 2-2 The agricultural-non-agricultural population and employment division of China in 1987 (millions)

	Non-agricultural population	Agricultural population	Total	Percentage(%)
Non-agricultural employment	130	81	211	40.0
Agricultural employment	8	309	317	60.0
Total	138	390	528	100
Percentage(%)	26.1	73.9	100	

Data source: SSB (1988)

based on urban areas which are in turn based on the administrative designation of cities and towns. These may not reflect the actual pace of urbanization in China because the regulations for city and town designation may not be strictly and universally followed. For example, the number of designated towns decreased from 5402 in 1953 to 2819 by 1982 and the average population scale of the towns increased from 4973 to 16,243 persons over this period. This change in the presentation of statistics may not in fact indicate that there was a turnaround of urbanization (Hu and Zhang, 1984).

Since 1978, because of the positive attitude towards urban development by the government, those areas eligible for city or town status were approved for the status more quickly than before. As a result of this policy change, the number of cities increased rapidly from 191 in 1978 to 450 by 1989. In 1984, the regulation for the town designation was changed so that many areas became eligible for town status. The number of towns increased from 2819 in 1982 to 10,609 by 1988.

In summary, the urbanization process in China has been strongly affected by government policy. Furthermore urban population statistics are also affected by institutional factors and may not reflect the actual pace of urbanization. However, as will be shown in the next section, it may also be true that China was underurbanized most of the years between 1961-1977, and that the urban population based on the 1982 definition may be somewhat overcounted since 1983.

2.3.2 Urban population data series

It is essential to discuss the urban population data of China first as there has been growing confusion about it. A new urban population definition was adopted in the 1982 census. Other urban population statistics covering various ranges of population were also appeared in various statistics yearbooks causing growing confusion about the urban population in China. In most studies undertaken by various researchers using data before 1982, the registered non-agricultural population in the urban areas is used as the urban population. This author prefers to use the official urban population definition adopted in 1982 which includes both the agricultural and non-agricultural populations in urban areas. The main reason is that this definition is adopted in the official statistics published by the State Statistical Bureau of China before 1990. The United Nations seem to have adopted this definition as well on the grounds that the national statistical authorities are in the best position to distinguish between the urban and rural populations in their own countries (United Nations, 1989). Hereafter, the statistics of the 1982 definition will be called urban population, and that of the old definition will be called urban registered non-agricultural population.

However it needs to be restated that the urban population data based on the 1982 definition may be overcounted since 1983. The reason for this is that a number of new cities and towns have been designated since 1983. These new cities and towns include a substantial proportion of real agricultural population. As a result substantial agricultural population has been included in the urban population statistics thereby inflating the urban population totals. Figure 2-1 shows the growth of the urban population and the urban registered non-agricultural population. The urban population growth has speeded up since 1983 while the urban registered non-agricultural population growth has been relatively stable. It is also relevant to examine the changes in the two main components of the urban population: the city population and the town population. Figure 2-2 shows that the city population growth has speeded up since 1983 probably because more and more places have been designated as cities. Though this designation wave began in 1978, the gap between the city population and the city registered non-agricultural population really only began to widen in 1983. This is mainly due to the increase of new county-level cities which include considerable agricultural population. Figure 2-3 shows that the town population growth was suddenly increased in 1984 when the new regulation for the town designation was introduced. The gap between the town population and the town registered non-agricultural population has dramatically widened since then. Figure 2-4 shows the changes of the proportions of the registered non-agricultural population in the city population, the town population and the urban population. It is clear that the urban registered non-agricultural population was a major proportion (over 69%) of the urban population and that this proportion was rather stable at levels around 72% before 1983. The gap between the urban population and the urban registered non-agricultural population began to widen in 1983 in cities and in 1984 in towns. The registered non-agricultural population proportion in the city population decreased from 67.84 in 1982 to 49.69 by 1987. The registered non-agricultural population proportion in the town population decreased from 71.98 in 1983 to 25.96 by 1987. As a whole, the registered non-agricultural population proportion in the urban population decreased from 69.55 in 1982 to 38.40 in 1987.

It is clear that urban population data after 1982 is not completely comparable with those before 1982. Goldstein (1990) pointed out the inconsistency between the urban population data and economic development. Comparing the 39.9% of the non-agricultural employment in total employment with the 46.6% of the urban population in the total population in 1987, it can be assumed that the urban population has been somewhat overcounted since 1983. It seems necessary to adjust the urban population data based on the 1982 definition to reflect the actual pace of urbanization in China since 1983. In the 1990 population census, the State Statistical Bureau of China

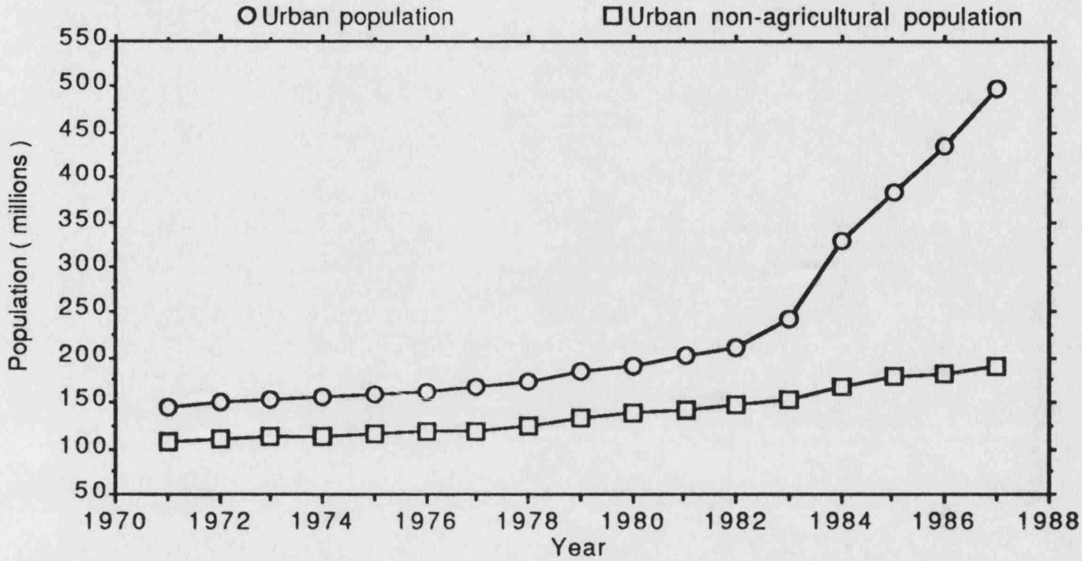

Figure 2-1 Urban population and urban registered non-agricultural population in China, 1971-1987

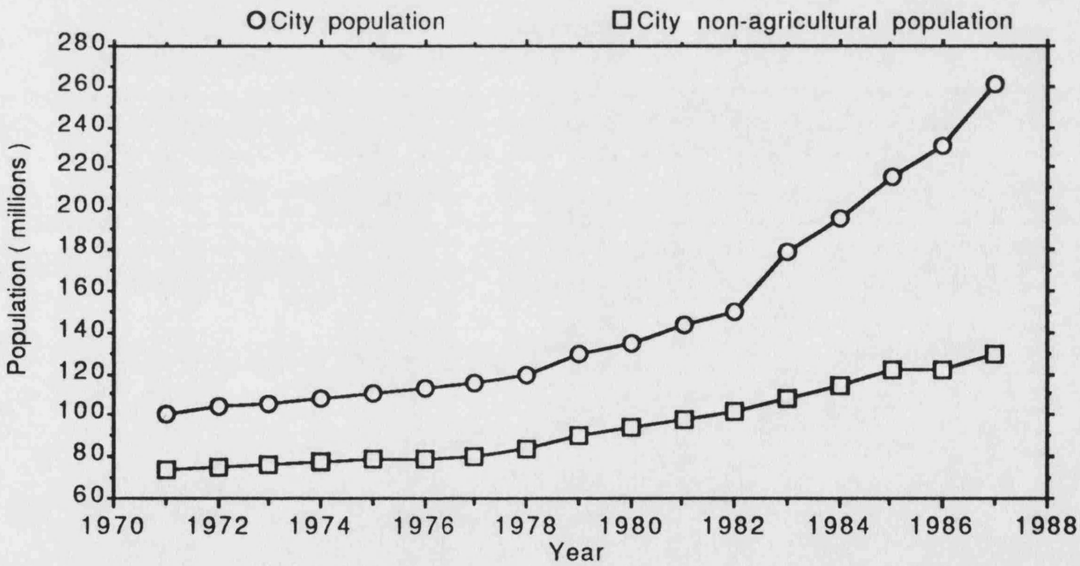

Figure 2-2 City population and city registered non-agricultural population in China, 1971-1987

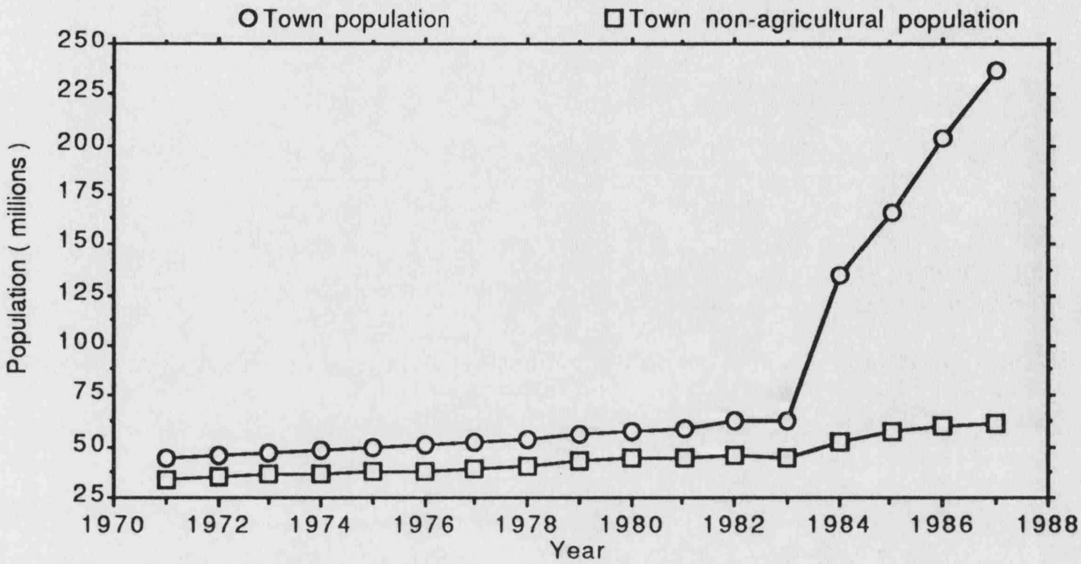

Figure 2-3 Town population and town registered non-agricultural population in China, 1971-1987

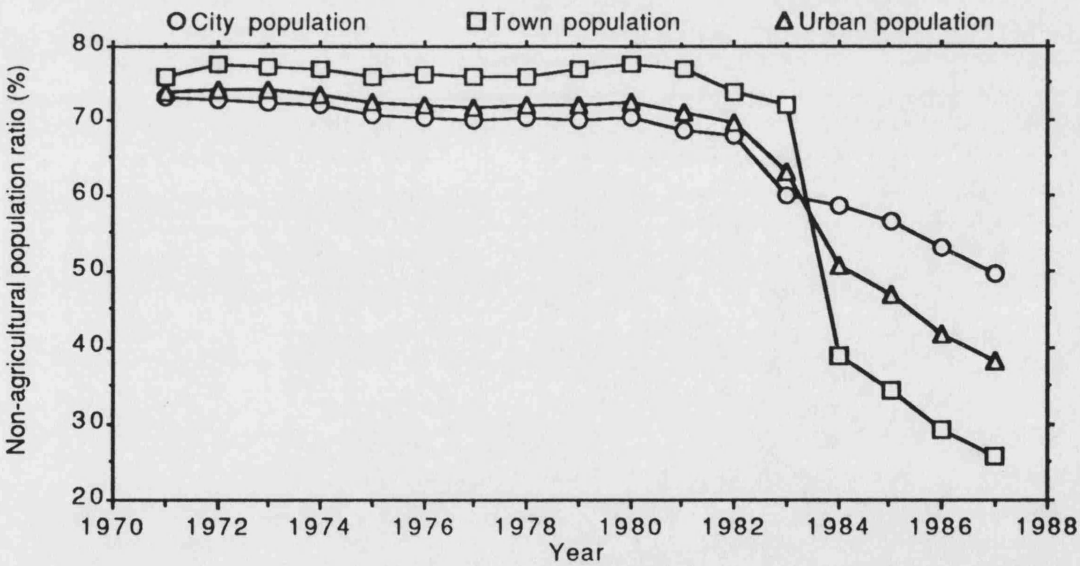

Figure 2-4 Registered non-agricultural population proportions in the urban population in China, 1971-1987

adopted another middle-way urban population definition. Cities are divided into two types according to whether a city is further divided into city districts or not. All the population including registered agricultural population and non-agricultural population in the city districts are counted as urban population. This is in line with the 1982 definition. Only the registered non-agricultural population in the cities which do not have city districts and in towns are counted as urban population. This is in line with the urban registered non-agricultural population definition. In the most recent official urban population data series (SSB, 1991), the urban population data before 1982 are based on the 1982 definition. The 1990 urban population figure is based on the above middle-way definition. The urban population data in the period 1982-1990 are obtained by gradually adjusting the 1982 figure to the 1990 figure. It is clear that this recent official urban population data series is not consistent and comparable. For example, 13.48 million registered agricultural population in towns were counted as urban population in 1981 and these population accounted for 6.68% of the urban population in that year. But no registered agricultural population in towns were counted as urban population in 1990.

One major reason to adopt the 1982 definition is the recent rapid increase of non-agricultural employment which still registered as agricultural population. In other words, the registered non-agricultural population no longer reflects the actual non-agricultural population. Table 2-3 shows the growth of the non-agricultural employment in the period 1978-1989. During this time the total non-agricultural employment almost doubled from 117.79 million in 1978 to 220.45 million in 1989. The proportion of the non-agricultural employment in total employment increased from 29.3% in 1978 to 39.8% in 1989. In the registered agricultural population, non-agricultural employment almost tripled from 31.5 million in 1978 to 84.95 million by 1989, and its share of the total non-agricultural employment increased from 26.7% to 38.5%. It may be assumed that most of the non-agricultural employment growth in the registered agricultural population may be provided by the registered agricultural population in urban areas. As mentioned above, this probably is the main reason why the government counts the registered agricultural population in the urban areas in the urban population statistics. At the same time however the government is not willing to register these persons as non-agricultural population to avoid considerable responsibilities for providing grain, housing and subsidies etc. In fact, this non-agricultural employment is responsible for itself. It has to acquire grain from native places or from free markets and generally provides for itself.

Here an attempt will be made to estimate the urban population figures for the period 1983-1987 on the basis of the estimated urban actual non-agricultural population. First,

Table 2-3 The growth of the non-agricultural employment in China, 1978-1989 (millions)

Year	Non-agricultural employment			
	in total population		in agricultural population	
	Absolute	Percent [a]	Absolute	Percent [b]
1978	117.79	29.3	31.50	26.7
1979	123.32	30.1	31.90	25.9
1980	131.80	31.1	35.02	26.6
1981	138.89	31.8	36.92	26.6
1982	143.78	31.7	38.05	26.5
1983	152.27	32.8	43.40	28.5
1984	172.70	35.8	58.88	34.1
1985	186.86	37.5	67.14	35.9
1986	199.71	38.9	75.22	37.7
1987	210.63	39.9	81.30	38.6
1988	220.26	40.5	86.11	39.1
1989	220.45	39.8	84.95	38.5

Data source: SSB (1989; 1990)
Notes:
a: non-agricultural employment as a proportion of the total employment.
b: non-agricultural employment in the registered agricultural population as a proportion of the total non-agricultural employment.

it is proposed that the urban actual non-agricultural population data may be estimated from the urban registered non-agricultural population data and the non-agricultural employment data, i.e., the urban registered non-agricultural population is inflated by the ratio of the total non-agricultural employment to the non-agricultural employment of the registered non-agricultural population. Table 2-4 shows the inflation ratios and the estimated urban actual non-agricultural population. Second, the ratio of the urban actual non-agricultural population to the urban population based on the 1982 definition is calculated. Table 2-4 shows that the ratio was over 94% in the period 1978-1982 and was gradually decreased to 62.55% by 1987. This change of the ratio indicates the extent of the overcounting of the urban population based on the 1982 definition. The urban population for the period 1983-1987 is estimated by applying the 1982 ratio to the estimated actual non-agricultural population data. Figure 2-5 and table 2-5 presents the three series of the urban population data for the period 1982-1987, one is based on the 1982 definition (SSB, 1989), one is most recent official series (SSB, 1991), and one estimated by this research.

2.3.3 Phases of urbanization since the 1950s

This section attempts to make a historical review of the urbanization processes ongoing in China since the 1950s. The recent history of China is characterized by unstable

Table 2-4 Estimated urban actual non-agricultural population in China, 1978-1987 (millions)

Year	Urban population [a]	Urban registered non-agricultural population	Inflation ratio [b]	Estimated urban non-agricultural population	
				Absolute	Percent [c]
1978	172.45	124.44	1.364	169.74	98.43
1979	184.96	133.12	1.350	179.71	97.16
1980	191.41	138.63	1.362	188.81	98.64
1981	201.72	143.20	1.362	195.04	96.69
1982	211.56	147.15	1.361	200.27	94.66
1983	241.23	152.34	1.399	213.12	88.35
1984	330.06	166.89	1.517	253.25	76.73
1985	382.44	179.71	1.560	280.36	73.31
1986	434.29	181.91	1.605	291.99	67.23
1987	497.78	191.17	1.629	311.35	62.55

Data source: DPS (1988b) and calculation by the author
Notes:
a: 1982 definition.
b: inflation ratio of actual non-agricultural population to registered non-agricultural population.
c: urban actual non-agricultural population as a proportion of the urban population.

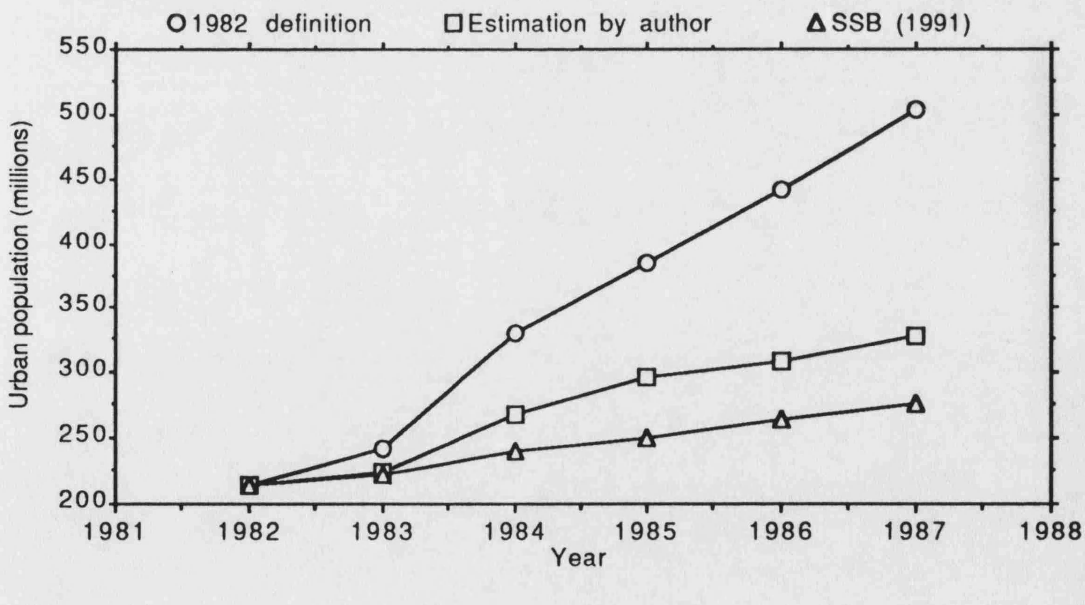

Figure 2-5 Official and estimated urban population totals in China, 1982-1987 (millions)

Table 2-5 Official and estimated urban population totals in China, 1982-1987 (millions)

Year	Estimation by the author	Official (1991) Series	1982 definition
1982	214.80	214.80	214.80
1983	225.14	222.74	241.50
1984	267.54	240.17	331.36
1985	296.18	250.94	384.46
1986	308.46	263.66	441.03
1987	328.91	276.74	503.62

Data source: 1982 definition and the official 1991 series from SSB (1989; 1991)

fluctuations of social and economic developments associated with a series of large and small political movements. Urban population growth is no exception. Urbanization during this time can be divided into five phases (Hu and Zhang, 1984). Note that the fifth phase can be extended to 1987. Although most discussions draw on the research of Hu and Zhang, it must be recognized that the urban population figures in the period 1949-1982 are based on the 1982 definition. Table 2-6 and figure 2-6 show the growth of the total population and the urban population in China since the 1950s. Table 2-7 shows the urban population growth in China in the above various phases. Figure 2-7 shows the change of the urban population proportion in the total population. Here all figures are of year-end.

Phase 1: 1950-1957. The years 1950-1952 comprise the three year economic recovery period. The first five-year plan period applies to the second part of the phases 1953-1957. This phase is often described as a rapid but normal period of urban growth. Urban population increased by 72.6% from 57.65 million in 1949 to 99.49 in 1957. On average, this represents an increase of 5.23 million each year. The urban population proportion of the total population increased by 4.8 points from 10.6 in 1949 to 15.4 by 1957. It is estimated that 56% of the urban population growth was contributed by net in-migrations from the rural areas though the natural increase rate of the urban population was over 3%, much higher than that of the rural population. The government attempted to implement stern rule on migration and to send back recent migrants in the urban population to the rural areas in 1955 so that there was net out-migration from the urban areas to the rural areas in that year (see Kirkby, 1985). However most of these persons may have moved back to the urban areas along with other new migrants in 1956. The year 1956 is the only year in this phase when in-migration to the urban areas is regarded subsequently by commentators as too great.

Table 2-6 Growth of total population and urban population in China, 1949-1987 (millions)

Year	Total population	Urban population Absolute	Urban population Percent
1949	541.67	57.65	10.6
1950	551.96	61.69	11.2
1951	563.00	66.32	11.8
1952	574.82	71.63	12.5
1953	587.96	78.26	13.3
1954	602.66	82.49	13.7
1955	614.65	82.85	13.5
1956	628.28	91.85	14.6
1957	646.53	99.49	15.4
1958	659.94	107.21	16.2
1959	672.07	123.71	18.4
1960	662.07	130.73	19.7
1961	658.59	127.07	19.3
1962	672.95	116.59	17.3
1963	691.72	116.46	16.8
1964	704.99	129.50	18.4
1965	725.38	130.45	18.0
1966	745.42	133.13	17.9
1967	763.68	135.48	17.7
1968	785.34	138.38	17.6
1969	806.71	141.17	17.5
1970	829.92	144.24	17.4
1971	852.29	147.11	17.3
1972	871.77	149.35	17.1
1973	892.11	153.45	17.2
1974	908.59	155.95	17.2
1975	924.20	160.30	17.3
1976	937.17	163.41	17.4
1977	949.74	166.69	17.6
1978	962.59	172.45	17.9
1979	975.42	184.95	19.0
1980	987.05	191.40	19.4
1981	1000.72	201.71	20.2
1982	1016.54	214.80	21.1
1983	1030.08	225.14	21.9
1984	1043.57	267.54	25.6
1985	1058.51	296.18	28.0
1986	1075.07	308.46	28.7
1987	1093.00	328.91	30.1

Data source: 1983-1987 urban population data estimated by the author. Others from SSB (1991)

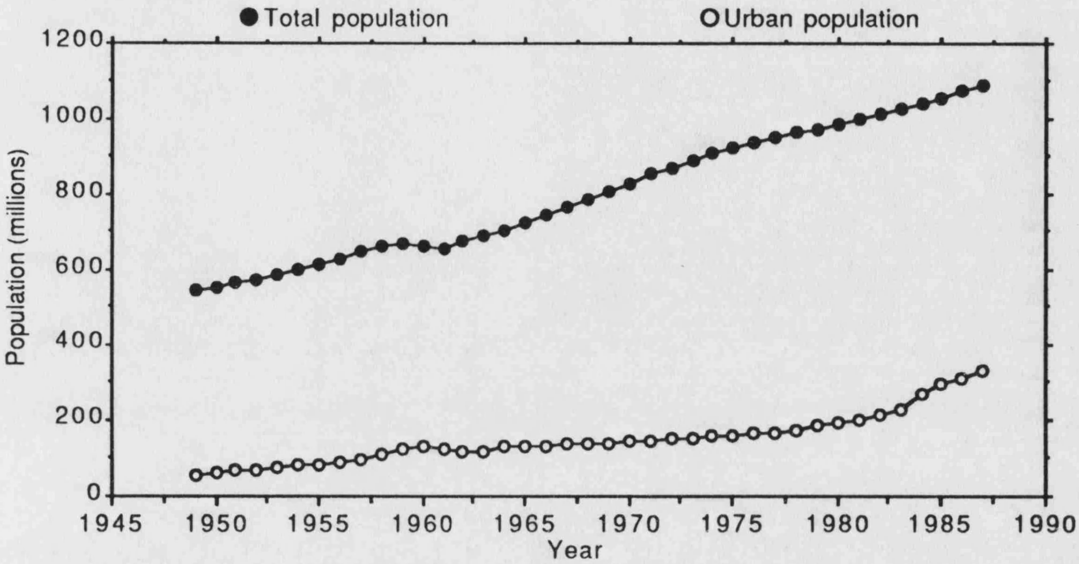

Figure 2-6 Growth of total population and urban population in China, 1949-1987 (millions)

Table 2-7 Phases of urban population growth in China since the 1950s (millions)

Phase	Total change			Average annual change	
	Absolute increase	Percentage increase	Change in share	Absolute increase	Change in share
1950-57	41.84	72.6	4.8	5.23	0.60
1958-60	31.24	31.4	4.3	10.41	1.43
1961-66	2.40	1.8	-1.8	0.40	-0.30
1967-76	30.28	22.7	-0.5	3.03	-0.05
1977-87	165.50	101.3	12.7	15.05	1.15
1950-87	271.26	470.5	19.5	7.14	0.51

Data source: See table 2-6

Phase 2: 1958-1960. This is the " Great Leap Forward " period when the government attempted to increase industrial output, especially iron and steel, rapidly and realize communism in a short period. Various small iron and steel works were established to increase iron and steel output. During this period, the urban population increased by 31.24 million from 99.49 million in 1957 to 130.73 million in 1960. On average, the urban population increased by 10.41 million each year which was about two times more than in the first phase. The urban population proportion increased by 4.3 points

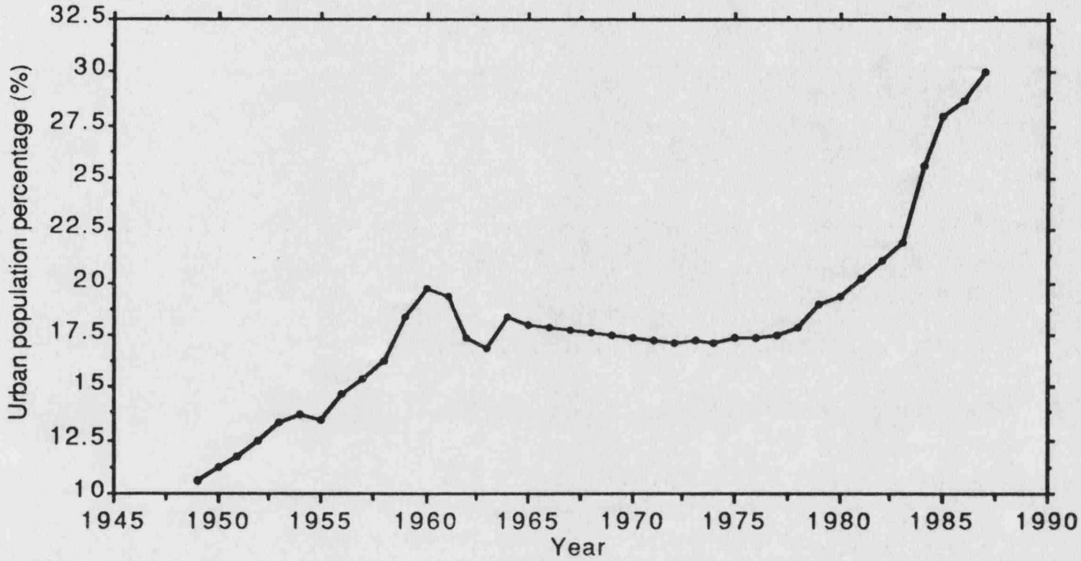

Figure 2-7 Urban population shares in China, 1949-1987

from 15.4 in 1957 to 19.7 by 1960. It is estimated that 90% of the urban population growth was contributed by net in-migrations from the rural areas. The " Great Leap Forward " movement (along with some unfortunate natural disasters) brought about a sharp decline in the agricultural production. The grain output per capita decreased by 28.5% from 303kg in 1958 to 217kg in 1960. The government faced great difficulties in obtaining grain to feed the increased non-agricultural population, most of these being defined as urban population. Dramatic events occurred in the next phase.

Phase 3: 1961-1966. In this period, the government determined to send back many urban residents to the rural areas in an attempt to solve the crises. The food shortage problem however also occurred and was much more severe in the rural areas. It is estimated that about 30 million people were sent back to the rural areas. This figure almost equals the total urban population growth in the previous phase. Due to natural increase, the urban population increased slightly by 1.8 to 133.13 million by 1966. The urban population proportion decreased by 1.8 points from 19.7 in 1960 to 17.9 in 1966. It is in this period that the really effective measures of migration control and urban resident deportations were developed.

Phase 4: 1967-1976. This is the turbulent " Cultural Revolution " period. Normal administrative, social and economic orders were disrupted. In ten years, the urban population only increased by 30.28 million from 133.13 million in 1966 to 163.41 million in 1976. On average, the urban population increased by only 3.03 million each year. The urban population share of total population even slightly decreased by 0.5

point. The urbanization process then was almost stagnant in this period.

One distinctive feature of this period is the large scale migrations in both directions between the urban areas and the rural areas. On the one hand, it is estimated that about 30 million urban youths and other urban residents, including workers, cadres and members of the intellingentia most of them with some kind of "political" problems, were sent to the rural areas to be re-educated by the poor and lower-middle peasants. On the other hand, it is estimated that about 20 million rural peasants were recruited by urban enterprises and organizations to meet their labour demands and hence became urban residents. Taking into account of other normal rural to urban migrations, it is estimated that net migrations from the urban areas to the rural areas were about 5 million in this phase.

Phase 5: 1977-1987. This is the period after the " Cultural Revolution ". With the improved political climate, millions of people who were removed to the rural areas during the previous phase were able to come back to the urban areas.

The economic reform since 1978 has brought about dramatic changes in various aspects of the social and economic development of China. Most important of all is the strategic change of the objective of the production. For a long period since 1950s, the government was keen to maximize capital accumulation and industrial expansion, especially in heavy industry, while at the same time suppressing the consumption demands of the population. From 1978 onwards, it was recognized that it is important to improve the living standards of the people. More and more products have been manufactured to meet consumption needs. Almost every person during this period has felt an improvement in living standards including housing. This strategic change has brought about economic growth as well as job opportunities especially in the non-agricultural sectors and urban areas. Secondly, urban growth is recognized as a positive factor in facilitating economic growth. Cities are regarded as economic centres being able to stimulate regional and national economic growth.

In 1984, new criteria for town designation were introduced so that more places were eligible for town status. Since then, the number of towns has been dramatically increased. In 1982, there were only 2819 towns. But in 1988, there were 10,609 towns. In the mean time, with economic growth and urban development, more places have become eligible for the city status. The number of cities was increased from 189 in 1977 to 381 in 1987.

As a result, the urban population increased by 165.50 million, or 101.3%, from 163.41 million in 1976 to 328.91 million in 1987. On average, urban population increased by 15.05 million each year. The urban population proportion has increased by 12.7 points from 17.4 in 1976 to 30.1 in 1987. The result was that urban population more than doubled in eleven years.

2.4 Conclusion

In summary, the urbanization process in China since 1950s is characterized by much instability and numerous fluctuations. The relatively rapid urban growth in the first phase 1950-1957 is regarded as normal. The " Great Leap Forward " period of the second phase may be regarded as an overurbanizing period. As a result of this overurbanization and the dramatic repatriations of the " Cultural Revolution ", the urbanization process was stagnant for two phases 1961-1966 and 1967-1976. During these two phases, the rural areas were used as a reservoir for a huge number of unwanted urban residents. Though many people were recruited and became urban residents during 1967-1976, generally speaking, urban population growth was slow compared with the rate of industrial growth in that period. The stagnant urbanization process partly resulted from the government's disregard of the demands for urban construction and increased consumption by the population. The notion of underurbanization is probably applicable to this period.

Rapid urban population growth has occurred in the last phase since 1977. More and more places have been designated as cities and towns because of the favourable policy of the government towards urbanization. The urban population based on 1982 definition may indeed be overcounted since 1983. Nevertheless, the estimated urban population based on the urban actual non-agricultural population shows that the urban population has probably doubled in this phase.

It seems quite clear that urbanization process in the recent history of China has been much affected by the government's policies and political movements. As a well-organized society under the leadship of the Communist party, this is inevitable. With the transition of China's economy towards a market economy, many powers are being decentralized. The future urbanization process may be subjected to less disturbance from the political movements. On the other hand, ongoing transition towards a market economy also runs the risk of losing control of rural to urban migration. If so, overurbanization and urban poverty may appear as already occurred in many developing countries. What will really happen depend on the balance of the government's regulation and the force of rural to urban migration.

This chapter aims to examine the forces driving the urbanization process in the world and particularly in China. The discussions on China's urbanization in the recent history may provide a background for further demographic analysis of urban-rural population changes. In the next chapter, an attempt will be made to analyze the urban-rural population dynamics in China.

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3
Analysis of urban-rural population dynamics

3.1 Introduction

One of the direct results of urbanization processes is differential urban and rural population change. In chapter two, an overview of the forces behind urbanization and the urbanization problems in China was presented. In this and the next chapter, an attempt will be made to analyze the urban-rural population dynamics of China and to make projections of the urban and rural populations in future. The multiregional (multistate) population modelling approach is adopted in this research rather than time-series extrapolation method because of concern for the population states in both the urban and the rural areas as urbanization proceeds. Detailed analysis of the impact of urbanization on population growth can only be carried out via an age-specific multiregional population model.

A general description of the urban-rural population system is provided in section 3.2. Population accounts and demographic rates estimation methods are discussed in section 3.3. The procedure to construct multiregional life tables will be discussed in section 3.4. The urban-rural population life tables are used to calculate fertility expectations in section 3.5 and out-migration expectations in section 3.6. The main findings are summarized in section 3.7. But first it is instructive to make a brief review of the state of the art of the multiregional population modelling.

Demographic models have been used in population analysis for a long time. Classic models include the life table model and the component-cohort survival model. They often deal with single region populations which are assumed to be closed in most cases. Only net migration is included in some cases. Since the middle 1960s, multiregional population models and multiregional life tables have been developed by Rogers and his collaborators (Rogers, 1966; 1973; 1975). Parallel to these developments, multiregional population accounts and accounts-based multiregional population models have been developed by other researchers. As pointed out by Rees and Wilson (1975), most population models have a problem of failure to match exactly age groups in the numerators and denominators of rate definitions. Their multiregional population accounts have the advantages that all demographic flows are systematically and precisely specified, so rates can be correctly defined and estimated. It is worthwhile to discuss multiregional population accounts first (Rees and Wilson, 1977).

Consider an aggregated case of two regions i and j. Following Rees and Wilson (1977), there are eight demographic flows from region i to region i or region j in period t to t+u:

S-flow — P^{eisi} is the population who exist in region i at time t and survive in region i at time t+u.

M-flow — P^{eisj} is the population in region i at time t who migrate and survive in region j at time t+u.

D-flow — P^{eidi} is the population in region i at time t who die in region i before time t+u.

MD-flow — P^{eidj} is the population in region i at time t who migrate and die in region j before time t+u.

B-flow — P^{bisi} is the number of births in region i who survive in region i at time t+u.

BM-flow — P^{bisj} is the number of births in region i who migrate and survive in region j at time t+u.

BD-flow — P^{bidi} is the number of births in region i who die in region i before time t+u.

BMD-flow — P^{bidj} is the number of births in region i who migrate and die in region j before time t+u.

Here u is the length of the period. There are eight similar demographic flows from region j to region i or region j in period t to t+u.

Population accounts can be constructed on the basis of the demographic flows identified above. Estimation procedures may need to be adopted or developed for the specific population data available. For example, transition data and movement data need different procedures. A multiregional population model can be developed on the basis of this type of population accounts framework (Rees and Wilson, 1977; Rees, 1989). Similar multiregional population models have been developed by Rogers (1966, 1975).

A life table deals with the life process of a group of people born at the same time. It is widely used in population analysis and projection. The multiregional life table was originally developed by Rogers (1973, 1975). Rees and Wilson (1977) also deal with the multiregional life table concept in the context of population accounts.

With some assumptions, model multiregional life tables can be constructed and specified as f (**EXP**, **q**). **EXP** is a diagonal matrix of regional expectations of life at birth. A matrix of migration levels comprise **q**. The model multiregional life table is useful to estimate basic multiregional demographic measures from incomplete data for population projection (Rogers, 1975).

The concept of a stable multiregional population is discussed by Rogers and Willekens (1984). The regional age compositions and regional shares of a closed multiregional population are completely determined by the initial state and recent history of fertility, mortality and internal migration. If a multiregional population has been subjected to unchanged fertility, mortality and migration schedules for a long time, it is called a stable multiregional population which has stable regional age compositions and regional shares, constant regional annual rates of birth, death and migration, and a fixed multiregional annual rate of growth.

The evolution of a multiregional population is governed by various rates of fertility, mortality and migration. There are remarkably persistent regularities in age-specific fertility, mortality and migration rates (Rogers, 1984). These age-specific rates can be expressed by mathematical functions called schedule models. Schedule models help to reduce the input variables of a multiregional population model, to separate the level of a component from its distribution across the ages, and to link trends of the model parameters to social or economic developments (Rees, 1989).

Public concern and debate over population control have a long history. Population control policies are sometimes proposed in specific cases, though different views of the results on population growth exist (Simon, 1986). Multiregional population control can be realized by control of regional birth rates or inter-regional migration. A multiregional population control model to account for such features has been discussed by Rogers (1984).

In recent years, demographic-economic models which take into account of the effects of the social-economic factors on demographic change rates have also been developed for the purposes of population projection (for example, Ledent, 1982; Isserman, 1985; 1986; Isserman et. al., 1985). Some of these will be returned to in chapter four.

3.2 The urban and rural population system

The spatial population system of interest consists of two interrelated parts: the urban population and the rural population of China. The system as a whole may be termed an urban and rural population system. The division of the urban population and the rural population is based on the definition of the urban area (cities and towns) and the rural area (counties) in 1987. The whole population system is assumed to be closed to external migration. The age and time intervals used in the models for this research are one year.

The urban and rural population system can be described by multiregional population accounts. Critical demographic parameters which describe the urban-rural population dynamics can be derived from multiregional population accounts. An urban-rural population model can also be established on the basis of multiregional population accounts. Hence, the first step is to estimate multiregional population accounts from the population data available.

Table 3-1 is the population account for period-cohort a, gender g of region i (urban) and region j (rural). a = 1, 2, ..., A; g=m, f. A is an open ended last period-cohort, so A+1 is also A.

Table 3-2 is the population account of infants of gender g.

The variables are defined as follows:

$Pk^*_{ag}(t)$ is the starting population of region k in period t to t+1 in period-cohort a of gender g, k=i,j. Period-cohort a refers to the same population group in the period t to t+1 that belongs to age-group a in time t.

$P^*k_{ag}(t+1)$ is the ending population of region k in period t to t+1 in period-cohort a of gender g, k=i,j.

P^{*dk}_{ag} is the population in period-cohort a of gender g who died in period t to t+1 in region k, k=i,j.

$Peksl_{ag}$ is the population of period-cohort a of gender g who exist in region k at time t and survive in region l in period t to t+1, k=i,j; l=i,j.

Table 3-1 The population account for period-cohort a and gender g

		Ending state in period t to t+1				
		Urban	Rural	Die in Urban	Die in Rural	Totals
Starting state at time t	Urban	$Peisi_{ag}$	$Peisj_{ag}$	$Peidi_{ag}$	$Peidj_{ag}$	$Pi^*_{ag}(t)$
	Rural	$Pejsi_{ag}$	$Pejsj_{ag}$	$Pejdi_{ag}$	$Pejdj_{ag}$	$Pj^*_{ag}(t)$
	Totals	$P^*i_{ag}(t+1)$	$P^*j_{ag}(t+1)$	P^{*di}_{ag}	P^{*dj}_{ag}	P^{**}_{ag}

Note: for key to entries see text

Table 3-2 The population account of infants of gender g

		Ending state in period t to t+1				
		Urban	Rural	Die in Urban	Die in Rural	Totals
Starting state in period t to t+1	Urban	$Pbisi_g$	$Pbisj_g$	$Pbidi_g$	$Pbidj_g$	Pbi^*_g
	Rural	$Pbjsi_g$	$Pbjsj_g$	$Pbjdi_g$	$Pbjdj_g$	Pbj^*_g
	Totals	Pb^*i_{0g}	Pb^*j_{0g}	Pb^{*di}_{0g}	Pb^{*dj}_{0g}	Pb^{**}_{0g}

Note: for key to entries see text

P^{ekdl}_{ag} is the population of period-cohort a of gender g in region k at time t who die in region l in period t to t+1, k=i,j; l=i,j.

P^{bk*}_{g} is the number of infants of gender g in region k in period t to t+1, k=i,j.

P^{bksl}_{g} is the number of infants of gender g in region k who survive in region l in period t to t+1, k=i,j; l=i,j.

P^{bkdl}_{g} is the number of infants of gender g in region k who die in region l in period t to t+1, k=i,j; l=i,j.

P^{b*k}_{0g} is the number of infants of gender g at the end of period t to t+1 in region k, k=i,j.

P^{b*dk}_{0g} is the number of infants of gender g who die in region k in period t to t+1, k=i,j.

Population accounts equations can be obtained from population accounts in table 3-1 and table 3-2. Row sum equations of period-cohort a of gender g are as follows:

$$P^{i*}_{ag}(t) = P^{eisi}_{ag} + P^{eisj}_{ag} + P^{eidi}_{ag} + P^{eidj}_{ag} \qquad (3\text{-}1)$$

$$P^{j*}_{ag}(t) = P^{ejsi}_{ag} + P^{ejsj}_{ag} + P^{ejdi}_{ag} + P^{ejdj}_{ag} \qquad (3\text{-}2)$$

Column sum equations of period-cohort a of gender g are as follows:

$$P^{*i}_{ag}(t+1) = P^{eisi}_{ag} + P^{ejsi}_{ag} \qquad (3\text{-}3)$$

$$P^{*j}_{ag}(t+1) = P^{eisj}_{ag} + P^{ejsj}_{ag} \qquad (3\text{-}4)$$

$$P^{*di}_{ag} = P^{eidi}_{ag} + P^{ejdi}_{ag} \qquad (3\text{-}5)$$

$$P^{*dj}_{ag} = P^{eidj}_{ag} + P^{ejdj}_{ag} \qquad (3\text{-}6)$$

Row sum equations of births of gender g are as follows:

$$P^{bi*}_{g} = P^{bisi}_{g} + P^{bisj}_{g} + P^{bidi}_{g} + P^{bidj}_{g} \qquad (3\text{-}7)$$

$$P^{bj*}_{g} = P^{bjsi}_{g} + P^{bjsj}_{g} + P^{bjdi}_{g} + P^{bjdj}_{g} \qquad (3\text{-}8)$$

Column sum equations of births of gender g are as follows:

$$P^{b*i}_{0g}(t+1) = P^{bisi}_{g} + P^{bjsi}_{g} \qquad (3\text{-}9)$$

$$P^{b*j}_{0g}(t+1) = P^{bisj}_{g} + P^{bjsj}_{g} \qquad (3\text{-}10)$$

$$P^{b*di}_{0g} = P^{bidi}_{g} + P^{bjdi}_{g} \qquad (3\text{-}11)$$

$$P^{b*dj}_{0g} = P^{bidj}_{g} + P^{bjdj}_{g} \qquad (3\text{-}12)$$

The main population data source used in this research is the 1% population sample survey of China in 1987 (DPS, 1988). The following population data are available: the data P^{*k}_{ag} and P^{b*k}_{0g} of the ending population of every one-year period-cohort, the birth data P^{bk*}_{g} and the death data D^{*k}_{ag} which gives the population who died at age a and involves two period-cohort a and a+1 in the period 1986 to 1987, and the data of migration population M^{kl}_{ag} who are in period-cohort a in the period 1986 to 1987 and have migrated in the period 1982 to 1987 and still survive at the end of period 1986 to 1987. In next section, estimation methods are discussed to establish population accounts in the period 1986 to 1987 from these population data that are available.

3.3 Population accounts and demographic rates estimation

Population accounts and demographic rates estimation methods will be developed on the basis of population accounts equations. The definitions of mortality rates and migration rates will be discussed first.

Basically, demographic rates can be defined in three ways. Take a simple single region example, assume the population of period cohort a is $P_a(t)$ at time t and $P_a(t+1)$ at time t+1. The population that died during the period t to t+1 is given by:

$$D_a(t,t+1) = P_a(t-1) - P_a(t) \qquad (3\text{-}13)$$

An average mortality rate or occurrence-exposure rate u^1_a can be defined as follows:

$$u^1_a = D_a(t,t+1) / PAR_a = D_a(t,t+1) / (0.5P_a(t) +0.5\, P_a(t+1)) \qquad (3\text{-}14)$$

where PAR_a is the population at risk and is most conveniently defined as the average population over the time interval (Rees, 1989).

A forward mortality rate which is often used in population projection models can be defined as:

$$u^2_a = D_a(t,t+1) / P_a(t) \qquad (3\text{-}15)$$

A backward mortality rate can be defined as:

$$u^3_a = D_a(t,t+1) / P_a(t+1) \qquad (3\text{-}16)$$

There is a unique relation among the three mortality rates defined above:

$$u^1_a = 2\, u^2_a\, u^3_a / (u^2_a + u^3_a) \qquad (3\text{-}17)$$

In this section, the forward demographic rate definition only is used so that estimation results can be input directly to the population projection model.

Mortality rates for period-cohort a of gender g for the urban region are defined as follows:

$$\begin{aligned} u^i_{ag} &= P^{*di}_{ag}/(P^{eisi}_{ag} + 0.5\, P^{cisj}_{ag} + 0.5\, P^{cjsi}_{ag} + P^{*di}_{ag}) \\ &= P^{*di}_{ag}/(P^{*i}_{ag}(t+1) + 0.5\, P^{cisj}_{ag} - 0.5\, P^{cjsi}_{ag} + P^{*di}_{ag}) \\ & \qquad a=1, 2, \ldots, A\text{-}2 \qquad (3\text{-}18) \end{aligned}$$

These equations apply to age groups up to A-2. The last two age groups in this case experience no migration and will be dealt with using a single-region method.

The denominator of RHS of equation (3-18) is the initial population corresponding to deaths of period-cohort a of gender g in the urban region. Similarly, mortality rates for period-cohort a of gender g for the rural region are defined as:

$$u^j_{ag} = P^{*dj}_{ag}/(\ P^{*j}_{ag}(t+1) + 0.5\ P^{ejsi}_{ag} - 0.5\ P^{eisj}_{ag} + P^{*dj}_{ag}\ )$$

$$a=1,\ 2,\ ...,\ A\text{-}2 \qquad (3\text{-}19)$$

Similarly, mortality rates for infants of gender g for the urban region and the rural region are defined as:

$$u^i_{0g} = P^{b*di}_{0g}/(\ P^{bisi}_{g} + 0.5\ P^{bisj}_{g} + 0.5\ P^{bjsi}_{g} + P^{b*di}_{0g}\ )$$

$$= P^{b*di}_{0g}/(\ P^{bi*}_{g} - 0.5\ P^{bisj}_{g} + 0.5\ P^{bjsi}_{g} + P^{bjdi}_{g} - P^{bidj}_{g}\ )$$

$$(3\text{-}20)$$

$$u^j_{0g} = P^{b*dj}_{0g}/(\ P^{bj*}_{g} - 0.5\ P^{bjsi}_{g} + 0.5\ P^{bisj}_{g} + P^{bidj}_{g} - P^{bjdi}_{g}\ ) \qquad (3\text{-}21)$$

A more general version of the mortality rate u^k_{ag} is defined for later use as the mortality rate of period-cohort a of gender g in region k, k=i,j; a=0, 1 ,..., A; g=m,f.

Out-migration rates for period-cohort a of gender g for the urban region are defined by migration flow P^{eisj}_{ag} dividing by initial population $P^{i*}_{ag}(t)$ as follows:

$$m^{ij}_{ag} = P^{eisj}_{ag}/P^{i*}_{ag}(t) \qquad (3\text{-}22)$$

Similarly, out-migration rates for period-cohort a of gender g for the rural region are defined as:

$$m^{ji}_{ag} = P^{ejsi}_{ag}/P^{j*}_{ag}(t) \qquad (3\text{-}23)$$

Similarly, out-migration rates for infants of gender g for the urban region and the rural region are defined as:

$$m^{ij}_{0g} = P^{bisj}_{g}/P^{bi*}_{g} \qquad (3\text{-}24)$$

$$m^{ji}_{0g} = P^{bjsi}_{g}/P^{bj*}_{g} \qquad (3\text{-}25)$$

It is convenient to define in-migration rates as well for later use as follows:

$$im^{ij}_{ag} = P^{eisj}_{ag}/P^{j*}_{ag}(t) = m^{ij}_{ag}\ P^{i*}_{ag}(t)/P^{j*}_{ag}(t) \qquad (3\text{-}26)$$

$$im^{ji}_{ag} = P^{ejsi}_{ag}/P^{i*}_{ag}(t) = m^{ji}_{ag}\ P^{j*}_{ag}(t)/P^{i*}_{ag}(t) \qquad (3\text{-}27)$$

$$im^{ij}_{0g} = P^{bisj}_{g}/P^{bj*}_{g} = m^{ij}_{0g}\ P^{bi*}_{g}/P^{bj*}_{g} \qquad (3\text{-}28)$$

$$im^{ji}_{0g} = P^{bjsi}_{g}/P^{bi*}_{g} = m^{ji}_{0g}\ P^{bj*}_{g}/P^{bi*}_{g} \qquad (3\text{-}29)$$

More general definitions of out-migration rates and in-migration rates for later use can also be expressed: m^{kl}_{ag} is the out-migration rate of region k to region l, k=i,j; l=i,j; and im^{kl}_{ag} is the in-migration rate of region l from region k, k=i,j; l=i,j.

Population accounts estimation equations will be derived as follows. Equations for flows of non-survival migrants of period-cohort a of gender g may be obtained on the basis of the forward mortality rate definition:

$$P^{eidj}_{ag} = 0.5u^j_{ag}\ P^{eisj}_{ag}\ /\ (1\text{-}0.5\ u^i_{ag} - 0.5\ u^j_{ag}\ ) \qquad (3\text{-}30)$$

$$P^{ejdi}_{ag} = 0.5u^i_{ag}\ P^{ejsi}_{ag}\ /\ (1\text{-}0.5\ u^i_{ag} - 0.5\ u^j_{ag}\ ) \qquad (3\text{-}31)$$

Here the initial potential migration population is estimated from the survival migrants first. Then the number of non-survival migrants is estimated by the initial potential migration population multiplying by the mortality rate and 0.5, the average exposure interval. It is assumed that the average exposure interval of the potential migration population is one half year in each region.

Different equations for flows of non-survival migrants of infants of gender g may be obtained as follows, as both the initial and ending populations of infants are known:

$$Pbidj_g = 0.5Pbisj_g / (1-0.5\ u^i_{0g} - 0.5\ u^j_{0g}) - 0.5\ Pbisj_g \quad (3\text{-}32)$$

$$Pbjdi_g = 0.5Pbjsi_g / (1-0.5\ u^i_{0g} - 0.5\ u^j_{0g}) - 0.5\ Pbjsi_g \quad (3\text{-}33)$$

Substitute equations (3-32) and (3-33) into equations (3-20) and (3-21) and using migration rate definitions (3-24), (3-25), (3-28) and (3-29), the following equations are obtained for mortality rates of infants of gender g:

$$u^i_{0g} = Pb^*di_{0g}/(\ Pbi^*_g(\ 1 - 0.5\ (\ m^{ij}_{0g} - im^{ji}_{0g}\ )/(\ 1 - 0.5\ (\ u^i_{0g} + u^j_{0g}\ )))) \quad (3\text{-}34)$$

$$u^j_{0g} = Pb^*dj_{0g}/(\ Pbj^*_g(\ 1 - 0.5\ (\ m^{ji}_{0g} - im^{ij}_{0g}\ )/(\ 1 - 0.5\ (\ u^i_{0g} + u^j_{0g}\ )))) \quad (3\text{-}35)$$

Substitute population accounts equations (3-1) and (3-2) into the migration rate definition equations (3-22) and (3-23), the following equations are obtained:

$$Peisj_{ag} = m^{ij}_{ag}(\ Peisi_{ag} + Peisj_{ag} + Peidi_{ag} + Peidj_{ag}\ ) \quad (3\text{-}36)$$

$$Pejsi_{ag} = m^{ji}_{ag}(\ Pejsi_{ag} + Pejsj_{ag} + Pejdi_{ag} + Pejdj_{ag}\ ) \quad (3\text{-}37)$$

$$Pi^*_{ag} + Pj^*_{ag} = Peisj_{ag} / m^{ij}_{ag} + Pejsi_{ag} / m^{ji}_{ag} = P^*i_{ag} + P^*j_{ag} + P^*di_{ag} + P^*dj_{ag} \quad (3\text{-}38)$$

The following equation can be obtained from (3-38):

$$Peisj_{ag} = m^{ij}_{ag}\ (\ P^*i_{ag} + P^*j_{ag} + P^*di_{ag} + P^*dj_{ag} - Pejsi_{ag} / m^{ji}_{ag}\ ) \quad (3\text{-}39)$$

Substitute $Pejsj_{ag}$ and $Pejdj_{ag}$ from equations (3-4) and (3-6) into equation (3-37), the following equation is obtained:

$$Pejsi_{ag} = m^{ji}_{ag}(\ Pejsi_{ag} + P^*j_{ag} - Peisj_{ag} + Pejdi_{ag} + P^*dj_{ag} - Peidj_{ag}\ ) \quad (3\text{-}40)$$

Substitute $Peidj_{ag}$ and $Pejdi_{ag}$ from equations (3-30) and (3-31) into equation (3-40), then

$$\begin{aligned} Pejsi_{ag} &= m^{ji}_{ag}(\ Pejsi_{ag} + P^*j_{ag} - Peisj_{ag} + 0.5u^i_{ag}\ Pejsi_{ag} / (1-0.5\ u^i_{ag} - 0.5\ u^j_{ag}) \\ &\quad + P^*dj_{ag} - 0.5u^j_{ag}\ Peisj_{ag} / (1-0.5\ u^i_{ag} - 0.5\ u^j_{ag}\ )\ ) \\ &= m^{ji}_{ag}(\ Pejsi_{ag}\ (\ 1 + 0.5u^i_{ag} / (1-0.5\ u^i_{ag} - 0.5\ u^j_{ag}\ )\ ) \\ &\quad - Peisj_{ag}\ (\ 1 + 0.5u^j_{ag} / (1-0.5\ u^i_{ag} - 0.5\ u^j_{ag}\ )) + P^*j_{ag} + P^*dj_{ag} \end{aligned} \quad (3\text{-}41)$$

Substitute $Peisj_{ag}$ from equation (3-39) into equation (3-41), and the following estimation equation for $Pejsi_{ag}$ can be obtained:

$$Pejsi_{ag} = mji_{ag} (P^{*j}_{ag} + P^{*dj}_{ag} - mij_{ag}(P^{*j}_{ag} + P^{*i}_{ag} + P^{*dj}_{ag} + P^{*di}_{ag})$$
$$(1 + uj_{ag} /(2 - ui_{ag}-uj_{ag}))) /(1 - mji_{ag}(1 + ui_{ag} / (2 - ui_{ag} - uj_{ag}))$$
$$- mij_{ag}(1 + uj_{ag} /(2 - ui_{ag}-uj_{ag}))) \quad (3\text{-}42)$$

A similar estimation equation for $Peisj_{ag}$ can be obtained in the same way. The general estimation equation for $Peksl_{ag}$ is given by:

$$Peksl_{ag} = mkl_{ag} (P^{*k}_{ag} + P^{*dk}_{ag} - mlk_{ag}(P^{*k}_{ag} + P^{*l}_{ag} + P^{*dk}_{ag} +$$
$$P^{*dl}_{ag}) (1 + uk_{ag} /(2 - uk_{ag}-ul_{ag}))) /(1-mkl_{ag}(1 + ul_{ag} /$$
$$(2 - uk_{a} - ul_{ag})) - mlk_{ag}(1 + uk_{ag} /(2 - uk_{ag}-ul_{ag})))$$
$$k=i, j; \; l=i, j; \; k \neq l \quad (3\text{-}43)$$

The following equation can be derived to estimate Pb^{*dk}_{0g} by using equations (3-32) and (3-33) and the migration rate definitions (3-24), (3-25), (3-28) and (3-29):

$$Pb^{*dk}_{0g} = Pbk^{*}_{g} - Pb^{*k}_{0g}(t+1) + Pblsk_{g} - Pbksl_{g} - Pbkdl_{g} + Pbldk_{g}$$
$$= Pbk^{*}_{g} (1 - 0.5 (mkl_{0g} - imlk_{0g})/(1 - 0.5 (uk_{0g} + ul_{0g}))$$
$$- 0.5 (mkl_{0g} - imlk_{0g})) - Pb^{*k}_{0g}(t+1)$$
$$k=i, j; \; l=i, j; \; k \neq l \quad (3\text{-}44)$$

The following equations are used to estimate P^{*dk}_{ag}:

$$P^{*dk}_{1g} = D^{*k}_{0g} - Pb^{*dk}_{0g} + 0.5 \, D^{*k}_{1g} \qquad k=i, j \quad (3\text{-}45)$$
$$P^{*dk}_{ag} = 0.5 (D^{*k}_{a-1g} + D^{*k}_{ag}) \qquad a=2, 3, \ldots, A\text{-}2; \; k=i,j \quad (3\text{-}46)$$

Here D^{*k}_{ag} is the population of gender g who die at age a in region k in period t to t+1, which is the available death data.

Given migration rates, mortality rates can be estimated using equations (3-44), (3-45), (3-46), (3-43), (3-18), (3-19), (3-34) and (3-35). Mortality rates for period-cohort A-1 and A (A=101, the last age group aged 100 at the beginning of a period) are estimated using a single region method, as these populations experience no migration.

It is more difficult to estimate the migration rates. The migration data M^{kl}_{ag} for the past five years are reported. The expression M^{kl}_{ag} is the migration of population of period-cohort a of gender g in period t to t+1 who have migrated in period t-4 to t+1 and survive at the end of period t to t+1. The basic idea of deriving the migration rate estimation equations is to construct equations for five-year total migrations on the basis of one-year migration rates. The first four-year total migrations of a period-cohort can be estimated using the one-year migration rates of younger period-cohorts. Then the final year migrations are calculated to estimate the one-year migration rate of the period-cohort concerned. The estimation method proceeds from the infant cohort to the last period-cohort.

The following equations which link the starting and the ending states of the same period-cohort are used to derive the migration rate estimation equations :

$$P^{*k}{}_{ag}(t+1) = P^{k*}{}_{ag}(t)\, h^{k}{}_{ag} = P^{*k}{}_{a-1g}(t)\, h^{k}{}_{ag} \qquad a=1, 2, ..., A-2; k=i, j \quad (3\text{-}47)$$

$$P^{b*k}{}_{0g}(t+1) = P^{bk*}{}_{g}(t)\, h^{k}{}_{0g} \qquad k=i, j \quad (3\text{-}48)$$

$$h^{k}{}_{ag} = (1 - m^{kl}{}_{ag} / (1 - 0.5\,(u^{k}{}_{ag} + u^{l}{}_{ag})))\,(1 - u^{k}{}_{ag}) + im^{lk}{}_{ag}$$

$$a=0, 1, ..., A-2; k=i, j; l=i, j; k\neq l \quad (3\text{-}49)$$

It is straightforward to find out that the total migration equations for the first two period-cohorts are as follows:

$$M^{kl}{}_{1g} = P^{bk*}{}_{g}(t)\, m^{kl}{}_{0g} \qquad k=i, j; l=i, j; k\neq l \quad (3\text{-}50)$$

$$M^{kl}{}_{2g} = P^{bk*}{}_{g}(t-1)\,(m^{kl}{}_{0g}\, h^{l}{}_{1g} + h^{k}{}_{0g}\, m^{kl}{}_{1g})$$

$$= (m^{kl}{}_{0g}\, h^{l}{}_{1g} + h^{k}{}_{0g}\, m^{kl}{}_{1g})\, P^{*k}{}_{1g}(t+1)/(h^{k}{}_{1g}\, h^{k}{}_{0g})$$

$$k=i, j; l=i, j; k\neq l \quad (3\text{-}51)$$

The migration rate estimation equation for infants of gender g can be derived directly from equation (3-50) as follows:

$$m^{kl}{}_{0g} = M^{kl}{}_{1g} / P^{bk*}{}_{g}(t) \quad (3\text{-}52)$$

The migration rate estimation equation for period-cohort 1 of gender g can be derived from equation (3-51) as follows:

$$m^{kl}{}_{1g} = (M^{kl}{}_{2g} - m^{kl}{}_{0g}\, h^{l}{}_{1g}\, P^{*k}{}_{1g}(t+1)/(h^{k}{}_{1g}\, h^{k}{}_{0g}))/(P^{*k}{}_{1g}(t+1)/ h^{k}{}_{1g})$$

$$(3\text{-}53)$$

The numerator of the RHS of equation (3-53) is the estimated final year migrations of period-cohort 1 of gender g. The denominator of the RHS of equation (3-53) is the initial population of period-cohort 1.

Similarly, we have following estimation equations:

$$m^{kl}{}_{2g} \doteq (M^{kl}{}_{3g} - (m^{kl}{}_{0g}\, h^{l}{}_{1g}\, h^{l}{}_{2g} + h^{k}{}_{0g}\, m^{kl}{}_{1g}\, h^{l}{}_{2g})\, P^{*k}{}_{2g}(t+1)$$

$$/(h^{k}{}_{2g}\, h^{k}{}_{1g}\, h^{k}{}_{0g}))/(P^{*k}{}_{2g}(t+1) / h^{k}{}_{2g}) \quad (3\text{-}54)$$

$$m^{kl}{}_{3g} = (M^{kl}{}_{4g} - (m^{kl}{}_{0g}\, h^{l}{}_{1g}\, h^{l}{}_{2g}\, h^{l}{}_{3g} + h^{k}{}_{0g}\, m^{kl}{}_{1g}\, h^{l}{}_{2g}\, h^{l}{}_{3g}$$

$$+ h^{k}{}_{0g}\, h^{k}{}_{1g} m^{kl}{}_{2g}\, h^{l}{}_{3g})\, P^{*k}{}_{3g}(t+1) / (h^{k}{}_{3g}\, h^{k}{}_{2g}\, h^{k}{}_{1g}\, h^{k}{}_{0g}))$$

$$/(P^{*k}{}_{3g}(t+1) / h^{k}{}_{3g}) \quad (3\text{-}55)$$

$$m^{kl}{}_{4g} = (M^{kl}{}_{5g} - (m^{kl}{}_{0g}\, h^{l}{}_{1g}\, h^{l}{}_{2g}\, h^{l}{}_{3g}\, h^{l}{}_{4g} + h^{k}{}_{0g}\, m^{kl}{}_{1g}\, h^{l}{}_{2g}\, h^{l}{}_{3g}\, h^{l}{}_{4g}$$

$$+ h^{k}{}_{0g}\, h^{k}{}_{1g}\, m^{kl}{}_{2g}\, h^{l}{}_{3g}\, h^{l}{}_{4g} + h^{k}{}_{0g}\, h^{k}{}_{1g}\, h^{k}{}_{2g}\, m^{kl}{}_{3g}\, h^{l}{}_{4g})$$

$$P^{*k}{}_{4g}(t+1) / (h^{k}{}_{4g}\, h^{k}{}_{3g}\, h^{k}{}_{2g}\, h^{k}{}_{1g}\, h^{k}{}_{0g}))/(P^{*k}{}_{4g}(t+1) / h^{k}{}_{4g}) \quad (3\text{-}56)$$

$$m^{kl}{}_{a+4g} = (M^{kl}{}_{a+5g} - (m^{kl}{}_{ag}\, h^{l}{}_{a+1g}\, h^{l}{}_{a+2g}\, h^{l}{}_{a+3g}\, h^{l}{}_{a+4g}$$

$$+ h^{k}{}_{ag}\, m^{kl}{}_{a+1g} h^{l}{}_{a+2g}\, h^{l}{}_{a+3g} h^{l}{}_{a+4g} + h^{k}{}_{ag}\, h^{k}{}_{a+1g}\, m^{kl}{}_{a+2g}\, h^{l}{}_{a+3g}\, h^{l}{}_{a+4g}$$

$$+ h^k_{ag}\, h^k_{a+1g} h^k_{a+2g}\, m^{kl}_{a+3g} h^l_{a+4g})\, P^{*k}_{a+4g}(t+1)$$

$$/\,(\, h^k_{a+4g}\, h^k_{a+3g}\, h^k_{a+2g}\, h^k_{a+1g}\, h^k_{ag}\,))/(\, P^{*k}_{a+4g}(t+1) \,/\, h^k_{a+4g})$$

$$a=1,2,\ldots, A-6;\ k=i, j;\ l=i, j;\ k\neq l \qquad (3\text{-}57)$$

The numerators and denominators of the RHS of equations (3-54)-(3-57) have the same meanings as for equation (3-53).

Migration rates can be estimated using equation (3-52)-(3-57). It is found that the estimation of the migration rate of a period-cohort depends on the estimates of previous period-cohorts, so that the estimation errors are cumulative. Some migration rate estimates of old period-cohorts are negative. Alternative estimation equations are derived from the above equations by assuming equal migration rates of five period-cohorts in the same equation.

An iterative procedure is introduced to estimate mortality rates and migration rates simultaneously. An iterative standard that the sums of the absolute error of the mortality rates and the migration rates are less than 0.000001 respectively is adopted. At the first step, the unknown rates are set to zero. At the second step, the mortality rates are estimated. At the third step, the migration rates are estimated. Then, step two and step three are repeated until the iterative standard is satisfied.

The following equations are used to estimate fertility rates :

$$P^{Sk*}_{af}(t) = 0.5\ (\, P^{*k}_{af}(t+1) + P^{*k}_{a+1f}(t+1)\,) \qquad (3\text{-}58)$$

$$B^{Sbk*}_a = 0.5\ (\, B^k_a + B^k_{a+1}\,) \qquad a=15,16,\ldots, 50;\ k=i,j \qquad (3\text{-}59)$$

Here, $P^{*k}_{af}(t+1)$ is the female population of age a in region k at time t+1, and is available. The expression $P^{Sk*}_{af}(t)$ is the estimated starting population of period-cohort a in period t-0.5 to t+0.5 in region k who survive at time t+1. The number of births of female population of age a at time t+1 in region k in period t-0.5 to t+0.5 is given by B^k_a, and is available. The quantity B^{Sbk*}_a is the estimated number of births of female population of period-cohort a in region k in period t-0.5 to t+0.5. The period-cohort a in period t-0.5 to t+0.5 involves two age groups with age a and a+1 at time t+1. A Lexis diagram (age-time graph) shows the life lines of individuals of various ages over time and is often used to derive relations between various age groups. According to the Lexis diagram, the population of period-cohort a in period t-0.5 to t+0.5 who survive at time t+1 can be conveniently estimated as the average population of age groups with age a and a+1 at time t+1. Now,

$$P^{k*}_{af}(t) = P^{Sk*}_{af}(t) + P^{k*}_{af}(t)\, u^k_{af} \qquad (3\text{-}60)$$

$$P^{bk*}_a = B^{Sbk*}_a + 0.5\, f^k_a\, P^{k*}_{af}(t)\, u^k_{af} \qquad a=15,16,\ldots, 50;\ k=i, j \qquad (3\text{-}61)$$

The fertility rate is defined as :

$f^k{}_a = P^{bk*}{}_a / P^{k*}{}_{af}(t)$ a=15,16,..., 50; k=i,j (3-62)

It is straightforward to find out that:

$f^k{}_a = B^{Sbk*}{}_a (1 - u^k{}_{af}) / (P^{Sk*}{}_{af} (1 - 0.5 u^k{}_{af}))$

a=15, 16, ..., 50; k=i, j (3-63)

The total fertility rate TFR^k can be calculated as follows:

$TFR^k = \Sigma_a f^k{}_a$ k=i, j (3-64)

The normal fertility rate $f^{nk}{}_a$ can be calculated as follows:

$f^{nk}{}_a = f^k{}_a / TFR^k$ a=15, 16, ..., 50; k=i, j (3-65)

From the foregoing a final version of the generalized population account can be constructed using equation (3-43) and the following equations :

$P^{ekdl}{}_{ag} = 0.5u^l{}_{ag} P^{eksl}{}_{ag} / (1 - 0.5u^k{}_{ag} - 0.5u^l{}_{ag})$

k=i, j; l=i, j; k≠l (3-66)

$P^{ekdk}{}_{ag} = P^{*dk}{}_{ag} - P^{eldk}{}_{ag}$ k=i, j; l=i, j; k≠l (3-67)

$P^{eksk}{}_{ag} = P^{*k}{}_{ag}(t+1) - P^{elsk}{}_{ag}$ k=i, j; l=i, j; k≠l (3-68)

$P^{k*}{}_{ag}(t) = P^{eksk}{}_{ag} + P^{eksl}{}_{ag} + P^{ekdk}{}_{ag} + P^{ekdl}{}_{ag}$

k=i, j; l=i, j; k≠l (3-69)

Survival rates can be calculated from population accounts using the following equation:

$S^{kl}{}_{ag} = P^{eksl}{}_{ag} / P^{k*}{}_{ag}(t)$ k=i, j; l=i, j (3-70)

Where $S^{kl}{}_{ag}$ is the survival rate of population of period-cohort a of gender g in region k at time t who survive in region l in period t to t+1, k=i,j; l=i,j.

A FORTRAN programme was written and run on a DEC VAX 11/780 mini-computer to estimate population accounts and demographic rates. Tables 3-3 to 3-7 show selected results of the estimated urban and rural population accounts, mortality rates, out-migration rates, fertility rates and survival rates respectively for China. Figures 3-1 to 3-4 show the mortality rates, out-migration rates and fertility rates of the urban and rural populations respectively.

The urban and rural population accounts for male and female infants, period-cohort 10, period-cohort 20 are shown in table 3-3. The population accounts show clearly the population changes in the period 1986 to 1987 for each period-cohort.

For example, some 4595.07 female infants were produced in the urban region in the period 1986 to 1987. Among these infants, 96.07 and 0.05 thousands died in the urban and rural regions respectively in the same period. At the end of the period, 4494.29 thousand female infants remained in the urban region, while 4.66 thousand had migrated (most likely along their parents) to the rural region and survived. There were

0.05 thousand non-surviving infant migrants from the urban region who died in the rural region. Similarly, some 6291.92 female infants were produced in the rural region in the period 1986 to 1987. Among these infants, 138.74 thousand died in the rural region, 0.17 thousand died in the urban region after they migrated to the urban region. At the end of the period, 6136.70 thousand remained in the rural region, and 16.31 thousand had migrated to the urban region and survived. At the end of the period 1986 to 1987, there were 4510.60 thousand females in the infants-cohort in the urban region and 6141.36 thousand in the rural region.

For another example, there were 4642.75 thousand females in the period-cohort 20 in

Table 3-3 Selected results of the estimated urban and rural population accounts for urban and rural areas in China (thousands)

		Ending state in period 1986 to 1987				
		Urban	Rural	Die in Urban	Die in Rural	Totals
Starting state in period to 1987	Male births					
	Urban	4888.23	2.29	101.27	0.03	4991.81
	Rural	16.62	6753.90	0.17	156.97	6927.66
	Totals	4904.85	6756.19	101.44	157.00	11919.47
	Male in period-cohort 10					
	Urban	4020.27	0.67	2.41	0	4023.35
	Rural	23.23	5780.60	0.01	4.03	5807.86
	Totals	4043.50	5781.27	2.41	4.03	9831.21
	Male in period-cohort 20					
	Urban	4653.16	2.72	6.17	0	4662.05
	Rural	98.88	6085.50	0.07	8.09	6192.55
	Totals	4752.04	6088.22	6.24	8.09	10854.60
	Female births					
	Urban	4494.29	4.66	96.07	0.05	4595.07
	Rural	16.31	6136.70	0.17	138.74	6291.92
	Totals	4510.60	6141.36	96.24	138.79	10886.99
	Female in period-cohort 10					
	Urban	3790.95	0.90	2.16	0	3794.01
	Rural	19.66	5397.92	0.01	2.67	5420.26
	Totals	3810.61	5398.81	2.17	2.67	9214.27
	Female in period-cohort 20					
	Urban	4625.44	12.05	5.26	0.01	4642.75
	Rural	104.87	6200.07	0.06	7.75	6312.74
	Totals	4730.30	6212.12	5.32	7.75	10955.49

the urban region at the beginning of the period 1986 to 1987. Among these females, 5.26 thousand died in the urban region and 0.01 thousand in the rural region during the one-year period. At the end of the period, 4625.44 thousand were still in the urban region (they were stayers), and 12.05 thousand had migrated to the rural region (they were surviving migrants. To rehearse the format in a different part of the table, there were 6312.74 thousand females in the period-cohort 20 in the rural region at the beginning of the period 1986 to 1987. Among these females, 7.15 thousand died in the rural region and 0.06 thousand in the urban region during the one-year period. At the end of the period, there were 6200.07 thousand who remained in the rural region and 104.87 thousand who had migrated and joined the urban region. At the end of the period 1986 to 1987, there were 4630.30 thousand females in the period-cohort 20 in the urban region and 6212.12 thousand in the rural region. During the one-year period, 5.32 thousand females in the period-cohort 20 died in the urban region and 7.75 thousand in the rural region.

The difference of population dynamics in the urban and rural regions is revealed by a comparison of their demographic rates.

Table 3-4 Selected results of the estimated mortality rates for urban and rural areas in China

Period-cohort	Male		Female	
	Urban	Rural	Urban	Rural
Birth	0.02026	0.02271	0.02089	0.02210
5	0.00083	0.00150	0.00078	0.00130
10	0.00060	0.00069	0.00057	0.00049
20	0.00132	0.00132	0.00113	0.00124
40	0.00192	0.00302	0.00163	0.00192
60	0.01778	0.01587	0.01185	0.01101
80	0.11362	0.10886	0.08303	0.07933

The estimated mortality rates are shown in table 3-4 and figures 3-1 and 3-2. Generally, the age specific mortality rates of the female population are less than those of the male population in both regions especially over age 60. This is due to the differences in the ageing process and living circumstances between males and females. For example, in the urban region, the mortality rate of period-cohort 60 is 0.01778 for the male population and 0.01185 for the female population; in the rural region, the mortality rate of period-cohort 60 is 0.01587 for the male population and 0.01101 for the female population.

The age specific mortality rates of the urban population are generally less than those of

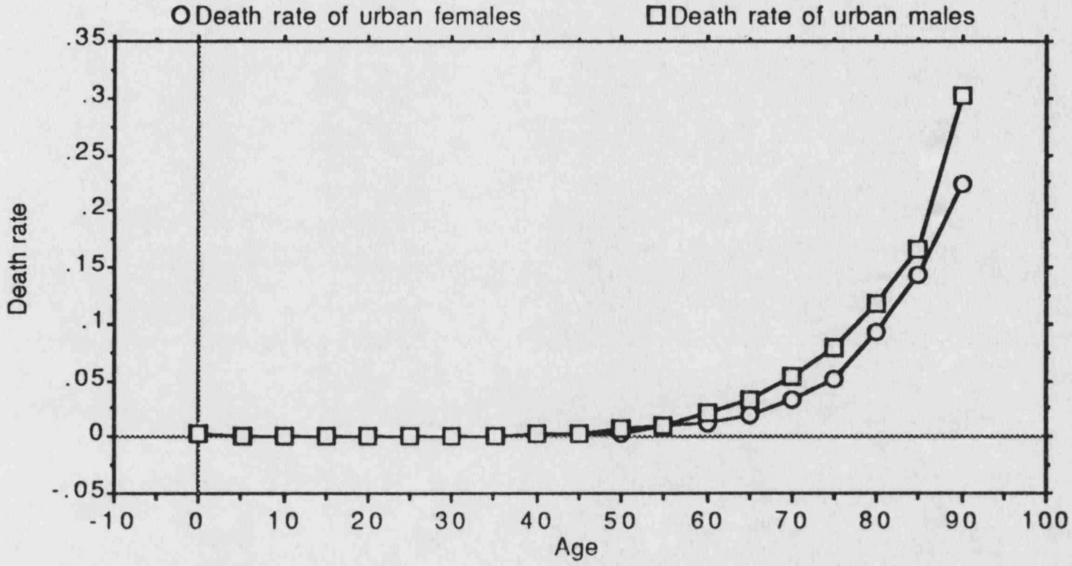


Figure 3-1 Mortality rates of urban female and male populations in China

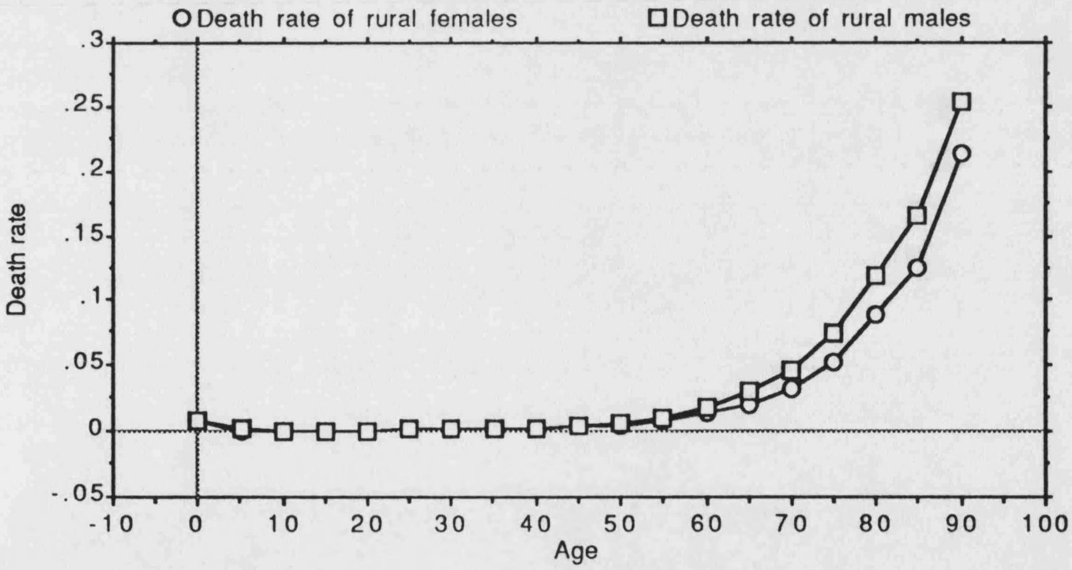


Figure 3-2 Mortality rates of rural female and male populations in China

the rural population for ages below 10 while reverse is true for ages over 60. For example, for the male population of period-cohort 5, the mortality rate is 0.00083 in the urban region and 0.00150 in the rural region. For the female population of period-cohort of 80, the mortality rate is 0.08303 in the urban region and 0.07933 in the rural region. This difference may be the result of difference of social and environmental conditions in the urban and rural regions in China. For example, the children in urban areas may have better health service than those in rural areas. Environmental pollution is much less in rural areas than in urban areas. Most farmers over 60 may still do some farmwork which may be beneficial to their health while most urban workers over 60 have retired in China.

The estimated out-migration rates are shown in table 3-5 and figure 3-3. The out-migration rates of the rural population are generally much higher than those of the urban population so that there is net migration from the rural region to the urban region. For example, for the male population of the period-cohort 5, the out-migration rate is 0.00025 in the urban region but reaches 0.00317 in the rural region.

Table 3-5 Selected results of the estimated out-migration rates for urban and rural areas in China

	Male		Female	
Period-cohort	Urban	Rural	Urban	Rural
Birth	0.00046	0.00240	0.00101	0.00259
5	0.00025	0.00317	0.00026	0.00290
10	0.00017	0.00400	0.00024	0.00363
20	0.00058	0.01597	0.00259	0.01661
40	0.00058	0.00383	0.00024	0.00481
60	0.00133	0.00281	0.00019	0.00269
80	0.00052	0.00374	0.00049	0.00328

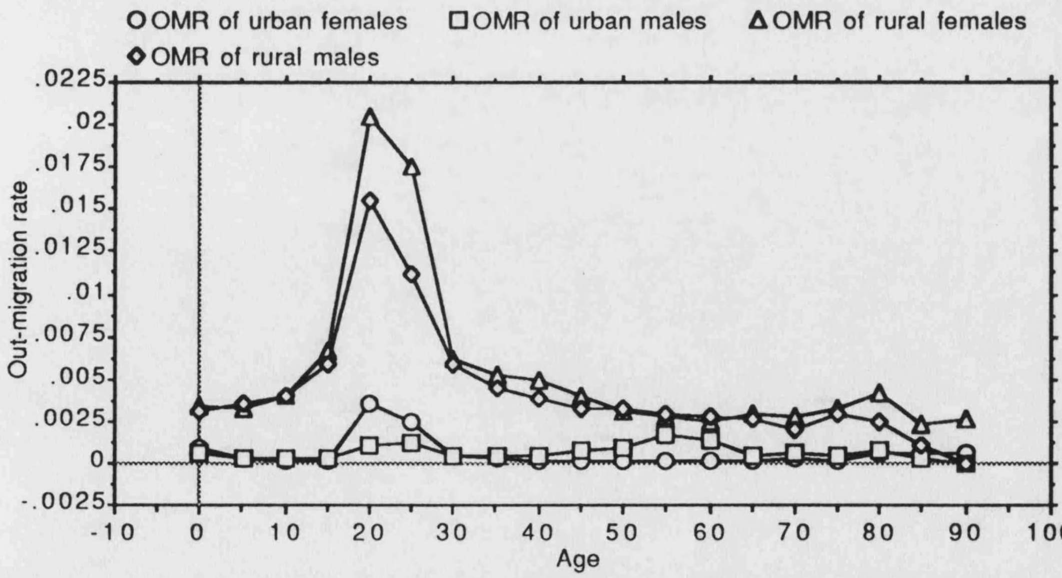


Figure 3-3 Out-migration rates (OMR) of urban and rural populations in China

Both rural male and female populations, and the urban female population have higher out-migration rates in age group 15-30 than other age groups which reflects the higher mobility of young groups. For example, for the rural male population, the out-migration rate is 0.00317 in the period-cohort 5, 0.01597 in the period-cohort 20, and 0.00383 in the period-cohort 40. It is interesting to note that the mobility of the young urban male population is not particularly pronounced. Indeed, young urban males rarely migrate to rural areas. However, young urban males do make a lot of migrations between urban areas which are not considered here (see chapter seven for these migrations). The urban male population does produce a small peak in its migration rate in the age group 55-60 which may reflect retirement migrations from urban to rural areas. For example, the out-migration rate for the urban male population is 0.00025 in the period-cohort 5, 0.00058 in the period-cohort 20, and 0.00133 in the period-cohort 60.

The female population has a higher out-migration rate than the male population in the age group 15-30 which probably reflects marriage migrations. For example, for the rural population of the period-cohort 20, the out-migration rate is 0.01597 for the male population and 0.01661 for the female population.

The total fertility rate of the urban population was 1.94 and the total fertility rate of the rural population was some 40 percent higher at 2.72 in 1987. Population reproduction in the urban region is below the replacement level while it is clearly well over the replacement level in the rural region. Generally speaking, an average rural couple has 0.78 more children than an average urban couple. This does have important implications for population control policy. More efforts should be made to reduce the total fertility rate in the rural region.

The estimated age-specific fertility rates are shown in table 3-6 and figure 3-4. The age-specific fertility schedules of the urban and rural populations are similar in structure and are shown in figure 3-4. However the age specific fertility rates of the rural population are generally higher than those of the urban population especially in the age group 20-30. For example, for the female population of the period-cohort 20, the fertility rate is 0.06428 in the urban region and 0.10648 in the rural region. For the female population of period-cohort 30, the fertility rate is 0.07725 in the urban region and 0.11907 in the rural region.

Table 3-7 shows selected results of the estimated survival rates. The survival rate is the probability that a person in one region at the beginning of the period will survive in the original or the other region to the end of the period. For example, for a male in period-cohort 20 in the urban region at the beginning of the one-year period, the probability that he will survive in the urban region to the end of the period is 0.99809

Table 3-6 Selected results of the estimated fertility rates for urban and rural areas in China

Period-cohort	Urban	Rural
15	0.00009	0.00020
20	0.06428	0.10648
25	0.22048	0.26051
30	0.07725	0.11907
35	0.02371	0.03976
40	0.00602	0.01358
45	0.00141	0.00449
50	0.00011	0.00043

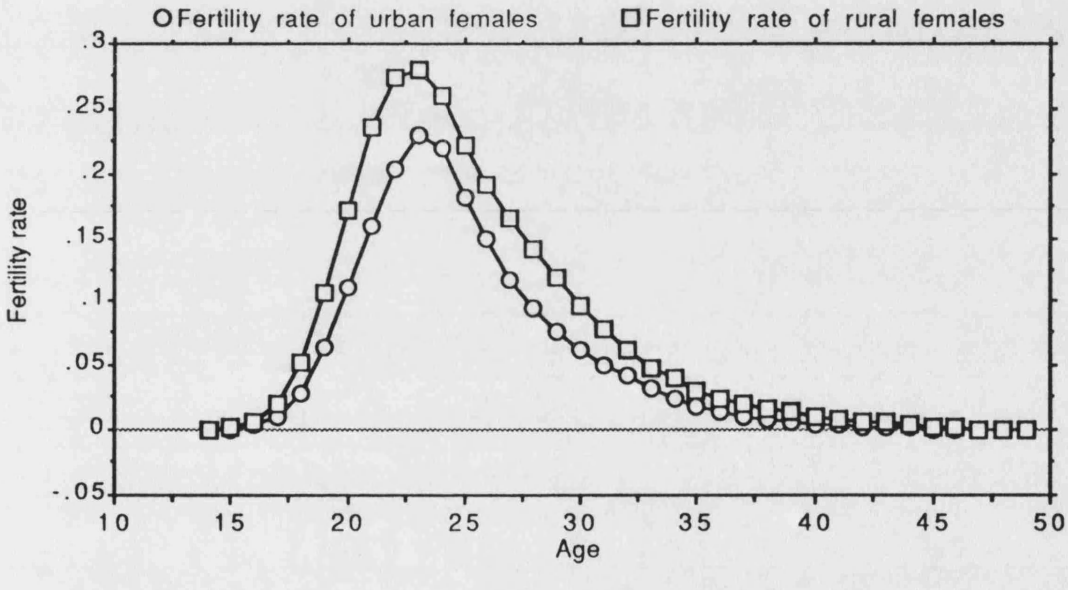


Figure 3-4 Fertility rates of urban and rural populations in China

and in the rural region 0.00058. For a female in period-cohort 20 in the rural region in the beginning of the one-year period, the probability that she will survive in the rural region to the end of the period is 0.98215 and in the urban region 0.01661.

In the next sections, further characteristics of urban-rural population dynamics will be revealed via the construction of urban-rural life tables.

3.4 Urban-rural population life tables

This section will construct urban-rural population life tables of the population at various ages of China on the basis of the results of the demographic rates estimation in the

Table 3-7 Selected results of the estimated survival rates for urban and rural areas in China

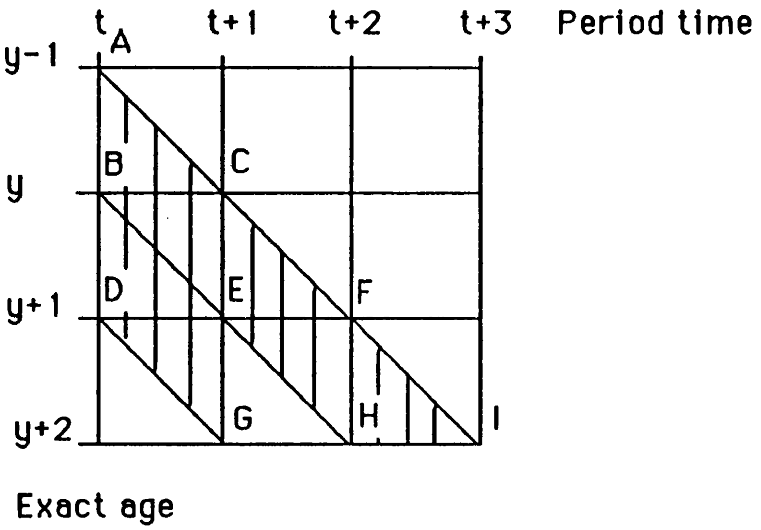
Period-cohort	From urban to Urban	From urban to Rural	From rural to Urban	From rural to Rural
	Male			
Birth	0.97925	0.00046	0.00240	0.97492
5	0.99892	0.00025	0.00317	0.99534
10	0.99923	0.00017	0.00400	0.99531
20	0.99809	0.00058	0.01597	0.98271
40	0.99751	0.00058	0.00383	0.99315
60	0.98089	0.00133	0.00281	0.98131
80	0.88586	0.00052	0.00374	0.88739
	Female			
Birth	0.97807	0.00101	0.00259	0.97533
5	0.99896	0.00026	0.00290	0.99580
10	0.99919	0.00024	0.00363	0.99588
20	0.99627	0.00259	0.01661	0.98215
40	0.99813	0.00024	0.00481	0.99327
60	0.98796	0.00019	0.00269	0.98629
80	0.91648	0.00049	0.00328	0.91738

previous research. The calculations are same for the male and female populations, so gender label g is omitted. The age and time intervals are one year. The age-specific forward mortality rates, fertility rates, out-migration rates and survival rates of various period-cohorts are available. These period-cohort rates will be used to estimate life-table-cohort rates. Figure 3-5 is a Lexis diagram showing the meaning of age, period-cohort and life-table-cohort notation. Period-cohort will be labeled as a and r(y). Life-table-cohort will be labeled as y. Exact age will be labeled as x, z as well as y to link exact age with life-table-cohort. Figure 3-5 will also be used to illustrate various interpolation and estimation procedures as will be explained later. The variables are defined as follows. Most definitions are same as in section 3.2 and 3.3 except that labels l and h are redefined here.

$u^k{}_a$ is the forward mortality rate of period-cohort a in region k, k=i,j; a=0, 1, ... A; i=urban; j=rural; The last period-cohort is labeled A and infants-cohort zero.

$f^k{}_a$ is the forward fertility rate of period-cohort a in region k, k=i,j.

$b^k{}_y$ is the occurrence-exposure fertility rate of life-table-cohort y in region k. Life-table-cohort y refers to the same population group who attaining exact age from y to y+1. y=15, 16, ... 49; k=i,j.



Note: life-table-cohort y refers to parallelogram BCEF which involves two periods t to t+1 and t+1 to t+2;
Period-cohort a=r(y) refers to parallelogram ABCE in period t to t+1.

Figure 3-5 Lexis diagram showing the meaning of age, period-cohort and life-table-cohort notation

m^k_a is the forward out-migration rate of period-cohort a in region k, k=i,j.

w^k_y is the occurrence-exposure out-migration rate of life-table-cohort y in region k. y=0, 1, ... G; k=i,j. The last life-table-cohort is labeled G with initial age G and ending open age G+1. G also refers to the last exact age considered in life tables and G+1 refers to the last open age of G+1 and over.

$S_a = [\ S^{kh}_a\ ]$ is the 2x2 matrix of the survival rates of period-cohort a. S^{kh}_a is the survival rate of the population of period-cohort a who are in region k at time t and survive in region h at time t+1. a=0, 1, ..., A; k=i,j; h=i,j.

$q_{yy+1} = [q^{kh}_{yy+1}]$ is the 2x2 matrix of the survival probabilities of life-table-cohort y. q^{kh}_{yy+1} is the probability that a person attaining exact age y in a period in region k will survive in region h to attain exact age y+1 in the next period, k=i,j; h=i,j.

$_x\mathbf{l}_y = [\ ^k{}_x l^h{}_y\ ]$ is the 2x2 matrix of the population in the life table of age x, where $^k{}_x l^h{}_y$ is the population of exact age y in region h who was in region k of age x before, y≥x; k=i,j; h=i,j.

$_x\mathbf{L}_{yy+1}=[\ ^{hk}{}_x L_{yy+1}]'$ is the 2x2 matrix of the person-years in the life table of age x, where $^{hk}{}_x L_{yy+1}$ is the person years lived by the population $^k{}_x l^k{}_x$ in region h from age y to age y+1 who was in region k of age x before, y≥x; k=i,j; h=i,j. Here ' refers to the operation of matrix transposition.

$_x\mathbf{T}_z = [\ ^{hk}T_z\ ]'$ is the 2x2 matrix of total person-years in the life table of age x, where $^{hk}{}_x T_z$ is the total person years lived by the population $^k{}_x l^k{}_x$ in region h beyond exact age z who was in region k of age x before, z≥x; k=i,j; h=i,j.

$_x\mathbf{e}_z = [\ ^{hk}{}_x e_z\ ]'$ is the 2x2 matrix of the expectations of life, where $^{hk}{}_x e_z$ is the expectation of life of a person of age x in region k will live in region h after attaining exact age z, z≥x; k=i,j; h=i,j.

This section aims to calculate the expectation of life of the population with an exact age in a region. Thus the concepts of exact age and region specific cohorts are adopted and a series of life tables based on regions of residence at particular ages are developed. A concise notation system is adopted as matrix expressions are used. Therefore, some standard intermediate variables are not necessary and do not appear in this text. For simplicity, some summation notation is omitted. Notation $^{hk}{}_x L_{yy+1}$, $^{hk}{}_x T_z$ and $^{hk}{}_x e_z$ refer to standard notation $^{hk}{}_x L^{**}{}_{yy+1}$, $^{hk}{}_x T^{**}{}_{z*}$ and $^{hk}{}_x e^{**}{}_{z*}$ (Rees and Wilson, 1977). A unit radix, i.e., one infant in the birth cohort, is assumed for each life table of a particular age. In this case, $^k{}_x l^h{}_y$ can also be interpreted as the probability that a person of exact age x in region k will attain exact age y in region h.

The following methods are used to calculate the life tables of various ages. The initial population in the life table of age x is assumed as follows.

$$_x\mathbf{l}_x = \begin{vmatrix} 1 & 0 \\ 0 & 1 \end{vmatrix} \qquad x=0,\ 1,\ \dots\ G \qquad (3\text{-}71)$$

The second year population of exact age 1 in the life table of age 0 is estimated as follows:

$$_0\mathbf{l}_1 = [\ ^k{}_0 l^h{}_1\ ] \qquad (3\text{-}72)$$

$$^k{}_0 l^h{}_1 = S^{kh}{}_0\ (\ 1 - 0.5\ u^h{}_1\ ) \qquad k=i,\ j;\ h=i,\ j \qquad (3\text{-}73)$$

The survival probability of the life-table-cohort y can be estimated using survival rates of period-cohorts r(y) and r(y+1). In figure 3-5, life- table-cohort rate q_{yy+1} refers to parallelogram BCEF and is best interpolated using period-cohort survival rates $S_{r(y)}$ involving parallelogram ABCE in period t to t+1 and $S_{r(y+1)}$ involving parallelogram CEFH in period t+1 to t+2. The survival rate involving parallelogram CEFH in period t+1 to t+2 is substituted by the rate involving parallelogram BDEG in period t to t+1 as constant rates are assumed in life table calculations. Therefore:

$$q_{yy+1} = 0.5\ (\ S_{r(y)} + S_{r(y+1)}\ ) \qquad y=1,\ 2,\ \ldots\ G\text{-}1 \qquad (3\text{-}74)$$

The second year population of age y+1 in the life table of age y is estimated as follows:

$$_{y}l_{y+1} = {}_{y}l_{y}\ q_{yy+1} = q_{yy+1} = 0.5\ (\ S_{r(y)} + S_{r(y+1)}\ ) \qquad y=1,\ 2,\ \ldots\ G\text{-}1 \qquad (3\text{-}75)$$

The person-years matrix for the population in the life table of age y lived from age y to age y+1 can be estimated by the average population of age y and age y+1. In figure 3-5, the population of exact age y in a life table $_{x}l_{y}$ refers to line BC. Similarly, $_{x}l_{y+1}$, $_{x}l_{y+2}$ refer to line EF and HI respectively. The person-years lived by life-table-cohort y involving parallelogram BCEF can be estimated as the average of $_{x}l_{y}$ and $_{x}l_{y+1}$. Similarly, the person-years lived by life-table-cohort y+1 involving parallelogram EFHI can be estimated as the average of $_{x}l_{y+1}$ and $_{x}l_{y+2}$. Therefore:

$$_{x}L_{yy+1} = 0.5\ (\ _{x}l_{y} + {}_{x}l_{y+1}\ ) \qquad (3\text{-}76)$$

$$_{x}L_{y+1y+2} = 0.5\ (\ _{x}l_{y+1} + {}_{x}l_{y+2}\ ) \qquad (3\text{-}77)$$

It is straightforward to obtain the following equation:

$$_{y}L_{yy+1} = 0.5\ (\ _{y}l_{y} + {}_{y}l_{y+1}\ ) \qquad y=0,1,\ \ldots\ G\text{-}1 \qquad (3\text{-}78)$$

The person-years matrix for the population in the life table of age x lived from age y+1 to age y+2 can be estimated using period-cohort survive rate. In figure 3-5, according to equations (3-76) and (3-77), $_{x}L_{yy+1}$ can be expressed by line CE and $_{x}L_{y+1y+2}$ by line FH. It is noted that parallelogram CEFH refers to period-cohort r(y+1) in period t+1 to t+2 and, assuming a constant rate, its survival rate is $S_{r(y+1)}$ of period-cohort r(y+1) in period t to t+1 involving parallelogram BDEG. Therefore, the relationship of person-years of life-table-cohort y and y+1 can be expressed as:

$$_{x}L_{y+1y+2} = {}_{x}L_{yy+1}\ S_{r(y+1)} \quad x=0,\ 1,\ \ldots\ G\text{-}2;\ y=x,\ x+1,\ \ldots G\text{-}2 \qquad (3\text{-}79)$$

The last person-years matrix for the population in the life table of age x lived after age G can be estimated as follows:

$$_{x}L_{GG+1} = (\ I - S_{r(G+1)}\ )^{-1}\ {}_{x}L_{G\text{-}1G}\ S_{r(G)} \qquad x=0,\ 1,\ \ldots\ G\text{-}1 \qquad (3\text{-}80)$$

The person-years matrix for the population in the life table of age G can also be estimated. Three procedures similar to equation (3-75), (3-78) and (3-80) are combined here, but the survival probability matrix of the life-table-cohort G is assumed to be the survival rate matrix of the last period-cohort A, i.e., r(G+1).

$$ {}_{G}L_{GG+1} = 0.5\ (\ I - S_{r(G+1)}\ )^{-1}\ (\ {}_{G}l_{G} + S_{r(G+1)}\ ) \qquad (3\text{-}81) $$

The total person-years lived by the population in the life table of age x beyond exact age z can be calculated as follows:

$$ {}_{x}T_{z} = \Sigma^{G}_{y=z}\ {}_{x}L_{yy+1} \qquad x=0,\ 1,\ \dots\ G;\ z=x,\ x+1,\ \dots\ G \qquad (3\text{-}82) $$

The population aged y+1 in the life table of age x can be estimated using the following equation obtained from equation (3-76):

$$ {}_{x}l_{y+1} = 2\ {}_{x}L_{yy+1} - {}_{x}l_{y} \qquad x=0,\ 1,\ \dots\ G\text{-}2;\ y=x+1,\ x+2,\ \dots\ G\text{-}1 \qquad (3\text{-}83) $$

It has been found that the estimation of ${}_{x}l_{y+1}$ using equation (3-83) fluctuates over ages because of the error-cumulative nature of equation (3-83). An alternative estimation method can be used as follows:

$$ {}_{x}l_{y+1} = 0.5\ (\ {}_{x}L_{yy+1} + {}_{x}L_{y+1y+2}\ ) $$

$$ x=0,\ 1,\ \dots\ G\text{-}3;\ y=x+1,\ x+2,\ \dots\ G\text{-}2 \qquad (3\text{-}84) $$

$$ {}_{x}l_{G} = 0.5\ (\ {}_{x}L_{G-1G}S_{r(G)} + {}_{x}L_{G-1G}\ ) \qquad x=0,\ 1,\ \dots\ G\text{-}2 \qquad (3\text{-}85) $$

Now, the expectation of life of a person of exact age x in region k will live in region h beyond exact age z can be calculated as follows:

$$ {}^{hk}{}_{x}e_{z} = {}^{hk}{}_{x}T_{z}\ /\ {}^{k}{}_{x}l^{*}{}_{z} = {}^{hk}{}_{x}T_{z}\ /\ ({}^{k}{}_{x}l^{i}{}_{z} + {}^{k}{}_{x}l^{j}{}_{z}) \qquad (3\text{-}86) $$

$$ x=0,1,\ \dots\ G;\ z=x,\ x+1,\ \dots\ G;\ k=i,j;\ h=i,j $$

$$ {}_{x}e_{z} = [\ {}^{hk}{}_{x}e_{z}\ ]' \qquad x=0,1,\ \dots\ G;\ z=x,\ x+1,\ \dots\ G \qquad (3\text{-}87) $$

To re-emphasize a unit radix is assumed in the calculation of life table of each age. Therefore, the following equation can be obtained to calculate the expectation of life of a person of exact age x in a particular region will live in each region in the rest of his or her life:

$$ {}_{x}e_{x} \doteq {}_{x}T_{x} = \Sigma^{G}_{y=x}\ {}_{x}L_{yy+1} \qquad x=0,1,\ \dots\ G \qquad (3\text{-}88) $$

Table 3-8 presents the life expectations ${}_{x}e_{x}$ for populations with particular age x in urban and rural areas, computed using the methods set out above. They describe clearly the expected life experience of persons who are age x and reside in one of the two regions. For example, female population at birth in the urban region may spend 71.82 years in the urban region and 1.77 years in the rural region; female population at birth in the rural region may spend 56.29 years in the rural region and 16.17 years in the urban region. The male population at birth in the urban region may spend 68.33 years in the urban region and 1.40 years in the rural region; male population at birth in the rural region may spend 56.58 years in the rural region and 12.41 years in the urban region. It is clear that the rural population is more mobile than urban population as

Table 3-8 Life expectations estimation for urban and rural areas in China

Age	Urban population life expectation in Urban	in Rural	Totals	Rural population life expectation in Urban	in Rural	Totals
	Male					
0	68.33	1.40	69.73	12.41	56.58	68.99
5	64.75	1.32	66.07	11.93	54.10	66.03
10	60.04	1.26	61.30	11.01	50.34	61.35
20	50.56	1.17	51.73	8.00	43.84	51.84
30	41.68	0.66	42.34	3.38	39.15	42.53
40	32.48	0.52	33.00	1.78	31.49	33.27
50	23.67	0.36	24.03	0.91	23.55	24.46
60	15.86	0.14	16.00	0.44	16.11	16.55
70	9.81	0.04	9.85	0.20	10.12	10.32
	Female					
0	71.82	1.77	73.59	16.17	56.29	72.46
5	68.46	1.64	70.10	15.80	53.88	69.68
10	63.73	1.58	65.31	14.94	49.98	64.92
20	54.33	1.40	55.73	11.86	43.47	55.33
30	46.03	0.24	46.27	4.54	41.40	45.94
40	36.66	0.14	36.80	2.51	34.09	36.60
50	27.53	0.09	27.62	1.21	26.37	27.58
60	19.21	0.05	19.26	0.65	18.66	19.31
70	12.01	0.03	12.04	0.32	11.93	12.25

regards urban-rural migration.

The young population in the rural region may spend a much longer period in the urban region than the older rural population as the young population have a much higher out-migration rate and a longer life expectation. For example, for the rural population of age 20, a male may spend 8.00 years in the urban region, and a female 11.86 years. But for the rural population of age 30, a male may spend 3.38 years in the urban region, and a female 4.54 years. For the rural population of age 40, a male may spend only 1.78 years in the urban region, and a female only 2.51 years.

The rural female population may spend a longer period in the urban region than the rural male population as they generally have higher out-migration rates in the age group 15-30. For example, a female of age 5 in the rural region may spend 15.80 years in the urban region, a male only 11.93 years. The urban female population aged below 30 may spend a longer period in the rural region than the urban male population due to higher out-migration rate of young urban females. The reverse is true for those aged over 30 due to higher out-migration rate of urban males aged over 30. A female of age 5 in the urban region may spend 1.64 years in the rural region, a male only 1.32 years. However, a female of age 50 in the urban region may spend only 0.09 year in the rural region, a male 0.36 year.

The total life expectation ${}^{*k}{}_{x}e_{z}$ of persons aged x in region k will live in all regions beyond exact age z can be straightforwardly calculated as follows:

$$ {}^{*k}{}_{x}e_{z} = {}^{ik}{}_{x}e_{z} + {}^{jk}{}_{x}e_{z} \qquad x=0,\ 1,\ \ldots\ G;\ z=x,\ x+1,\ \ldots\ G;\ k=i,\ j \qquad (3\text{-}89) $$

The life expectation at birth of the urban population is higher than that of the rural population. The female population has a higher life expectation at birth than the male population. For example, the life expectation of female population at birth is 73.59 years in the urban region and is 72.46 years in the rural region. The life expectation of male population at birth is 69.73 years in the urban region and is 58.99 years in the rural region. However, the rural population will have higher life expectations than the urban population for males aged over 20 and for females aged over 60 because of the urban-rural difference of age-specific out-migration rates and mortality rates. The mortality rates of the rural population aged over 56 are generally less than the corresponding mortality rates of the urban population. For example, for the male population of age 60, the life expectation is 16.00 years in the urban region and 16.55 years in the rural region. For the female population of age 70, the life expectation is 12.04 years in the urban region and 12.25 years in the rural region.

3.5 Spatial fertility expectation

Similarly to life expectation calculations, spatial fertility expectations and out-migration expectations can be calculated.

The net reproduction rate NRR^{kh} of the population at birth is the expected births that a female born in region k will produce in region h in her whole life. Here only the female population is involved.

$$ NRR^{kh} = \Sigma^{49}{}_{y=15}\ b^{h}{}_{y}\ {}^{hk}{}_{0}L_{yy+1} \qquad k=i,\ j;\ h=i,\ j \qquad (3\text{-}90) $$

The expression $b^{k}{}_{y}$ is the occurrence-exposure fertility rate of the life-table-cohort y which can be estimated as follows:

$$ b^{k}{}_{15} = f^{k}{}_{15}/(\ 1 - 0.5\ u^{k}{}_{15}\ ) + 0.5\ f^{k}{}_{16}/(\ 1 - 0.5\ u^{k}{}_{16}\ ) \qquad k=i,j \qquad (3\text{-}91) $$

$$ b^{k}{}_{y} = 0.5\ (\ f^{k}{}_{r(y)}/(\ 1 - 0.5\ u^{k}{}_{r(y)}\ ) + f^{k}{}_{r(y+1)}/(\ 1 - 0.5\ u^{k}{}_{r(y+1)})) $$

$$ y=16,\ 17,\ \ldots\ 48;\ k=i,\ j \qquad (3\text{-}92) $$

$$ b^{k}{}_{49} = 0.5\ f^{k}{}_{49}/(\ 1 - 0.5\ u^{k}{}_{49}\ ) + f^{k}{}_{50}/(\ 1 - 0.5\ u^{k}{}_{50}) \qquad k=i,\ j \qquad (3\text{-}93) $$

Here two procedures are combined. Firstly, the occurrence-exposure fertility rates of period-cohorts are estimated from the forward fertility rates of period-cohorts using forward mortality rates. Secondly, the occurrence-exposure fertility rate of the life-table-cohort y is calculated from the occurrence-exposure fertility rates of period-cohorts r(y) and r(y+1). The second procedure is similar to the interpolation of the survival probability of the life-table-cohort y using the survival rates of period-cohorts r(y) and r(y+1) as discussed above.

The 2x2 matrix of net reproduction rate **NRR** = [NRR^{kh}] is obtained as follows:

$$\mathbf{NRR} = \begin{vmatrix} 1.82 & 0.06 \\ 0.35 & 2.10 \end{vmatrix} \qquad (3\text{-}94)$$

A female born in the urban region is expected to produce 1.82 children in the urban region and 0.06 children in the rural region. A female born in the rural region is expected to produce 2.10 children in the rural region and 0.35 children in the urban region. The population reproduction in the urban region is below the replacement level while it is well over the replacement level in the rural region. It would seem then that population growth is extremely sensitive to its location in the rural region compared to the urban region. The implication is clear in the context of a policy to control population and it is that more efforts should be made to reduce the net reproduction rate in the rural region. In summary, the rural population has a much higher net reproduction rate than the urban population and furthermore it has a higher propensity to produce children in the urban region than the urban population does in the rural region.

3.6 Spatial out-migration expectation

Similar to the net reproduction rate used for the analysis of spatial fertility expectation, an index called net migraproduction rate can be used to analyze spatial out-migration expectation (see Rogers and Willekens, 1986). A net migraproduction rate is the expected number of out-migrations that an individual makes from a region during his or her whole life, Thus the net migraproduction rate NMR^{kh} of the population at birth is the expected number of out-migrations that a person born in region k will make in region h in his or her whole life.

$$NMR^{kh} = \Sigma^{G}_{y=0}\, w^{h}_{y}\, {}^{hk}{}_{0}L_{yy+1} \qquad k=i, j;\ h=i, j \quad (3\text{-}95)$$

The expression w^{k}_{y} is the occurrence-exposure out-migration rate of the life-table-cohort y which can be estimated as follows:

$$w^{k}_{0} = m^{k}_{0} /((1 - 0.5\, u^{k}_{0})(1 - 0.5\, u^{h}_{0})) + 0.5\, m^{k}_{1} / ((1 - 0.5\, u^{k}_{1})(1 - 0.5\, u^{h}_{1}))$$
$$k=i, j;\ h=i, j;\ k\neq h \qquad (3\text{-}96)$$

$$w^{k}_{y} = 0.5\, (m^{k}_{r(y)} /((1 - 0.5\, u^{k}_{r(y)})(1 - 0.5\, u^{h}_{r(y)})) \qquad (3\text{-}97)$$
$$+ m^{k}_{r(y+1)} / ((1 - 0.5\, u^{k}_{r(y+1)})(1 - 0.5\, u^{h}_{r(y+1)})))$$
$$y=1, 2, \ldots G\text{-}1;\ k=i, j;\ h=i, j;\ k\neq h$$

Here three procedures are combined. Firstly, the occurrence-exposure out-migration rates of period-cohorts are estimated from the forward out-migration rates of period-cohorts. For simplicity, only the mortality rates are implicitly considered in the calculation of the population at risk. Secondly, the out-migration rates are modified to take into account those non-survival migrants by using the mortality rates of the destination region. Thirdly, the occurrence-exposure out-migration rate of the life-table-cohort y is calculated from the occurrence-exposure out-migration rates of period-cohorts r(y) and r(y+1). The third procedure here is similar to the second procedure in the estimation of the occurrence-exposure fertility rates of life-table-cohorts above.

The quantity $w^k{}_G$ equals zero as the out-migration rates of the period-cohorts r(G) and r(G+1) are zero.

The 2x2 matrix of net migraproduction rate **NMR** = [NMR^{kh}] is obtained and is as follows for the female population:

$$\mathbf{NMR_f} = \begin{vmatrix} 0.0451 & 0.0096 \\ 0.0080 & 0.3491 \end{vmatrix} \qquad (3\text{-}98)$$

and for the male population it is:

$$\mathbf{NMR_m} = \begin{vmatrix} 0.0475 & 0.0054 \\ 0.0099 & 0.2903 \end{vmatrix} \qquad (3\text{-}99)$$

A female born in the urban region has a propensity to make 0.0451 out-migrations from the urban region while a female born in the rural region has a propensity to make 0.3491 out-migrations from the rural region. A male born in the urban region has a propensity to make 0.0475 out-migrations from the urban region which is more than for a female. A male born in the rural region has a propensity to make 0.2903 out-migrations from the rural region which can be seen to be less than for a female. In summary, the rural population has a much higher propensity to make out-migrations than the urban population. The rural female population in turn has a much higher propensity to make out-migrations than the rural male population. The urban male population has a slightly greater propensity to make out-migrations than the urban female population.

3.7 Conclusion

This preliminary analysis of the urban-rural population dynamics of China has used a multiregional demographic accounting approach. The population data available are the one year age and one year time birth data, death data, one year age and five year time migration data, and the end date population data. The procedures to estimate the urban-rural population accounts and the urban-rural life tables are developed on the basis of the multiregional population accounts concept. The multiregional population accounts and demographic rates of fertility, mortality and migration are estimated and urban-rural population life tables of China are constructed. The urban-rural population life table at birth is used to calculate fertility expectations and out-migration expectations. The estimation results reveal fundamental characteristics of urban-rural population dynamics of China. These can be summarized under six basic headings

Firstly, the life expectation at birth of the urban population is slightly higher than that of the rural population mainly due to the lower mortality rate of children aged below 10 in the urban region. The urban-rural differentials are significant in terms of living standards. Health service and nutrition are much better in urban areas than in rural areas in China. Thus children have lower mortality rate in urban areas. For those aged over 60, the mortality rate is slightly higher in the urban region than in the rural region probably because of social and environmental differences.

Secondly, the out-migration rates of the rural population are generally much higher than those of the urban population so that there is net migration from the rural region to the urban region. China is still at the stage of industrialization and urbanization. Thus there is a steady flow of rural to urban migration. Most of these migrations are for employment, business or training. The young population has a much higher out-migration rate. The mobility of the young urban male population is not particularly pronounced. The urban male population does have a small peak in its migration rate in age group 55-60 which may reflect the retirement migrations from urban to rural areas.

Thirdly, the total fertility rate in the urban region is significantly less than that in the rural region which may have important implications for population control policy. The population reproduction in the urban region is below the replacement level, while it is well over the replacement level in the rural region. This difference in the urban and rural fertilities is due to the significant differentials in the living standards, attitudes towards childbearing and the efforts of government's family planning campaigns between urban and rural areas. Generally, urban peoples are willing to have fewer children than rural peoples. The government's family planning policy is more effectively implemented in the urban areas than in the rural areas. More efforts should be made to reduce the total fertility rate in the rural region.

Fourthly, because of the higher out-migration rate of the rural population, the rural female population at birth will spend 16.17 years in the urban region and the male rural population 12.41 years. These are much longer periods than the urban population at birth will spend in the rural region. As a result, the rural population has a much higher propensity to produce children in the urban region than the urban population does in the rural region. As most out-migrations are made by the young population, the young population in the rural region will spend a much longer period in the urban region than the older rural population.

Fifthly, because of the urban-rural difference of age-specific out-migration rates and mortality rates, the rural population will have a higher life expectation than the urban population for males aged over 20 and females aged over 60. However, the urban population at birth do have a higher life expectation than the rural population at birth as already mentioned.

Sixthly, the age-specific mortality rates of the female population are less than those of the male population in both regions especially over age 60. Their expectation of life at birth is higher than that of the males. The female population has a higher out-migration rate than the male population in the age group 15-30 which may reflect marriage migrations. As a whole, the rural female population has a higher propensity to make out-migrations than the rural male population. The urban male population has a slightly greater propensity to make out-migrations than the urban female population.

The analyses in this chapter produce a clear picture of current urban-rural population dynamics in China. In the next chapter, an attempt will be made to establish an urban-rural population model. The model will be used to project future urban-rural population growth in China.

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4
Urban-rural population projection

4.1 Introduction

Sound population projections are essential for well founded planning of socio-economic development. A series of population projections for China have been produced since the early 1980s (for instance, Song et al., 1981; Jiang and Lan, 1987; Zhang, 1987; Wang, 1988). These projections were valuable in the formation of population control policies in China. There are also growing concerns on population ageing in China (Zeng, Zhang and Peng, 1990). Rapid population ageing may imply serious socio-economic problems such as labour force shortages and care of the elderly. It can be assumed that there will be severe population ageing in the urban areas due to extremely low fertility there. A detailed age-specific urban and rural population projection is desirable to understand and tackle these problems. Wang was the first to carry out an urban-rural population projection of China, but the vital urban-rural migration component was disregarded in his projection model (Wang, 1988). Zeng and Vaupel used a multiregional (urban-rural) population model to study the impact of urbanization and delayed childbearing on population growth and ageing in China (1989). The various demographic rates used in their model, however, were not estimated using an accounts-based approach. Their model does on the other hand have the merit that urban-rural migration was considered even though rural to urban population transition was disregarded in their projection.

The United Nations (1989; 1991) has also produced urban and rural population projections for China until 2025. However, these projections of urban and rural populations are calculated from the projected proportion of urban population, and total population and vital age compositions of urban and rural populations are not available.

A multiregional demography approach has been used to estimate the mortality, fertility and migration rates of the urban and rural populations of China in chapter three. In this chapter, an accounts-based urban-rural population projection model will be established to make an urban-rural population projection for China.

One point needs to be discussed first with regard to urban-rural population migration and the process of transition. The migration rates estimated in chapter three only reflect pure urban-rural population migration. In reality, the urban population is partly increased by the creation of new cities and towns and the actual expansion of urban areas. This may be called rural-urban population transition. It seems that rural-urban population transition will continue to contribute to urban population growth while urban-rural migration is more strictly controlled by government in China. However, it is necessary to take into account both of these components of urban population growth in urban-rural population projections. A demo-economic model will be established in this part of the research to project total urban-rural population migration and rural-urban transition on the basis of a dynamic general equilibrium model (Lee, 1984). The urban-rural population migration will be projected using fixed migration rates if there are some rural-urban transitions. Reduced migration rates will be used if there is no rural-urban transition. The rural-urban population transition will be calculated as a residual. There will be no rural-urban transition if the residual is zero. This procedure is similar to some recent studies which have attempted to model migration using demo-economic models (Ledent, 1982; Isserman, 1985; 1986; Isserman et al., 1985). In these studies, selected economic variables were used to model or project population migration, birth and death rates.

In section 4.2, a demo-economic model of urban and rural sectors will be discussed. In section 4.3, an accounts-based urban-rural population projection model will be proposed to make urban-rural population projections of China. In section 4.4, urban-rural population projection results will be presented and analyzed. In section 4.5, the effect of urbanization on future population growth of China will be simulated and discussed. Some conclusions are given in section 4.6.

4.2 The demo-economic model of urban and rural sectors

This section will attempt to establish a demo-economic model of urban and rural sectors in an effort to model the long-term trend of urbanization in terms of urban-rural population migration. For simplicity, the word "migration" here refers both to migration and transition in this section.

There have been a number of theoretical studies dealing with the economic forces determining differential urban-rural , or more generally, sectoral growth. From these the direction of labour mobility between sectors could be deduced.

About four decades ago, Simon (1947) was the first to consider these issues. His main purpose was to reveal the anatomy of the mechanisms that are responsible for the rural to urban population shift. He used two simple economic models. His main conclusion was that a shift of labour from agricultural to nonagricultural occupations, and consequent shifts in the rural-urban population ratio, will take place when there is an increase in industrial productivity as great (or nearly so) as in agricultural productivity. This result stems from the greater income-elasticity of demand for industrial as compared with agricultural goods.

Baumol (1967) studied the problem of unbalanced sectoral growth using a simple macroeconomic model. Baumol assumed that an economy can be divided into two sectors, a non-progressive sector in which the productivity of labour is constant, and as a progressive sector where output per man-hour grows accumulatively at a constant compounded rate. One of his main findings was that there is a tendency for the output ratio of the non-progressive sector whose demands are not highly inelastic to decline and even to vanish. It should be noted that Baumol is mainly concerned with the output ratio of sectors rather than the labour ratio in his research. It is possible that the labour ratio of two sectors will remain constant even if the output ratio of the non-progressive sector declines.

Artle, Humes and Varaiya (1977) studied the same problem addressed by Simon earlier using an excess demand analysis. Here for the first time price elasticity of the demand for goods was incorporated into the model. In addition to deriving similar findings to Simon and Baumol, they reached a stronger conclusion: if the demand for food is inelastic with respect to its price, and that the demand for non-food is elastic with respect to its price, labour migrates towards the non-food sector if there is a productivity increase in the non-food sector, and if there is increasing, stable or even minor decreasing levels of productivity in the food sector. In their derivation, it was shown that the income elasticity and price elasticity of demands for goods are not independent. Furthermore this approach can be viewed as similar to comparative statics analysis though an intermediate procedure of disequilibrium analysis, namely, excess demand analysis was used to facilitate the derivation. In fact, Simon (1982) did derive the same conclusion using a comparative statics analysis in a more recent paper.

Vislie (1979) used specific production and demand functions to derive fundamental conclusions obtained by others under same assumptions including equal wages in two sectors. A most interesting finding in his paper is that the direction of migration may be quite different if wages and their growth rates in two sectors are assumed to be different. For example, in the case of Simon's problem (1947), labour may migrate to the less income elastic sector if the wage rate of this sector grows slower than the wage rate of the other sector. This is because the slower growth rate of the wage in this less income elastic sector makes its product relatively more competitive compared to the product of the other sector. Varaiya, Artle and Humes (1979) reached same conclusions obtained by Vislie though their model reflects the more general case.

Lee (1984) established a two-sector dynamic general equilibrium model to investigate the direction of migration in response to differing demographic and consumption demand behaviour, as well as variations in production conditions. He incorporated returns to scale and natural increase rate of sectoral population growth into the model as important determinants of the direction of migration, in addition to price and income elasticities, and the sectoral technical change rate. In addition to those findings obtained earlier by others, he also found that no definite conclusions regarding the direction of migration can be made in the case of decreasing returns to scale in both sectors.

Some detailed research has also been undertaken in modelling urban-rural migration and three fairly recent examples can be cited. A computable general equilibrium model of the Indian economy has been established to model migration and city growth (Becker et al., 1986). It is a long-run model of the Indian economy divided into ten sectors. Urban immigration and city growth are driven by a variety of forces which include capital deepening; skill accumulation per worker; unbalanced total factor productivity advance; demand shifts with an urban bias; changes in world market conditions and government policies. An urban-rural labour migration model has been produced for South Korea (Park and Fullerton, 1980). Here a simultaneous equations system was used to describe the rural and urban labour market and migration behaviour in postwar Korea. The urban-rural labour migration was driven by urban-rural wage and unemployment differentials in their model. The empirical results are generally consistent with economic theory. Finally, a model of urbanization has been used by Berry et al. for several countries including China (Ran and Berry, 1989). This model was used to assess the extent of underurbanization of China in the period 1949-1986. Here urban-rural migration was driven by urban-rural differentials in the growth of productivity. The demand side was not considered in their model.

For the purpose of a long-term trend projection of urbanization, a demo-economic model of urban and rural sectors based on a general equilibrium model (Lee, 1984) has been chosen for this research. Several simplifications are made in the model. First, the production function is simplified by linking output and labour input using the labour productivity rate. Second, it is assumed that demands for agricultural and industrial goods are determined by income while the effect of price on the demand for goods is disregarded. Therefore, the price elasticity of the demand for goods does not appear in the model. In fact, income and price elasticity of the demand for goods are not independent variables as is shown by Artle, Humes and Varaiya (1977). Simon (1982) also challenged that the assumption of price elasticity of the demand for goods is not likely to be satisfied in a real economy. This is especially so in underdeveloped countries where foodstuffs are available at not much above the subsistence level. This assumption means a decrease in the price of manufactured products will decrease the consumption of agricultural products. There are several advantages in using this model. First, it is relatively simple to implement. It may be of course much more desirable to establish a detailed econometric model of the urban and rural economy of China but this undoubtedly would result in much greater data requirements. Second, the model has a sound theoretical basis. It is a general equilibrium model and both the supply side and the demand side are incorporated. Third, exogenous variables are kept to minimum. In any projection, exogenous variables need to be projected first. The meanings of projection results are as a result much clearer if only a few exogenous variables are involved.

A basic assumption of the demo-economic model is that an industrial product and an agricultural product are produced in the urban sector and rural sector respectively and consumed by the whole population. Thus, the urban sector corresponds to the non-agricultural sector, and the rural sector to the agricultural sector.

The variables are defined as follows:

$P(t)$	is the total population at the end of period t-1 to t.
$L^{Pk}(t)$	is the labour force in sector k at the end of period t-1 to t, k=i (urban; non-agricultural), j (rural; agricultural).
$n^{P}(t)$	is the natural increase rate of total population in period t-1 to t.
$n^{Lk}(t)$	is the forward natural increase rate of labour force in sector k in period t-1 to t, k=i, j.
$r^{k}(t)$	is the labour productivity in sector k in period t-1 to t, k=i, j.
$o^{k}(t)$	is the growth rate of labour productivity in sector k in period t-1 to t, k=i, j.
$Q^{k}(t)$	is the output of industrial or agricultural product in sector k in period t-1 to t, k=i, j.
$c^{k}(t)$	is the consumption per capita of the product produced in sector k in period t-1 to t, k=i, j.
$y(t)$	is the income per capita in period t-1 to t.
$e^{k}(t)$	is the income elasticity of the consumption of the product produced in sector k in period t-1 to t, k=i, j.
$M^{NL}(t)$	is the net urban-rural labour migration in period t-1 to t.

The following equations can be obtained. For simplicity, the year-end labour force and population figures are used in both the production and consumption equations. The production equation is:

$$Q^{k}(t) = r^{k}(t)\, L^{Pk}(t) \qquad k=i, j \qquad (4\text{-}1)$$

The consumption equation is:

$$Q^{k}(t) = P(t)\, c^{k}(t) \qquad k=i, j \qquad (4\text{-}2)$$

The labour productivity increase equation is:

$$r^{k}(t) = (1 + o^{k}(t))\, r^{k}(t-1) \qquad k=i, j \qquad (4\text{-}3)$$

The equation of the income elasticity of consumption is:

$$e^k(t) = dlnc^k(t) / dlny(t) = (c^k(t) - c^k(t-1)) / c^k(t-1) / dlny(t) \quad k=i, j \tag{4-4}$$

The total population increase equation is:

$$P(t) = (1+n^P(t)) P(t-1) \tag{4-5}$$

The labour force increase equations are:

$$L^{Pi}(t) = (1 + n^{Li}(t)) L^{Pi}(t-1) + M^{NL}(t) \tag{4-6}$$

$$L^{Pj}(t) = (1 + n^{Lj}(t)) L^{Pj}(t-1) - M^{NL}(t) \tag{4-7}$$

It is assumed that $o^k(t)$ and $e^k(t)$ are exogenous variables representing the supply and demand conditions. The demographic variables $n^P(t)$ and $n^{Lk}(t)$ can be endogenously calculated from the urban-rural population model described in the next section. Hence, it is useful to derive the equation for $M^{NL}(t)$ in terms of these exogenous and endogenous variables and the labour force $L^{Pk}(t-1)$ in the previous year.

The following equations can be obtained from equations (4-1) and (4-2):

$$r^k(t) L^{Pk}(t) = P(t) c^k(t) \quad k=i,j \tag{4-8}$$

$$r^k(t-1) L^{Pk}(t-1) = P(t-1) c^k(t-1) \quad k=i,j \tag{4-9}$$

It follows that:

$$c^k(t)/c^k(t-1) = P(t-1)r^k(t) L^{Pk}(t)/ (P(t) r^k(t-1)L^{Pk}(t-1)) \quad k=i,j \tag{4-10}$$

Substitute equations (4-3) and (4-5) into the equation (4-10) to produce:

$$c^k(t)/c^k(t-1) = (1+o^k(t))/(1+n^P(t)) L^{Pk}(t)/ L^{Pk}(t-1) \quad k=i,j \tag{4-11}$$

The following equation can be obtained from (4-4):

$$e^i(t)/e^j(t) = (c^i(t)/ c^i(t-1) - 1) / (c^j(t)/ c^j(t-1) - 1) \quad k=i,j \tag{4-12}$$

Substitute equation (4-11) into (4-12) and rearrange to produce:

$$\begin{aligned} &e^i(t)/e^j(t)(1+o^j(t))/(1+n^P(t)) L^{Pj}(t)/L^{Pj}(t-1) - e^i(t)/e^j(t) \\ &= (1+o^i(t))/(1+n^P(t))L^{Pi}(t)/ L^{Pi}(t-1) - 1 \quad k=i,j \end{aligned} \tag{4-13}$$

Substitute equations (4-6) and (4-7) into (4-13) and rearrange and the following projection equation for $M^{NL}(t)$ can be obtained:

$$\begin{aligned} M^{NL}(t) = &(e^i(t)/e^j(t) (1+ o^j(t))(1 + n^{Lj} (t))/(1+ n^P(t)) - (1 + o^i(t)) (1+ n^{Li} (t)) \\ &/(1 + n^P(t)) - e^i(t)/e^j(t) + 1) / (e^i(t)/e^j(t) (1 + o^j(t)) /(1 + n^P(t))/L^{Pj} (t-1) \\ &+ (1 + o^i(t))/(1 + n^P(t))/L^{Pi} (t-1)) \end{aligned} \tag{4-14}$$

Equations (4-6), (4-7) and (4-14) constitute the demo-economic model of urban and rural sectors.

It is assumed in the model that the national economy can be divided into an urban sector and a rural sector. In reality, there are no statistics based on such division. Therefore, the division into an agricultural sector and a non-agricultural sector has to be used to estimate the exogenous variables needed in the model. Again in reality there are some rural dwellers employed in the non-agricultural sector though of course most of the rural population are employed in the agricultural sector. For a more detailed discussion of the difference between the division of urban-rural population and the division of agricultural and non-agricultural labour force see section 2.3.1, table 2-1 and table 2-2. There is no doubt that the conversion of labour force from the agricultural to the non-agricultural sector is the main cause of rural to urban population migration and transition. The agricultural and non-agricultural employment data for China in the period 1979-1988 will be used to test the performance of the model in the first instance. Then the urban and rural employment data for the period 1979-1987 will be used to further test the performance of the model.

Agricultural and non-agricultural employment data are available from official Chinese sources (SSB, 1989). The GNP data for any particular year are based on the current price of that year and are unsuitable for calculating the growth rates in productivity. However the GNP growth index data are based on a comparable price. Therefore, the GNP produced by the agricultural sector and the non-agricultural sector at a comparable price are calculated using the GNP data in 1978 and the GNP growth index data in subsequent years (SSB, 1989). Table 4-1 shows the annual growth rates of productivity in the two sectors and the income elasticity of consumption of agricultural and non-agricultural products in the period 1979-1988. In most years except 1981 and 1982, the income elasticity of consumption of the agricultural product is less than one while that of the non-agricultural product is more than one, as expected. Generally, the

Table 4-1 Rate of productivity increases and income elasticity of consumption of the products in two sectors

Year	Growth rate of productivity (%)		Income elasticity of consumption	
	Agricultural	Non-agricultural	Agricultural	Non-agricultural
1979	5.21	3.22	0.8061	1.0743
1980	-3.45	4.22	-0.4548	1.5421
1981	4.74	-1.65	1.8339	0.7231
1982	7.87	4.04	1.4233	0.8565
1983	7.50	4.77	0.8035	1.0695
1984	13.97*	1.54	0.8772	1.0419
1985	1.86	7.30	0.1370	1.2914
1986	2.63	2.82	0.2338	1.2294
1987	3.16	6.99	0.3192	1.1909
1988	4.12	8.07	0.0898	1.2370
1979-1988	4.2918	4.0945	0.5239	1.1463

Note: * the productivity in agriculture was greatly increased in 1984 as a large number of labourers were released to the non-agricultural sector in that year.

consumption of agricultural products is not income elastic. Therefore, most of the increased income will be used for the consumption of non-agricultural products. There was a slowdown of non-agricultural production in 1981 and 1982 so that its growth rate was less then that of the agricultural sector. Because of this change in supply conditions, the consumption of agricultural products was increased faster than that of non-agricultural products in 1981 and 1982. If these annual growth rates of productivity and income elasticity of consumption are used, the demo-economic model will estimate exactly the amount of the agricultural and non-agricultural employment and the net "migration" between the two sectors. Instead, the average growth rates of productivity and the income elasticity of consumption in the period 1979-1988 will be used to test if the model can capture the general trend of the net "migrations" between the two sectors. As shown in table 4-1, the average annual rate of productivity increase is 4.2918% for the agricultural sector and 4.0945% for the non-agricultural sector for the period 1979-1988. The income elasticity of consumption is 0.5239 for the agricultural product and 1.1463 for the non-agricultural product over the same period.

The natural increase rates of the national population for the period 1979-1988 are readily available (SSB, 1989). However the natural increase rates of the work forces in the two sectors are not available. The annual data of work forces registered as agricultural population and non-agricultural population (SSB, 1989) are used to calculate the natural increase rates of the work forces in two sectors (see chapter two for the difference between actual non-agricultural employment and non-agricultural employment in registered non-agricultural population). The data for labour "migration" from registered agricultural population to registered non-agricultural population are available for 1978, 1980 and 1983-1988 (SSB, 1989). The "migration" data for unreported years are estimated as the average "migration" of two adjacent years when these data are available. These "migration" data are used to adjust the annual data of work forces registered as agricultural population and non-agricultural population to calculate the natural increase rates of the work forces in the two sectors.

The labour force in the non-agricultural sector consists of two parts: those registered as non-agricultural population and those as agricultural population in China. This is also true for urban population. Therefore, the real net labour "migration" between the agricultural sector and the non-agricultural sector in China consists of two parts. The first part is the labour "migration" from registered agricultural population to registered non-agricultural population. The data on this component are available as explained above and are shown in table 4-2. The second part is the net labour "migration" between two sectors by the registered agricultural population. This part is estimated using the natural increase rate of the work force in the agricultural sector and the

Table 4-2 Net labour "migration" between agricultural and non-agricultural sectors (millions)

Year	Estimation one			Estimation two	Model result
	Part one	Part two	Total		
1	2	3	4	5	6
1979	1.379	-0.140	1.239	1.670	2.39
1980	1.270	2.155	3.429	3.789	4.06
1981	0.978	0.873	1.851	2.009	3.84
1982	0.978	-0.331	0.647	0.996	6.66
1983	0.682	4.349	5.031	5.214	5.32
1984	1.230	13.727*	14.957*	15.425*	7. 19
1985	1.502	6.218	7.720	8.126	6.14
1986	1.665	6.103	7.768	7.945	6.02
1987	1.668	3.750	5.418	5.610	6.49
1988	1.599	2.252	3.851	4.099	6.90
Total			51.911	54.883	55.01

Data source: SSB (1989) for 1980, 1983-1988 of column two.
Notes: * a great shift of labour from agricultural to non-agricultural sector occurred as a result of the expansion of township firms in 1984.
Column
1: year.
2: labour "migration" between the registered agricultural population and urban non-agricultural population.
3: estimated net labour "migration" between the two sectors by the registered agricultural population.
4: estimation of total net labour "migration" between the two sectors. Column two plus column three.
5: estimation of net labour "migration" by using natural increase rate data.
6: net labour "migration" projected by the model.

non-agricultural employment in the registered agricultural population, and is also shown in table 4-2. An estimation of the real net labour "migration" between two sectors is obtained by adding these two parts.

A second estimation of the real net labour "migration" between two sectors can be obtained by using the data for the agricultural employment and the natural increase rate of the work force in the agricultural sector. This second estimation is also shown in table 4-2. These two estimations of the real net labour "migration" between the two sectors are similar as is shown in figure 4-1. According to the first estimation, there are 51.911 million net labour "migrations" in the period 1979-1988. The second estimation produces some 54.883 million net labour "migrations" in the same period.

The demo-economic model equations (4-6), (4-7) and (4-14) are next used to project the net labour "migration" and the agricultural and non-agricultural employment in the period 1979-1988. The base year is 1978. Table 4-2 and figure 4-1 show the resulting

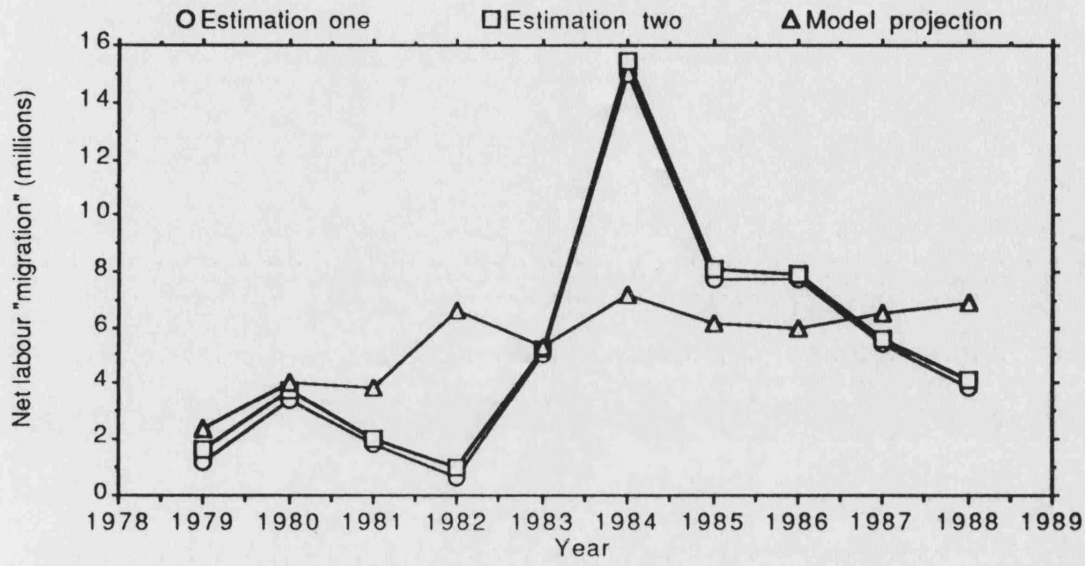

Figure 4-1 Comparison of estimated real net labour "migration" and projected net labour "migration" between the agricultural and non-agricultural sectors

projected net labour "migration" between two sectors. The relative error is especially susceptible to small real net labour "migration" as in 1982. Excluding 1982, the RMSE (Root of the Mean of the Square of relative Errors) of the projected net labour "migration" are 58.53% and 46.15% for estimation one and estimation two of the real net labour "migration" respectively. The total amount of net labour "migration" projected by the model in the period 1979-1988 is 55.01 million which is close to estimation two of the real net labour "migration". It seems that the general trend of the net labour "migration" is captured by the model as only the average parameters of the period have been used.

Table 4-3 and figure 4-2 show the real employment and projected employment in the agricultural and non-agricultural sectors in the period 1979-1988. The relative errors of the projected employment are small. The maximum relative error of the projected agricultural employment is -2.88% in 1983. Overall the RMSE of the projected agricultural employment is 1.37%. The maximum relative error of the projected non-agricultural employment is 6.45% in 1982. Overall the RMSE of the projected non-agricultural employment is 3.09%.

The model is next tested against the urban-rural employment data in the period 1979-1987 using the same parameters as were used in the above test against the real agricultural and non-agricultural employment data. Because urban-rural labour populations will be used in the demo-economic model for the urban-rural migration projection, it is sensible to test the model performance using urban-rural employment

Table 4-3 Comparison of real employment and projected employment produced by the model in the agricultural and non-agricultural sectors (millions)

Year	Real employment		Projected employment	
	Agricultural	Non-agricultural	Agricultural	Non-agricultural
1979	286.92	123.32	286.20	124.48
1980	291.81	131.80	290.79	133.51
1981	298.36	138.89	295.48	142.81
1982	309.17	143.78	300.52	153.05
1983	312.09	152.27	303.11	161.71
1984	309.27	172.70	308.16	173.85
1985	311.87	186.86	312.70	186.09
1986	313.11	199.71	315.89	196.73
1987	317.20	210.63	319.19	208.01
1988	323.08	220.26	322.33	219.71

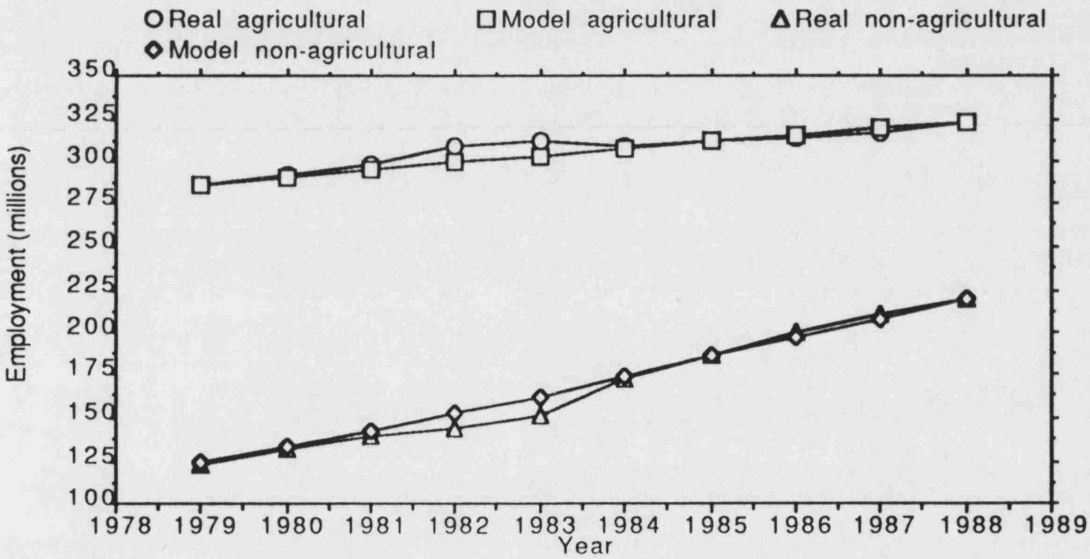

Figure 4-2 Comparison of real employment and projected employment produced by the model in the agricultural and non-agricultural sectors

data instead of the real agricultural and non-agricultural employment data.

However in fact the urban-rural employment data are not available. The rural employment data are estimated using the rural population data (see table 2-5) and the participation rate data of the registered agricultural population. This participation rate is defined as the amount of labour force divided by the total population in the registered agricultural population. The participation rate data are calculated using the total employment data of the registered agricultural population (SSB, 1989) and the registered agricultural population data (DPS, 1988b). The urban employment data are estimated as the difference between the total employment of China (SSB, 1989) and the estimated rural employment. The natural increase rates of the work forces in the urban and rural sectors are estimated by the natural increase rates of work forces registered as non-agricultural population and agricultural population.

The real urban-rural net labour migration is estimated using the estimated rural employment data and the natural increase rate data of the rural work force. The demo-economic model equations (4-6), (4-7) and (4-14) are used to project the urban-rural net labour migration between the urban and rural sectors. Table 4-4, and figures 4-3 and 4-4 show the estimated real urban and rural employment, urban-rural net labour migration and the projections of the model. Except for 1980 and 1983 when the real net labour migration is relatively small and the relative projection error is large, the RMSE of the projected net labour migration is 37.89%. The total amount of net labour migration in the period 1979-1987 projected by the model is 46.64 million which is close to the estimated 40.74 million real net migrations. The relative errors of the projected employment are small. The maximum relative error of the projected rural employment is -3.19% in 1983. The RMSE of the projected rural employment is 1.83%. The maximum relative error of the projected urban employment is 8.07% in 1983. The RMSE of the projected urban employment is 4.24%.

Table 4-4 Comparison of estimated net urban-rural labour migration, urban and rural employment and model projections (millions)

Year	Labour migration		Real employment		Projected employment	
	Real	Projection	Rural	Urban	Rural	Urban
1979	2.44	2.27	301.44	108.80	301.61	108.78
1980	1.30	3.87	309.26	114.35	306.86	116.99
1981	2.51	3.68	315.82	121.43	312.18	125.45
1982	3.65	6.40	324.67	128.28	318.13	135.00
1983	1.25	5.14	331.96	132.40	321.36	143.09
1984	12.24*	6.98	333.13	148.84	327.36	154.46
1985	6.20	6.00	338.48	160.25	332.71	165.88
1986	5.08	5.91	343.36	169.46	336.60	175.90
1987	6.07	6.39	347.93	179.90	340.64	186.58
Total	40.74	46.64				

Note: * the urban-rural labour migration was greatly increased in 1984 due to the expansion of non-agricultural sector.

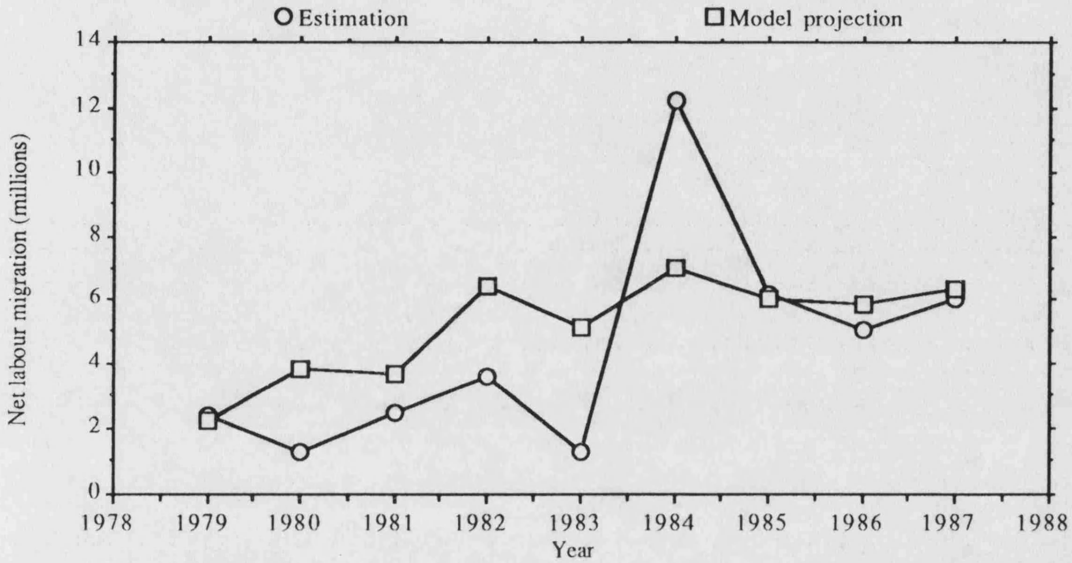

Figure 4-3 Comparison of estimated real net labour migration and projected net labour migration between the urban and rural sectors

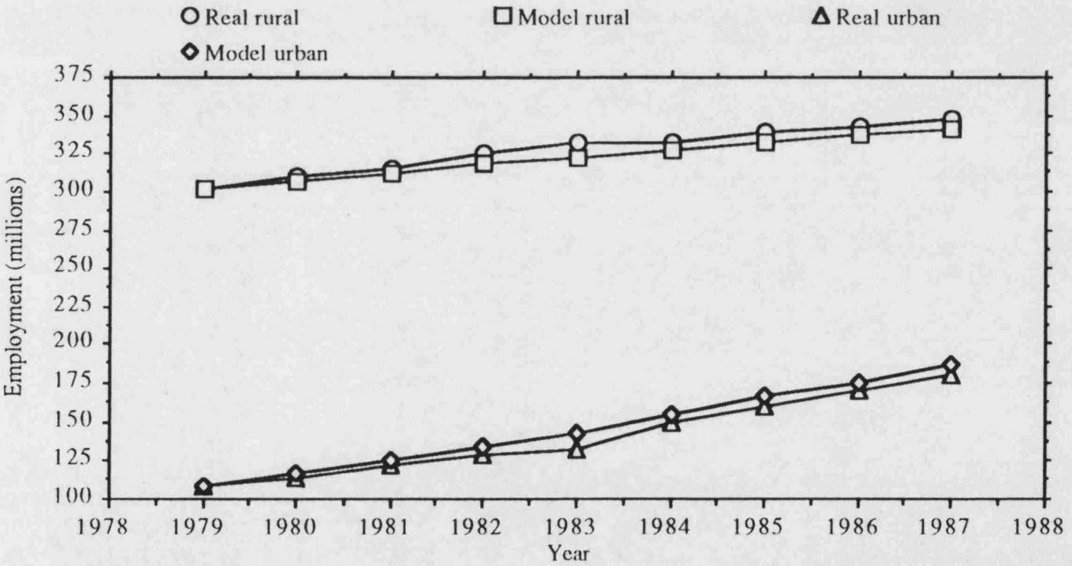

Figure 4-4 Comparison of estimated real employment and projected employment in the urban and rural sectors

It seems that the model performance is relatively satisfactory in projecting the general trends of the urban-rural net labour migration and employment growth. The model will be used to drive the urban-rural migration and transition in the urban-rural population projection model proposed in the next section.

4.3 The urban-rural population projection model

An accounts-based urban-rural population projection model will be proposed in this section on the basis of the multiregional population accounts concept. The demo-economic model proposed in the previous section will be linked with the population projection model. Labour population variables will be used in this section to replace the labour force variables used in the previous section in the demo-economic model though same notations are used in both sections. This replacement assumes that the ratio of labour force to labour population is constant and it will not affect population projection as long as this assumption is valid. In fact, the participation rate of population has been stable in China as almost every person who is able to work is in the labour force. The variables are defined as follows:

u^k_{ag}	is the mortality rate of period-cohort a and gender g in region k, k = i (urban), j (rural); g = m (male), f (female).
f^{nk}_a	is the normal fertility rate of female population of period-cohort a in region k.
$m^k_{ag}(t)$	is the out-migration rate of period-cohort a and gender g in region k in period t-1 to t.
$S^{kl}_{ag}(t)$	is the survival rate of population of period-cohort a and gender g in region k at time t-1 who survive in region l at time t, k=i, j; l=i, j; k≠l.
S^{exk}_g	is the ratio of gender g in births in region k.
$TFR^k(t)$	is the total fertility rate in region k in period t-1 to t.
$P^{b(k)*}_g(t)$	is the births of gender g in region k in period t-1 to t.
$P^{b(*)k}_{0g}(t)$	is the population of infants-cohort of gender g in region k at the end of period t-1 to t.
$P^{k*}_{ag}(t-1)$	is the population of period-cohort a and gender g in region k at the starting time of period t-1 to t.
$P^{*k}_{ag}(t)$	is the population of period-cohort a and gender g in region k at the end of period t-1 to t.
$P'^{*k}_{ag}(t)$	is the population of period-cohort a and gender g in region k at the end of period t-1 to t taking into account of rural to urban transition.
$P^{*d(k)}_g(t)$	is the deaths of gender g in region k in period t-1 to t.
$M^{PLk}(t)$	is the pure labour out-migration from region k in period t-1 to t using fixed out-migration rates.
$M^{Pk}_g(t)$	is the pure population out-migration of gender g from region k in period t-1 to t.

$M^{PTk}(t)$ is the gross population out-migration and transition from region k in period t-1 to t.

$R^M(t)$ is the ratio of gross rural out-migration and transition to the pure rural out-migration using fixed rural out-migration rates.

$R^S(t)$ is the rural population transition ratio.

$R^T(t)$ is the ratio of rural to urban transition to gross rural out-migration and transition.

Fixed urban out-migration rates will be used in the model. Total net urban-rural labour population migration and transition will be projected by the demo-economic model developed in the previous section. Then the gross rural labour out-migration and transition will be calculated by adding together the urban labour out-migration and the net urban-rural labour migration and transition. It is proposed that if the amount of gross rural labour out-migration and transition is less than that of rural labour out-migration projected by using fixed rural out-migration rates, then the rural out-migration rates will be scaled down. Otherwise, fixed rural out-migration rates will be used to project the pure rural out-migration. The rural-to-urban labour transition will be projected as the difference between the gross rural labour out-migration and transition, and the pure rural labour out-migration. At the end of each projection year, some rural population will transit to urban population in proportion to the projected rural-to-urban labour transition. According to the projection results described in the next section, the ratio of rural to urban transition to the gross rural out-migration and transition will gradually increase from about 60% in the year 1988 to about 80% in 2087. Some assumptions could be made to propose alternative trends for this ratio. For example, this ratio may be assumed to be fixed at the base year figure or decrease gradually to zero in 2087. For simplicity, these alternative assumptions are not introduced into the model at this stage.

The equations in the urban-rural population projection model will be discussed in the following according to the sequence of calculations.

The natural increase rates of the urban and rural labour populations are calculated as if there was no urban-rural migration as follows:

$$n^{Lk}(t) = (\Sigma^{59}_{a=18} P^{k*}_{af}(t-1)(1 - u^k_{af}) + \Sigma^{64}_{a=18} P^{k*}_{am}(t-1)$$
$$(1 - u^k_{am}))/ L^{PK}(t-1) - 1 \qquad k=i,j \qquad (4\text{-}15)$$

$$L^{Pk}(t-1) = \Sigma^{59}_{a=18} P'^{*k}_{af}(t-1) + \Sigma^{64}_{a=18} P'^{*k}_{am}(t-1)$$
$$= \Sigma^{60}_{a=19} P^{k*}_{af}(t-1) + \Sigma^{65}_{a=19} P^{k*}_{am}(t-1) \qquad k=i,j \qquad (4\text{-}16)$$

The labour population consists of females in period-cohorts 18-59 or aged 18-59 and males in period-cohorts 18-64 or aged 18-64 at the end of one-year periods (Song et al., 1981).

The natural increase rate of population $n^P(t)$ can be estimated by disregarding migration for the moment as follows:

$$n^P(t) = (\Sigma_k \, TFR^k(t) \, \Sigma^{50}{}_{a=15} \, P^{k*}{}_{af}\,(t-1) \, f^{nk}{}_a \, \Sigma_g \, S^{exk}{}_g \, (1 - u^k{}_{0g}) + \Sigma_k \Sigma_g \Sigma^A{}_{a=1} \, P^{k*}{}_{ag}\,(t-1)(1 - u^k{}_{ag}) \,) \,/\, P(t-1) - 1 \qquad (4\text{-}17)$$

$$P(t-1) = \Sigma_k \Sigma_g \Sigma_a \, P'^{*k}{}_{ag}(t-1) = \Sigma_k \Sigma_g \Sigma_a \, P^{k*}{}_{ag}(t-1) \qquad (4\text{-}18)$$

The natural increase rates obtained from the equations (4-15) and (4-17) are used in the demo-economic model equation (4-14) to project the total net urban-rural labour migration and transition $M^{NL}(t)$.

The pure labour out-migration from region k using fixed out-migration rates can be calculated as follows. Only survival migrants are counted because the demo-economic model is only concerned with the balance of work force at the end of the period t-1 to t.

$$M^{PLk}(t) = \Sigma^{59}{}_{a=18} \, P^{k*}{}_{af}(t-1) \, m^k{}_{af}\,(t_0) + \Sigma^{64}{}_{a=18} \, P^{k*}{}_{am}(t-1) \, m^k{}_{am}\,(t_0) \qquad k=i,j \qquad (4\text{-}19)$$

The ratio of the gross rural labour out-migration and transition to the pure rural labour out-migration using fixed rural out-migration rates can be calculated as follows:

$$R^M(t) = (\, M^{NL}(t) + M^{PLi}(t)) \,/\, M^{PLj}(t) \qquad k=i,j \qquad (4\text{-}20)$$

The rural out-migration rates are adjusted as follows:

$$m^j{}_{ag}(t) = \begin{cases} m^j{}_{ag}(t_0) & R^M(t) \geq 1 \\ R^M(t) \, m^j{}_{ag}(t_0) & R^M(t) < 1 \end{cases} \qquad a=0,1,\ \ldots,\ A \quad (4\text{-}21)$$

New rural survival rates are calculated using following equations:

$$S^{ji}{}_{ag}(t) = m^j{}_{ag}(t) \qquad a=0,1,\ \ldots,\ A \qquad (4\text{-}22)$$

$$S^{jj}{}_{ag}(t) = (1 - m^j{}_{ag}(t) / (\, 1 - 0.5 \, u^i{}_{ag} - 0.5 \, u^j{}_{ag} \,) \,) \, (\, 1 - u^j{}_{ag}) \qquad a=0,1,\ \ldots,\ A \qquad (4\text{-}23)$$

The births in period t-1 to t can be calculated using the following equation. The initial populations corresponding to survival migrants and survival non-migrants are calculated first as forward fertility rates are used in the equation.

$$P^{b(k)*}{}_g(t) = S^{exk}{}_g \, TFR^k\,(t) \, \Sigma^{50}{}_{a=15} \, f^{nk}{}_a \, (\, P^{k*}{}_{af}(t-1) \, S^{kk}{}_{af}(t) / (\, 1 - u^k{}_{af}\,) + 0.5 \, (\, P^{k*}{}_{af}(t-1) \, S^{kl}{}_{af}(t) + P^{l*}{}_{af}(t-1) S^{lk}{}_{af}(t)) / (\, 1 - 0.5 u^k{}_{af} - 0.5 u^l{}_{af}\,)) \qquad k=i,\ j;\ l=i,\ j;\ k \neq l \qquad (4\text{-}24)$$

The ending population of the infants-cohort of gender g in region k in period t-1 to t can be calculated as follows:

$$P^{b(*)k}{}_{0g}(t) = P^{b(k)*}{}_g(t) \, S^{kk}{}_{0g}(t) + P^{b(l)*}{}_g(t) \, S^{lk}{}_{0g}(t) \qquad k=i,\ j;\ l=i,\ j;\ k \neq l \quad (4\text{-}25)$$

The ending population of the period-cohort a of gender g in region k in the period t-1 to t is produced from:

$$P^{*k}_{ag}(t) = P^{k*}_{ag}(t-1)\ S^{kk}_{ag}(t) + P^{l*}_{ag}(t-1)\ S^{lk}_{ag}(t) \qquad (4\text{-}26)$$

$$a=1,2, \dots A;\ k=i, j;\ l=i, j;\ k\neq l$$

Total out-migration of gender g from region k in period t-1 to t can be calculated as follows. Non-survival migrants are also counted.

$$M^{Pk}_{g}(t) = P^{b(k)*}_{g}(t)\ S^{kl}_{0g}(t)/(1-0.5u^{l}_{ag}) + \Sigma^{A}_{a=1}\ P^{k*}_{ag}(t-1)\ S^{kl}_{ag}(t)/(1-0.5u^{l}_{ag})$$

$$g=m, f \qquad (4\text{-}27)$$

Total deaths of gender g in region k in period t-1 to t are estimated by:

$$P^{*d(k)}_{g}(t) = (P^{b(k)*}_{g}(t)\ S^{kk}_{0g}(t)/(1-u^{k}_{0g}) + 0.5(\Sigma_{v,w=i,j;v\neq w}P^{b(v)*}_{g}(t)\ S^{vw}_{0g}(t))$$

$$/(1-0.5u^{i}_{0g}-0.5u^{j}_{0g}))\ u^{k}_{0g} + \Sigma^{A}_{a=1}(P^{k*}_{ag}(t-1)\ S^{kk}_{ag}(t)/(1-u^{k}_{ag})$$

$$+ 0.5(\Sigma_{v,w=i,j;v\neq w}P^{v*}_{ag}(t-1)\ S^{vw}_{ag}(t))/(1-0.5u^{i}_{ag}-0.5u^{j}_{ag}))\ u^{k}_{ag}$$

$$k=i,j \qquad (4\text{-}28)$$

The rural labour population transition ratio $R^{S}(t)$ is calculated as follows in case of $R^{M}(t) > 1$. Otherwise, $R^{S}(t)$ equals zero.

$$R^{S}(t) = (\ M^{NL}(t) + M^{PLi}(t) - M^{PLj}(t))/\ (\ \Sigma^{59}_{a=18}\ P^{*j}_{af}(t) + \Sigma^{64}_{a=18}\ P^{*j}_{am}(t)\ )$$

$$(4\text{-}29)$$

The gross population out-migration and transition from region k in period t-1 to t is derived from:

$$M^{PTi}(t) = \Sigma_{g}M^{Pi}_{g}(t) \qquad (4\text{-}30)$$

$$M^{PTj}(t) = \Sigma_{g}M^{Pj}_{g}(t) + R^{S}(t)\ \Sigma_{g}\Sigma^{A}_{a=0}P^{*j}_{ag}(t) \qquad (4\text{-}31)$$

The ratio of rural to urban transition to the gross rural out-migration and transition is the result of:

$$R^{T}(t) = 1- \Sigma_{g}M^{Pj}_{g}(t)/M^{PTj}(t) \qquad (4\text{-}32)$$

The projection results from equation (4-25) and (4-26) are modified by the population transition as follows. The rural labour population transition ratio is applied to the whole rural population.

$$P'^{*i}_{0g}(t) = P^{b(*)i}_{0g}(t) + P^{b(*)j}_{0g}(t)\ R^{S}(t) \qquad g=m, f \qquad (4\text{-}33)$$

$$P'^{*i}_{ag}(t) = P^{*i}_{ag}(t) + P^{*j}_{ag}(t)\ R^{S}(t) \qquad a=1,2 \dots A;\ g=m, f \qquad (4\text{-}34)$$

$$P'^{*j}_{0g}(t) = P^{b(*)j}_{0g}(t) - P^{b(*)j}_{0g}(t)\ R^{S}(t) \qquad g=m, f \qquad (4\text{-}35)$$

$$P'^{*j}_{ag}(t) = P^{*j}_{ag}(t) - P^{*j}_{ag}(t)\ R^{S}(t) \qquad a=1,2 \dots A;\ g=m, f \qquad (4\text{-}36)$$

It is assumed that the population transition takes place at the end of period t-1 to t. $P'^{*k}_{ag}(t)$ is the projected population of the period-cohort a of gender g at the end of period t-1 to t. Various population indexes can be calculated from these basic projections.

The starting populations for the next period t to t+1 are as follows:

$$Pk^*_{ag}(t) = P'^*k_{a-1g}(t) \qquad a=1,2,..., A-1;\ k=i,j \quad (4\text{-}37)$$

$$Pk^*_{Ag}(t) = P'^*k_{A-1g}(t) + P'^*k_{Ag}(t) \qquad k=i,j \quad (4\text{-}38)$$

Equations (4-14) - (4-38) constitute the urban-rural population projection model. In this model, the urban-rural population migration and transition is driven by the demo-economic model proposed in section 4.2. If urban-rural population projections are to be made on the basis of fixed urban and rural areas in the base year, so that only pure urban-rural migration needs to be taken into account, an alternative urban-rural population projection model can be obtained by simply assigning the rural transition ratio $R^S(t)$ to zero. This kind of projection is not considered here but it may produce results between the two projections, with or without urban-rural migration and transition, which will be discussed in section 4.5.

4.4 Urban-rural population projections

This section will discuss urban-rural population projections of China using the urban-rural population projection model in section 4.3. Four points need to be emphasized first. These concern the urban and rural populations in the base year 1987, the adjustment of the age composition of populations in the base year to take into account of the armed forces, the mortality rates estimation, and the future trend in the total fertility rate in China.

First, it has been found in chapter two that the urban population data based on the 1982 definition are overcounted. A series of urban population data for the period 1983-1987 has been estimated in chapter two. It is deemed preferable to use the estimated total urban population in 1987 as the basis for urban-rural population projections in this section. The 1% sampling data of 1987 (DPS, 1988a) which were used to estimate demographic rates in chapter three are based on the 1982 urban population definition. In other words, according to the estimated total urban population, some urban population based on the 1982 definition is reclassified as rural population. This reclassified population is 158.49 million in 1987 and accounts for 33.2% of urban population and 26.1% of rural population in 1987 based on the 1982 definition. According to the estimation results in chapter three, the total fertility rates of the urban and the rural populations based on the 1982 definition were 1.936 and 2.719 respectively in 1987. It is assumed that this reclassified population had an average total fertility rate of the urban and rural populations based on the 1982 definition. Total fertility rates of the estimated urban and rural populations can then be calculated and proved to be 1.741 and 2.638 respectively. For simplicity, the estimations of mortality rates, migration rates and normal fertility rates obtained in chapter three are used directly for urban-rural population projections in this section.

Second, the armed forces are not included in the 1% sampling data of 1987 (DPS, 1988a). According to SSB (1987) and DPS (1988b), it can be inferred that there were 3.14 million males and 0.10 million females in the armed forces in 1987. Their age composition is unknown, but it again can be inferred that most of them were in period-cohorts 19 to 27 as indicated by the relatively low male to female ratio in these period-cohorts in the 1% sampling data. The following procedures were used to allocate members of the armed forces to these period-cohorts. It was assumed that males and females of the armed forces have same age structure. The sample population data were inflated to the real civil population excluding the armed forces. A male to female ratio of the population including the armed forces in period-cohorts 19 to 27 was calculated. The male and female members of the armed forces were than allocated to each of the period-cohorts 19 to 27 so that these period-cohorts have same male to female ratio. A similar procedure was used by Coale (1984) in his adjustment of China's population census data of 1982 to account for the armed forces.

Third, it is found that some mortality rate estimations for the period-cohorts over 92 obtained in chapter three show relatively large deviations from the general trend of increasing mortality rate with age. An exponential model is adopted to express the relation of age-specific mortality rate with age.

$$u^k_{ag} = b_0 \, EXP \, (b_1 a + e) \qquad (4\text{-}39)$$

Here b_0 and b_1 are parameters and e is a random item. The linear form of equation (4-39) is as follows:

$$\ln u^k_{ag} \doteq \ln b_0 + b_1 a + e \qquad (4\text{-}40)$$

The parameters in equation (4-40) are estimated separately for each gender in each region by linear regression using the mortality rate estimations of period-cohorts 71-91 obtained in chapter three. The estimated results are as follows:

Urban females $$\ln u^i_{af} = -10.074 + \underset{(57.468)}{0.096} a \qquad (4\text{-}41)$$

R=0.997 Adj R^2=0.994 F=3303

Rural females $$\ln u^j_{af} = -9.735 + \underset{(66.241)}{0.091} a \qquad (4\text{-}42)$$

R=0.998 Adj R^2=0.995 F=4388

Urban males $\ln u^{i}_{am} = -8.750 + 0.083\ a$ (4-43)

$(\ 42.707\ )$

R=0.995 Adj R^2=0.989 F=1284

Rural males $\ln u^{j}_{am} = -8.698 + 0.081\ a$ (4-44)

$(\ 45.091\ )$

R=0.995 Adj R^2=0.990 F=2033

All t-statistics for the estimated parameters and F-statistics for the equations are significant at level 0.001. These equations are used to extrapolate mortality rates for period-cohorts 92 and over which are used in the population projection model.

Survival rates for period-cohorts 92 and over are calculated according to the extrapolated mortality rates as follows:

$$S^{kk}_{ag} = (1-m^{kl}_{ag}/(1-0.5\ u^{k}_{ag} -0.5\ u^{l}_{ag}))\ (1-u^{k}_{ag})$$

$$k=i,j;\ l=i,j;\ k\neq l;\ g=m,f;\ a=92,93,\ ...,\ A \qquad (4\text{-}45)$$

Last, the total fertility rate in China has declined significantly in the past two decades. The total fertility rate was 5.746 in 1970 and 2.618 in 1982 (Coale and Chen, 1987). The available fertility rate data for urban and rural populations are based on the old urban population definition, i.e., urban registered non-agricultural population (see chapter two). Based on this old definition, the total fertility rate of the urban population began to decline in the late 1950s from 6.165 in 1957 to 1.499 in 1982 except for an abnormal fluctuation in the period 1961-1964. The fertility rate decline in the rural population was much later. The total fertility rate of the rural population began to decline in the early 1970s from 6.313 in 1970 to 2.857 in 1982. The decline of the total fertility rate in China is associated with the overall level of socio-economic development and a series of government birth control campaigns (Kane, 1987; Tien, 1991). It seems that both of these have contributed to the dramatic decline of the fertility rate in past two decades in China (Birdsail and Jamison, 1983). There has been a trend to intensify the birth control campaign from the early 1970s to the late 1980s. The most controversial "one-child campaign" was launched in 1978. However, the rigorous birth control policy has been somewhat relaxed since 1984 in that most rural couples are now allowed to have two children (Peng, 1991; Greenhalgh, 1986). Meanwhile, generally the government is still strongly encouraging couples to have only one child. Most urban couples are still required to have only one child. The recent economic reforms and the introduction of the household production responsibility system in rural areas may decrease the effect of government birth control efforts. The overall implication is that socio-economic development and modernization may play much greater role in the future trend of the fertility rate in China. Government birth control efforts will still have some effects and there are arguments that they need to be maintained, if not intensified, if population growth in China is to be slowed down feasibly and quickly. In fact, the total fertility rate of China has been further decreased from 2.618 in 1982 to 2.374 by 1987.

For the purpose of urban-rural population projections, three sets of total fertility rate trends in China are assumed. In set (A), it is assumed that the total fertility rates of urban and rural populations will remain unchanged from the base year 1987. The projection (A) based on this assumption shows the consequence of continuing population growth if fertility rates are not reduced in future.

Total fertility rates of urban and rural populations however are likely to decline in future because of population control policy and changes of social, economic and psychological factors. According to previous population projection practices in China, it is recognized that a U-shaped total fertility rate trend is probably both desirable and feasible (for example, Jiang and Lan, 1987). A realistic long term target for the population control policy may be a zero population growth rate (Song et al., 1981; Hu and Zhang, 1984). The total fertility rate $TFR^k{}_0$ for a stable zero growth rate population can be calculated using the following equation. For simplicity here, the urban-rural migration is disregarded.

$$TFR^k{}_0 = 1/\left(S^{exk}{}_f \, \Sigma^{50}{}_{a=15} f^{nk}{}_{af} \, P_{x=0,1,..a-1} \, (1-u^k{}_{xf})\right) \qquad k=i,j \quad (4\text{-}46)$$

A female birth ratio of 48.4% (Song et al., 1981) and the normal fertility rates and mortality rates estimated in chapter three can be used. The total fertility rates at replacement level are about 2.2 for both the urban and the rural populations. Thus the total fertility rate of 2.2 is partly used in some of the assumptions of sets (B) and (C) about the future total fertility rate trend in China.

In set (B), it is assumed that the total fertility rate of the urban population will gradually decline to 1.5 by 2000, remain unchanged until 2010, gradually increase to 2.2 in 2030, and then remain unchanged until 2087. The total fertility rate of the rural population is assumed to decline gradually to 2.2 in 2020, then remain unchanged until 2087.

However there may be concern that once the total fertility rate of the urban population has declined to a low level, it may be difficult to reverse the trend and increase the total fertility rate unless the earlier decline is a forced one. In set (C), it is assumed that the total fertility rate of the urban population will decline to 1.5 by 2000, then remain unchanged until 2087. For this projection (C) the total fertility rate trend of the rural population is assumed to be the same as in set (B).

The basic inputs to the urban-rural population projection model are summarized as follows. Fixed mortality rates, out-migration rates, survival rates and normal fertility rates estimated in chapter three are used with two exceptions. First, mortality rates and survival rates for the period-cohorts 92 and over are based on equations (4-39) - (4-44). Second, the rural out-migration rates will be scaled down if the amount of projected rural out-migration by the demo-economic model is less than the amount projected by using fixed out-migration rates. In this case, fixed normal out-migration rates are used implicitly in the population projection model. It does however appear that this situation does not occur in the following projections. The amount of projected out-migration by the demo-economic model is always greater than the amount projected by using fixed out-migration rates.

Average income elasticity of consumption of the agricultural and non-agricultural products and average growth rates of productivity in the agricultural and non-agricultural sectors in the period 1979-1988 are used in the demo-economic model throughout the projection period. Three sets of total fertility rate trends (A), (B) and (C) are assumed as mentioned above. Thus there are three sets of projections called (A), (B) and (C). The base year is 1987. The projection period runs from 1988 to 2087.

The main results of the urban-rural population projections are presented in tables 4-5, 4-6 and 4-7. The labour population includes males aged 18-64 and females aged 18-59. The elderly population includes males aged 65 and over and females aged 60 and over (Song et al., 1981). The population stock data (for example, total population and labour population) refer to mid-year. The population flow data (for example, births and deaths) refer to one year period from previous mid-year to the mid-year concerned.

Projection (A) assumes that the urban and rural total fertility rates will remain unchanged though the total fertility rate of China will decline because of the increasing urban population component. Table 4-5 presents the result of projection (A). For this the total population of China will continue to grow until 2040 (figure 4-5). It will increase from 1100.84 million in 1988 to 1312.00 million in 2000 and 1603.60 million in 2040. It will decline slowly after 2040 to 1369.55 million in 2087. The urban population will increase from 334.40 million in 1988 to 530.51 million in 2000 and reach 1199.28 million by 2050. The urban population will be almost stable around 1220.00 million after 2050. The rural population will slightly increase from 766.44 million in 1988 to 781.49 million in 2000. Then it will gradually decline to 481.01 million in 2040 and 151.02 million in 2087. The urban population percentage will steadily increase from 30.38 in 1988 to 40.44 in 2000 to 70.00 in 2040 and reach almost 89 by 2087 (figure 4-6). Urban out-migration will increase from 0.25 million in 1988 to 0.79 million in 2050, then will be stable around 0.80 million (figure 4-7).

Table 4-5 Urban-rural population projection (A) for China to 2087 (millions)

Year	Population	Births	Deaths	Out-migration	Labour population	Labour %	Elderly %	Mean Age(year)	Urban %
Urban China									
1988	334.40	5.70	1.94	0.25	206.74	61.83	6.99	29.17	
1990	367.40	6.51	2.20	0.28	231.72	63.07	7.25	29.52	
1995	450.04	8.14	2.91	0.33	286.21	63.60	7.87	30.30	
2000	530.51	8.08	3.62	0.35	335.70	63.28	8.43	31.26	
2010	702.50	8.70	5.51	0.45	456.01	64.91	9.34	33.78	
2020	875.66	11.48	8.08	0.60	570.11	65.11	12.12	35.85	
2030	1015.66	11.22	11.32	0.65	624.99	61.54	16.10	37.69	
2040	1122.59	12.37	15.08	0.73	675.69	60.19	19.04	39.10	
2060	1233.56	12.68	19.03	0.80	732.54	59.38	20.23	40.06	
2087	1218.53	12.29	20.40	0.79	716.95	58.84	21.58	40.95	
Rural China									
1988	766.44	17.88	4.84	12.18	425.69	55.54	7.16	27.54	
1990	768.51	18.51	5.07	12.36	435.80	56.71	7.48	27.89	
1995	778.57	18.91	5.55	11.00	446.21	57.31	8.09	28.54	
2000	781.49	16.39	5.87	13.11	442.83	56.66	8.48	29.31	
2010	725.12	12.94	6.10	15.43	422.91	58.32	9.36	31.51	
2020	654.56	12.66	6.24	13.82	385.31	58.87	11.55	33.03	
2030	578.95	9.72	6.30	12.68	325.13	56.16	14.12	34.30	
2040	481.01	8.42	6.03	13.24	267.46	55.60	16.18	35.19	
2060	306.86	5.23	4.09	9.55	170.00	55.40	16.04	35.32	
2087	151.02	2.68	2.04	5.71	83.86	55.53	15.94	35.28	
China total				(Net migration)					
1988	1100.84	23.58	6.78	11.93	632.43	57.45	7.10	28.03	30.38
1990	1135.91	25.03	7.27	12.08	667.52	58.77	7.40	28.42	32.34
1995	1228.61	27.05	8.46	10.67	732.42	59.61	8.01	29.19	36.63
2000	1312.00	24.48	9.49	12.76	778.53	59.34	8.46	30.10	40.44
2010	1427.61	21.64	11.61	14.98	878.93	61.57	9.35	32.63	49.21
2020	1530.22	24.14	14.31	13.22	955.42	62.44	11.87	34.64	57.22
2030	1594.61	20.94	17.62	12.03	950.13	59.58	15.38	36.46	63.69
2040	1603.60	20.79	21.10	12.51	943.15	58.81	18.18	37.93	70.00
2060	1540.42	17.91	23.12	8.75	902.54	58.59	19.40	39.12	80.08
2087	1369.55	14.98	22.44	4.92	800.82	58.47	20.96	40.32	88.97

Note: Projection (A) assumes that the total fertility rates of the urban and rural populations will remain unchanged as in 1987 in the whole projection period.

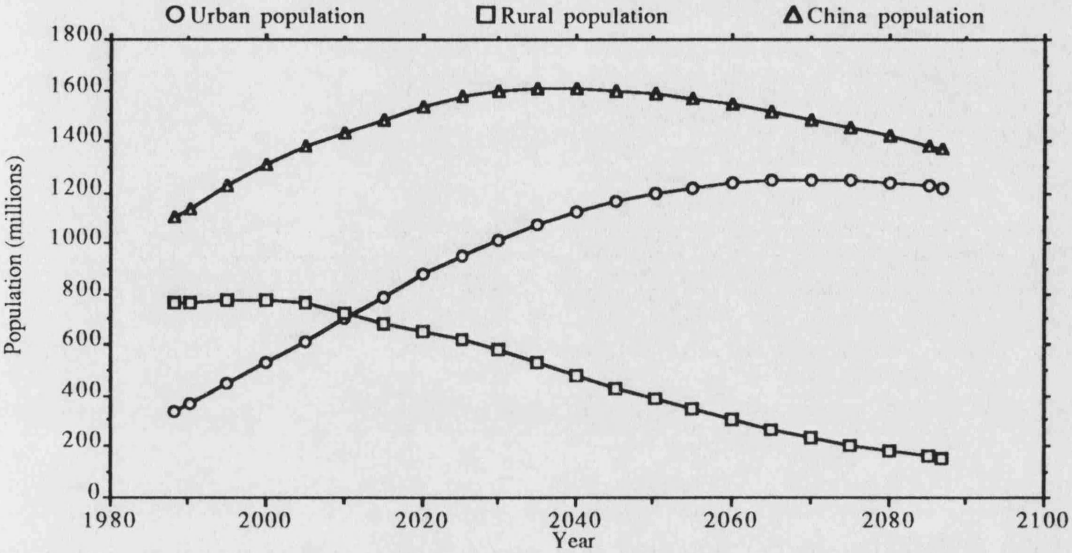

Figure 4-5 Population projections (A) for China to 2087

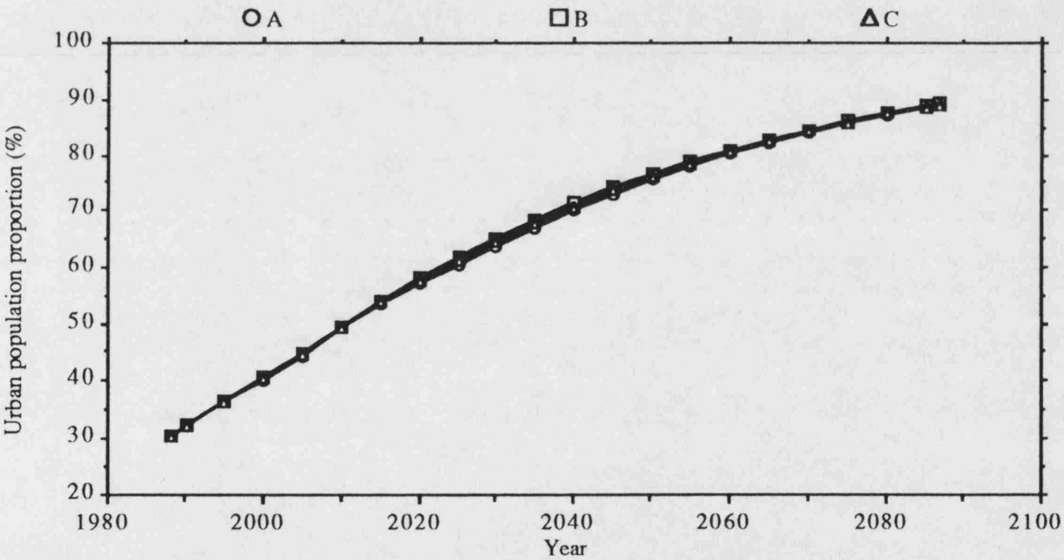

Figure 4-6 Percentage urban population (Projections A, B, C) for China to 2087

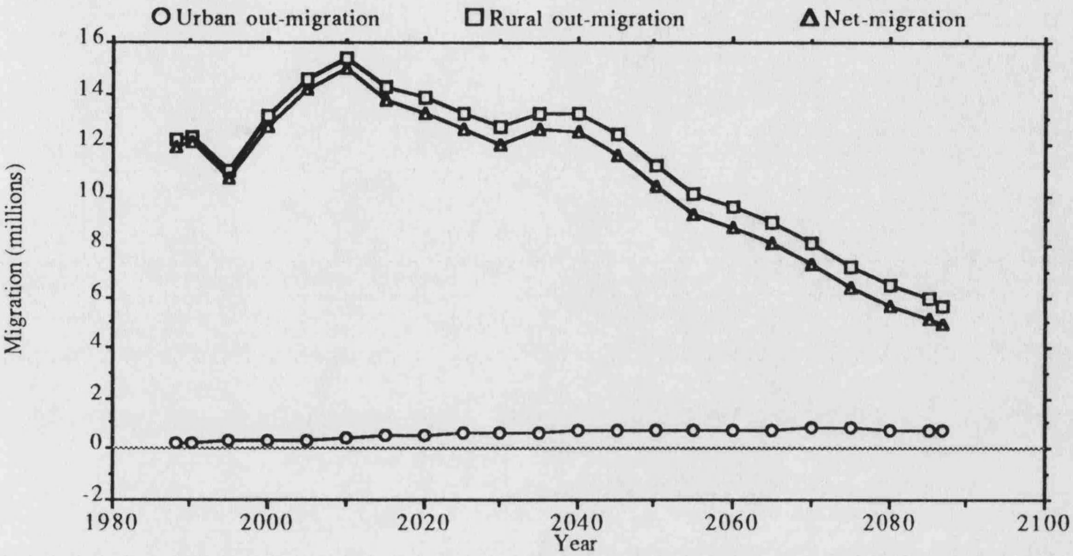

Figure 4-7 Urban-rural migration (including transition, Projection A) for China to 2087

Rural out-migration (including rural to urban transition) will increase from 12.18 million in 1988 to 15.43 million in 2010, decrease to 12.68 million in 2030, slightly increase to 13.27 million in 2035, then will gradually decrease to 5.71 million in 2087. Net rural to urban migration shows a similar trend as the rural out-migration because the urban out-migration is relatively small.

The labour population of China will increase from 632.43 million in 1988 to 778.53 million in 2000, 962.56 million in 2025, then decrease slowly to 800.82 million in 2087. Its percentage of China will be relatively stable at around 59 in the projection period 1988-2087 (figure 4-8). The urban population has a slightly higher labour population percentage than rural population. The percentage of elderly population in China will increase slowly from 7.10 in 1988 to 9.35 in 2010, then increase rapidly to 18.18 in 2040, and increase slowly to 20.96 in 2087 (figure 4-8). The elderly population percentages of the urban and rural populations show similar increasing trends as the whole population before 2040. There will be almost no urban-rural difference in the elderly population percentage before 2020. But the difference begins to widen after 2020. The elderly population percentage of rural population will be less than that of the urban population and will be stable at around 16.00 after 2040. The elderly population percentage of urban population will increase slowly from 18.60 in 2050 to 21.58 in 2087, similar to that of the whole population of China.

Projection (B) assumes that the total fertility rates of the urban and rural populations

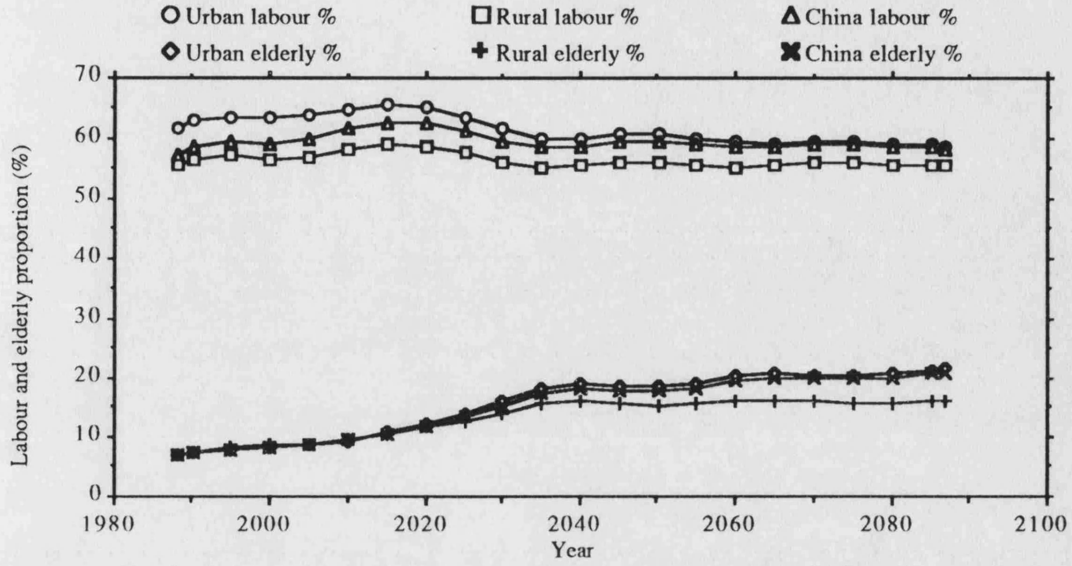

Figure 4-8 Percentage labour and elderly population (Projection A) for China to 2087

will decline in future, but that the total fertility rate of the urban population will have a U-shaped trend which means that the urban and rural populations will have the same total fertility rate of 2.2 after 2030. Table 4-6 presents the result of projection (B). For this the total population of China will also continue to grow until 2035 (figure 4-9). It will increase to 1296.49 million in 2000 and reach 1519.00 million in 2035. It will decline slowly after 2035 to 1414.70 million in 2087. The urban population will increase to 525.33 million in 2000, 1150.97 million in 2050, then increase slowly to 1262.76 million in 2087. The rural population will increase slowly to 774.28 million by 1995, then decrease gradually to 434.97 million in 2040 and reach only 151.95 million in 2087. The trend of the urban population percentage of projection (B) is similar to if slightly higher than that of projection (A) (figure 4-6). Urban out-migration will gradually increase from 0.25 million in 1988 to 0.83 million in 2087 (figure 4-10). Rural out-migration will increase from 12.21 million in 1988 to 15.36 million in 2010, then decrease gradually to 10.21 million in 2040 and 4.10 million in 2087. Net rural to urban migration shows a similar trend to the rural out-migrations.

With these projection assumptions the labour population of China will increase from 632.43 million in 1988 to 778.54 million in 2000, 935.89 million in 2020, then decline slowly to 813.86 million in 2087. Its percentage will be relatively stable at around 60 in the period 1988-2030 and then reduced to around 58 in the period 2030-2087 (figure 4-11). The urban population will have a higher labour population proportion than rural

Table 4-6 Urban-rural population projection (B) for China to 2087 (millions)

Year	Population	Births	Deaths	Out-migration	Labour population	Labour %	Elderly %	Mean Age(year)	Urban %
Urban China									
1988	334.36	5.63	1.94	0.25	206.76	61.84	6.99	29.18	
1990	367.16	6.30	2.20	0.28	231.81	63.14	7.26	29.56	
1995	448.22	7.44	2.90	0.33	286.88	64.00	7.93	30.48	
2000	525.33	6.97	3.60	0.35	337.41	64.23	8.56	31.68	
2010	687.51	7.51	5.51	0.45	458.66	66.71	9.64	34.57	
2020	851.26	11.55	8.12	0.58	561.84	66.00	12.58	36.61	
2030	986.09	12.62	11.37	0.62	596.87	60.53	16.65	38.02	
2040	1080.95	13.94	14.95	0.69	625.42	57.86	19.62	38.95	
2060	1188.35	15.61	18.19	0.77	668.84	56.28	19.85	38.45	
2087	1262.76	17.17	18.16	0.83	727.94	57.65	18.05	37.70	
Rural China									
1988	766.33	17.79	4.84	12.21	425.67	55.55	7.16	27.54	
1990	767.82	18.24	5.06	12.44	435.70	56.75	7.48	27.91	
1995	774.28	18.14	5.52	11.23	445.54	57.54	8.12	28.65	
2000	771.15	15.29	5.81	13.38	441.13	57.20	8.56	29.55	
2010	700.90	11.34	5.99	15.36	417.90	59.62	9.59	32.10	
2020	614.36	10.08	6.04	13.08	374.05	60.88	12.14	34.22	
2030	528.62	7.39	6.12	10.81	309.64	58.58	15.34	36.15	
2040	434.97	6.12	5.98	10.21	250.36	57.56	18.26	37.64	
2060	280.84	3.77	4.40	6.38	158.86	56.56	19.56	38.56	
2087	151.95	2.14	2.44	4.10	85.93	56.55	19.34	38.37	
China total				(Net migration)					
1988	1100.69	23.43	6.78	11.96	632.43	57.46	7.11	28.04	30.38
1990	1134.98	24.54	7.26	12.16	667.52	58.81	7.41	28.44	32.35
1995	1222.50	25.59	8.42	10.90	732.42	59.91	8.05	29.32	36.66
2000	1296.49	22.26	9.42	13.04	778.54	60.05	8.56	30.41	40.52
2010	1388.40	18.85	11.50	14.91	876.56	63.13	9.61	33.32	49.52
2020	1465.62	21.63	14.17	12.49	935.89	63.86	12.40	35.61	58.08
2030	1514.71	20.00	17.49	10.19	906.51	59.85	16.19	37.37	65.10
2040	1515.93	20.06	20.93	9.52	875.78	57.77	19.23	38.58	71.31
2060	1469.19	19.38	22.59	5.62	827.69	56.34	19.79	38.47	80.88
2087	1414.70	19.32	20.60	3.27	813.86	57.53	18.19	37.77	89.26

Note: Projection (B) assumes that the total fertility rate of the urban population will gradually decline to 1.5 in 2000, remain unchanged until 2010, gradually increase to 2.2 in 2030, and then remain unchanged until 2087. The total fertility rate of the rural population is assumed to decline to 2.2 in 2020, then remain unchanged until 2087.

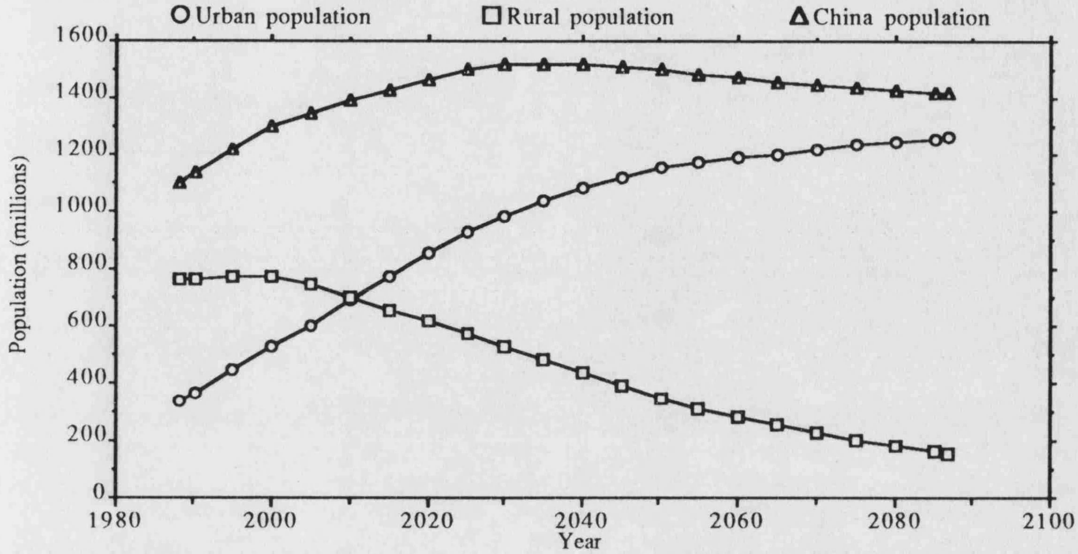

Figure 4-9 Population projections (B) for China to 2087

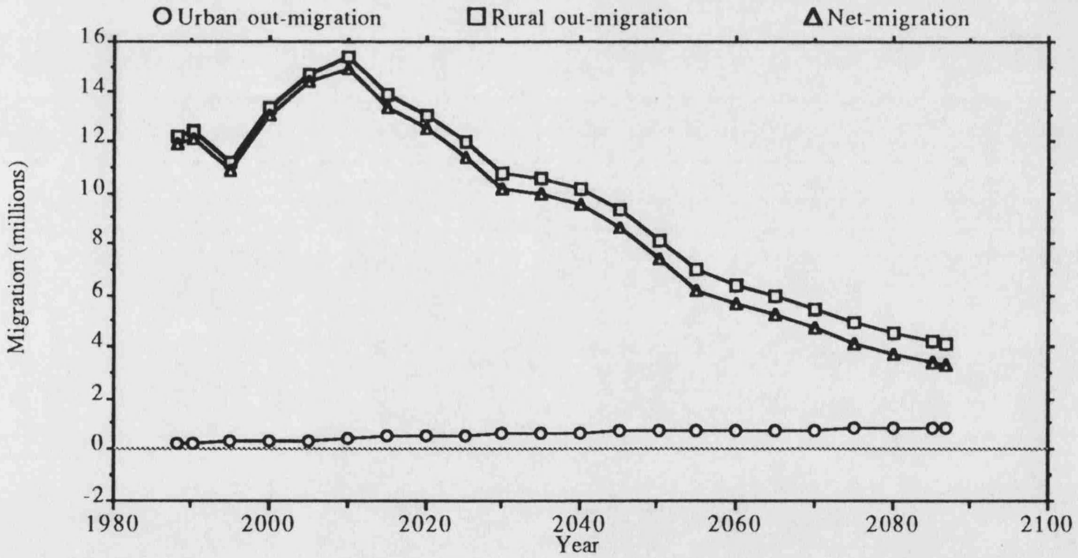

Figure 4-10 Urban-rural migration (including transition, Projection B) for China to 2087

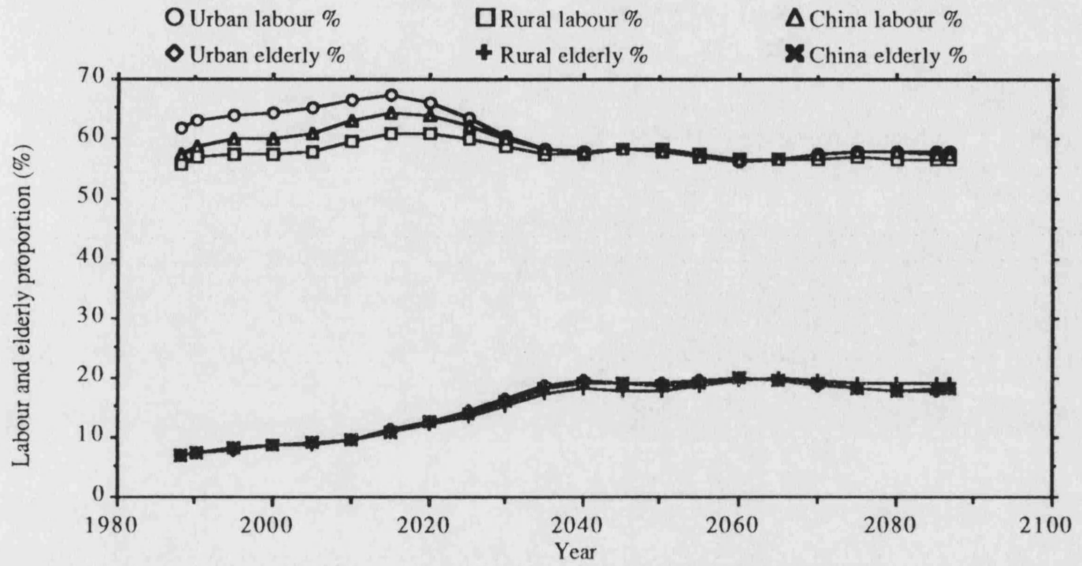

Figure 4-11 Percentage labour and elderly population (projection B) for China to 2087

population before 2040. The difference will be about 6.00 percent points in the period 1988-2015. But the difference will decrease rapidly in the period 2015-2040. The urban and rural populations will have almost same labour population percentage after 2040. This is due mainly to the assumption of same total fertility rate of urban and rural populations after 2030.

The percentage of the elderly population in China will increase slowly from 7.11 in 1988 to 9.61 in 2010, increase rapidly to 19.23 by 2040, then will be stable at around 19.00 during period 2040-2087 (figure 4-11). The urban-rural difference in the elderly population percentage is small in the whole period 1988-2087. Thus the elderly population percentage trends of the urban and rural populations are again similar to that of the whole population of China.

Projection (C) assumes that total fertility rates of urban and rural populations will decline in future, and that the total fertility rate of the urban population will remain at a level lower than the replacement level. Table 4-7 presents the result of projection (C). For this the total population of China will continue to grow until 2025 (figure 4-12). It will increase to 1296.49 million in 2000 and 1471.90 million in 2025. It will decrease rapidly after 2025 to 951.61 million in 2087. The urban population will increase to 525.33 million in 2000, reach 1031.51 million by 2050, then decrease slowly to 848.63 million in 2087. The rural population will increase slowly to 774.28 million in 1995, then decrease gradually to 419.38 million in 2040 and 102.98 million in 2087.

Table 4-7 Urban-rural population projection (C) for China to 2087 (millions)

Year	Population	Births	Deaths	Out-migration	Labour population	Labour %	Elderly %	Mean Age(year)	Urban %
Urban China									
1988	334.36	5.63	1.94	0.25	206.76	61.84	6.99	29.18	
1990	367.16	6.30	2.20	0.28	231.81	63.14	7.26	29.56	
1995	448.22	7.44	2.90	0.33	286.88	64.00	7.93	30.48	
2000	525.33	6.97	3.60	0.35	337.41	64.23	8.56	31.68	
2010	687.51	7.51	5.51	0.45	458.66	66.71	9.64	34.57	
2020	841.91	9.38	8.08	0.58	563.00	66.87	12.75	37.06	
2030	949.84	8.64	11.31	0.61	600.22	63.19	17.39	39.44	
2040	1010.82	8.99	14.95	0.65	618.39	61.18	21.26	41.36	
2060	1006.51	8.12	18.29	0.64	595.21	59.14	24.10	43.06	
2087	848.63	6.66	17.17	0.54	493.56	58.16	25.84	44.10	
Rural China									
1988	766.33	17.79	4.84	12.21	425.67	55.55	7.16	27.54	
1990	767.82	18.24	5.06	12.44	435.70	56.75	7.48	27.91	
1995	774.28	18.14	5.52	11.23	445.54	57.54	8.12	28.65	
2000	771.15	15.29	5.81	13.38	441.13	57.20	8.56	29.55	
2010	700.90	11.34	5.99	15.36	417.90	59.62	9.59	32.10	
2020	612.44	10.05	6.03	13.41	372.89	60.89	12.14	34.23	
2030	521.87	7.31	6.05	11.42	305.76	58.59	15.34	36.15	
2040	419.38	5.91	5.79	11.22	241.47	57.58	18.27	37.66	
2060	243.96	3.26	3.87	7.20	138.08	56.60	19.73	38.73	
2087	102.98	1.42	1.74	3.77	58.03	56.34	20.14	38.96	
China total				(Net migration)					
1988	1100.69	23.43	6.78	11.96	632.43	57.46	7.11	28.04	30.38
1990	1134.98	24.54	7.26	12.16	667.52	58.81	7.41	28.44	32.35
1995	1222.50	25.59	8.42	10.90	732.42	59.91	8.05	29.32	36.66
2000	1296.49	22.26	9.42	13.04	778.54	60.05	8.56	30.41	40.52
2010	1388.40	18.85	11.50	14.91	876.56	63.13	9.61	33.32	49.52
2020	1454.35	19.43	14.11	12.83	935.89	64.35	12.49	35.87	57.89
2030	1471.71	15.95	17.36	10.82	905.98	61.56	16.66	38.28	64.54
2040	1430.20	14.90	20.73	10.57	859.86	60.12	20.38	40.27	70.68
2060	1250.47	11.38	22.16	6.56	733.29	58.64	23.25	42.21	80.49
2087	951.61	8.08	18.90	3.23	551.59	57.96	25.22	43.55	89.18

Note: Projection (C) assumes that the total fertility rate of the urban population will decline to 1.5 in 2000, then remain unchanged until 2087. The total fertility rate trend of the rural population is assumed to be the same as in projection (B) and to decline gradually to 2.2 in 2020, then remain unchanged until 2087.

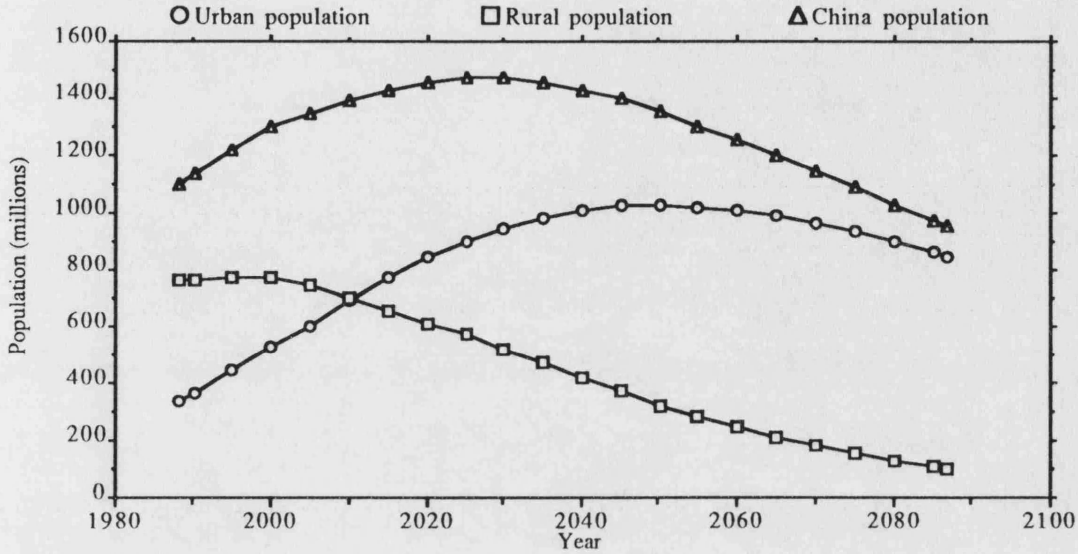

Figure 4-12 Population projections (C) for China to 2087

The urban population percentage trend of projection (C) is again similar to those of projections (A) and (B) (figure 4-6).

Urban out-migration will increase gradually from 0.25 million in 1988 to 0.68 million in 2050, then decrease slowly to 0.54 million in 2087 (figure 4-13). Rural out-migration will increase from 12.21 in 1988 to 15.36 million in 2010, then decrease gradually to 11.22 million in 2040 and 3.77 million in 2087. Again net rural to urban migration shows a similar trend to the rural out-migration.

The labour population of China will increase to 935.89 million in 2020 as was the case in projection (B), then decline rapidly to 551.59 million by 2087. The labour population percentage of China will be once again relatively stable at around 59 in the projection period 1988-2087 (figure 4-14). The urban population has a higher labour population percentage than the rural population. This difference will decrease gradually from 6.29 percent points in 1988 to 1.82 percent points in 2087.

The percentage of elderly population in China will increase slowly from 7.11 in 1988 to 9.61 in 2010, increase rapidly to 20.38 in 2040, then increase slowly to 25.22 by 2087 (figure 4-14). The urban and rural populations have similar trends in the proportion of elderly population as the whole population. The elderly population percentage of the rural population will be relatively stable at around 18 during the period 2040-2055 and around 20 after 2055. But the urban population will have an increasingly higher proportion of elderly population compared to the rural population

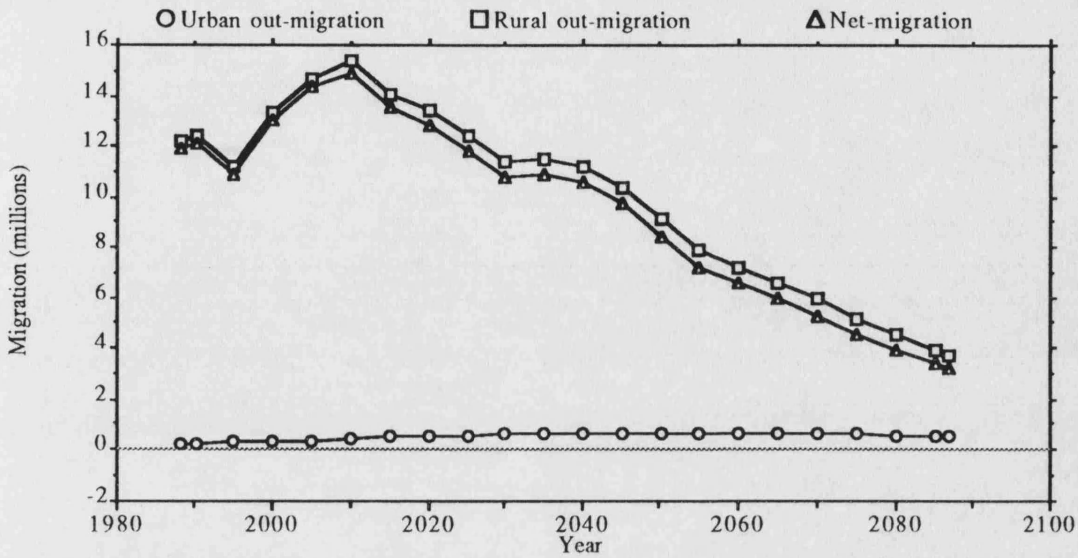

Figure 4-13 Urban-rural migration (including transition, Projection C) for China to 2087

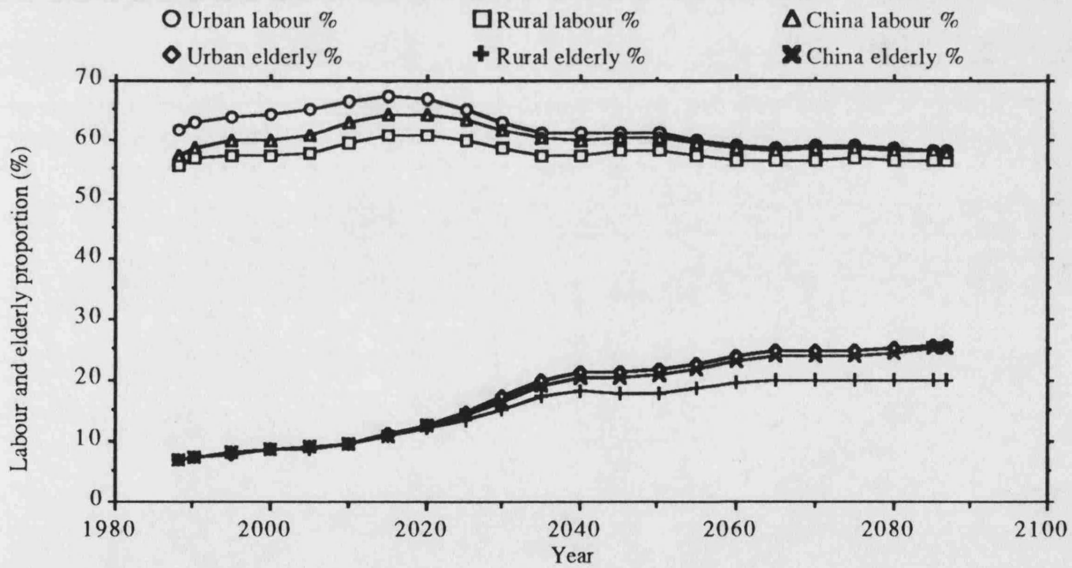

Figure 4-14 Percentage labour and elderly population (Projection C) for China to 2087

after 2020. In 2087, the elderly population percentage will be 25.84 in the urban population and 20.14 in the rural population.

The results of projections (A), (B) and (C) can be compared in terms of the whole population of China. Projection (A) generally projects a greater total population of China than projection (B) and (C) (figure 4-15). Projection (B) assumes urban and rural total fertility rates will remain at replacement level after 2030. According to projections (A) and (B), the total population of China will continue to grow until the late 2030s, then it will decrease slowly. Projection (C) assumes a lower urban total fertility rate than projection (B). According to projection (C), the total population of China will continue to grow until 2025, then it will decline rapidly to 951.61 million in 2087 which was approximately the actual total population of China in 1977 year-end (SSB, 1991).

Figure 4-16 shows the projections of total births and deaths under (A), (B) and (C) assumptions. The projections of total deaths are similar. Total deaths in China will increase rapidly in the period 1988-2045 mainly due to the rapid ageing of population in that period and then will be relatively stable. Total births in China will continue to increase to a peak in 1995. There is a corresponding births' peak in late 2010s. Total births from projections (A) and (C) show decreasing trends except for these peaks. Total births from projection (B) will be relatively stable after 2015. The total deaths will surpass the total births in 2040, 2035 and 2030 according to projection (A), (B) and (C) respectively.

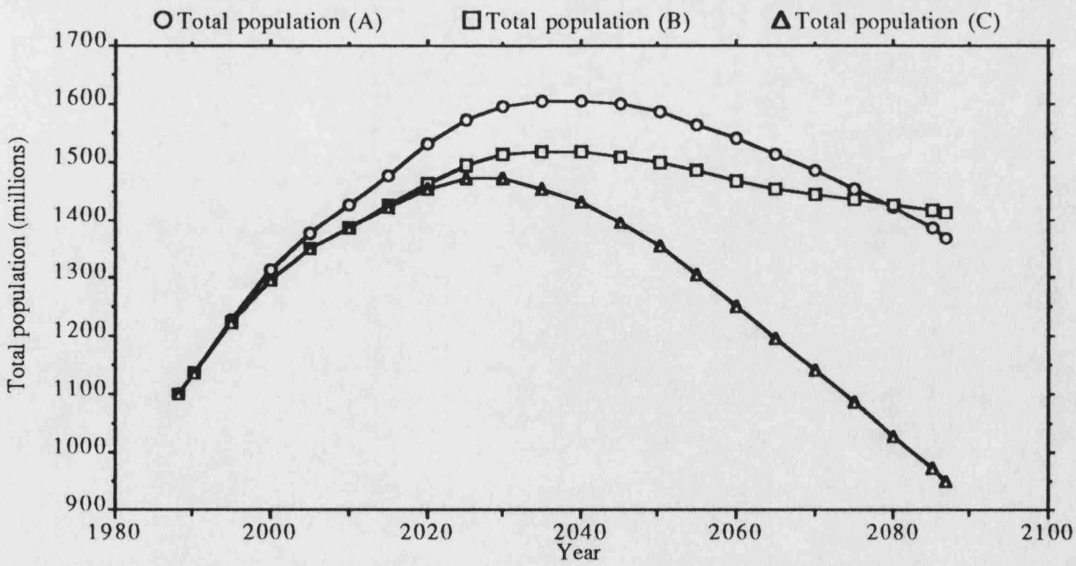

Figure 4-15 Total population projections (A, B, C) for China to 2087

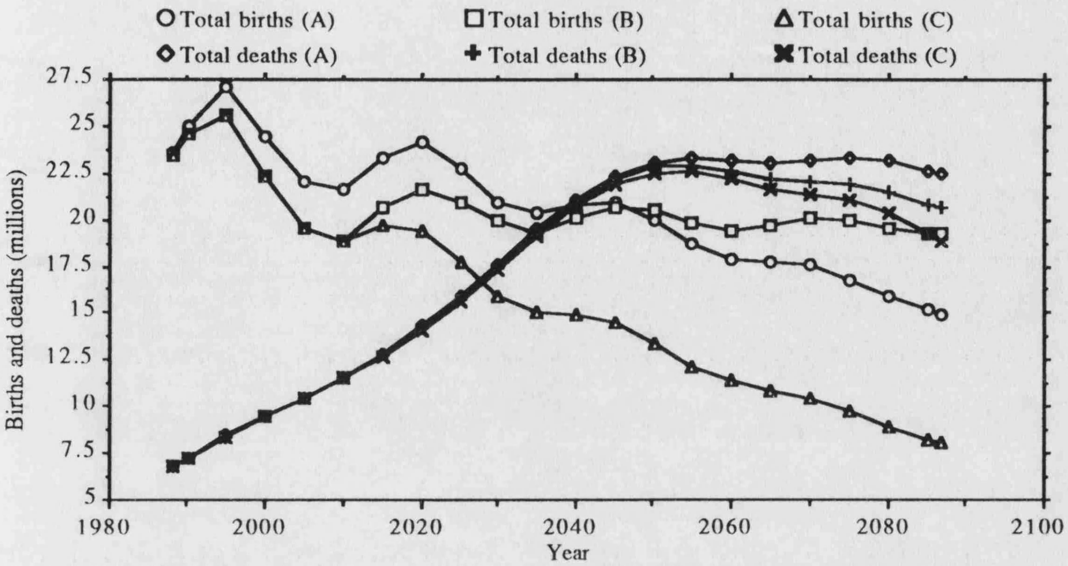

Figure 4-16 Births and deaths projections (A, B, C) for China to 2087

Figure 4-17 shows the net urban-rural migration of projections (A), (B) and (C). The general trends are similar though the magnitudes of projection (A) are greater than those of projection (C) which themselves are still greater than those of projection (B). As mentioned before the three projections of urban population proportions are similar (figure 4-6).

Figure 4-18 shows the labour population projections. The labour population of China will increase rapidly from 632.43 million in 1988 to over 935.00 million by 2020 in all three projections. Then, after 2020 in projection (B) or 2025 in projection (A), the labour population will decline slowly to about 800.00 million by 2087. According to projection (C), the labour population will decline rapidly to 551.59 million by 2087. Figure 4-19 shows the similar profiles of the labour population percentages of China of projections (A), (B) and (C).

Figure 4-19 also shows percentages of elderly population in China from projection (A), (B) and (C). All projections show similar increasing trends before 2040. Projection (A) and (B) generally project a lower proportion of elderly population than projection (C).

For the purpose of comparison, table 4-8 shows the relative projection errors of the total population of China for three years 1988, 1989 and 1990. The real population data are based on the 1990 population census (SSB, 1991). The errors are small. All are much less than one percent, the largest being 0.145% for projection (A) in 1990.

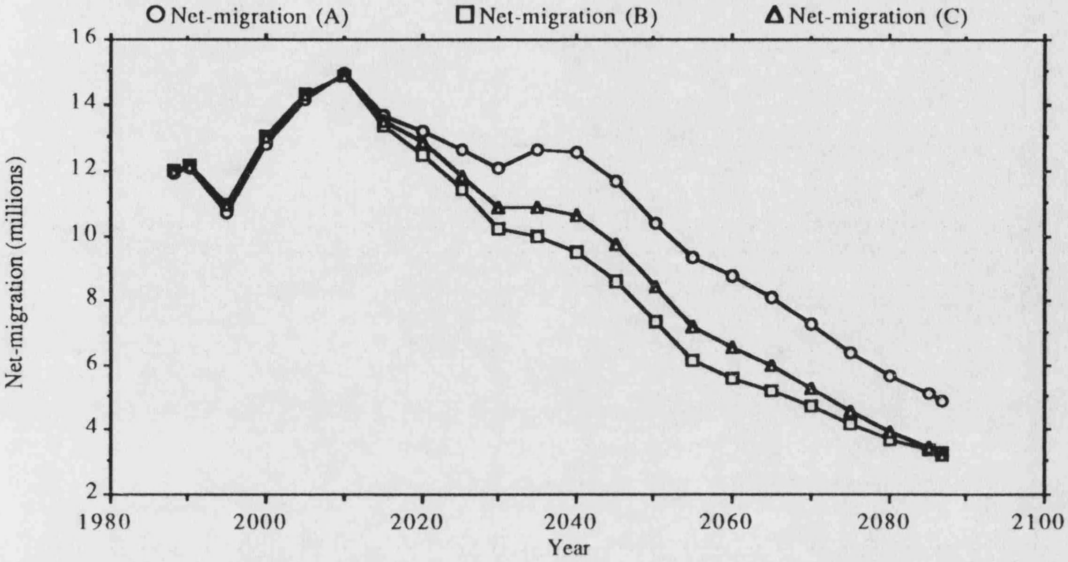

Figure 4-17 Net urban-rural migration (including transition) projections (A, B, C) for China to 2087

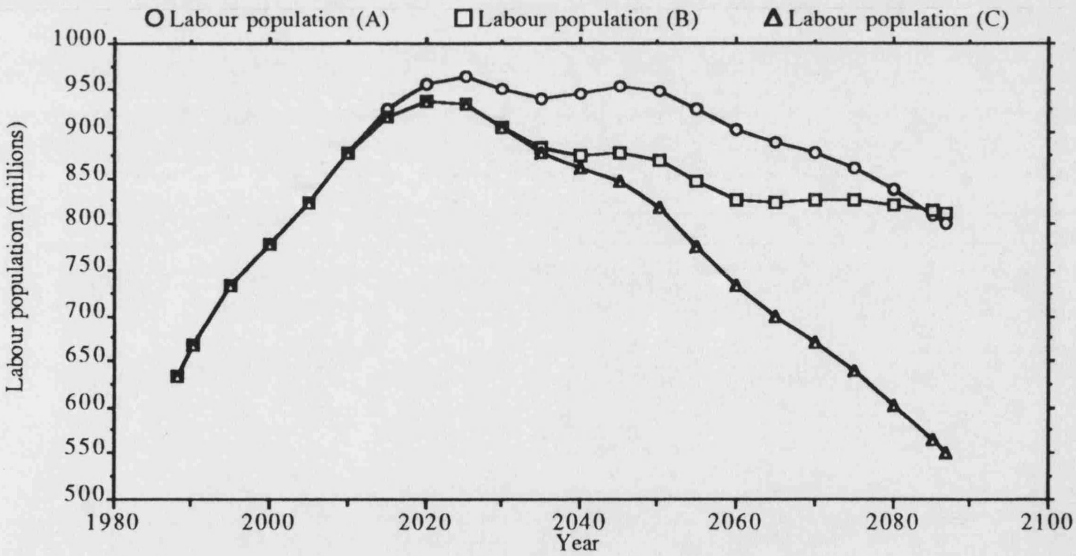

Figure 4-18 Labour population projections (A, B, C) for China to 2087

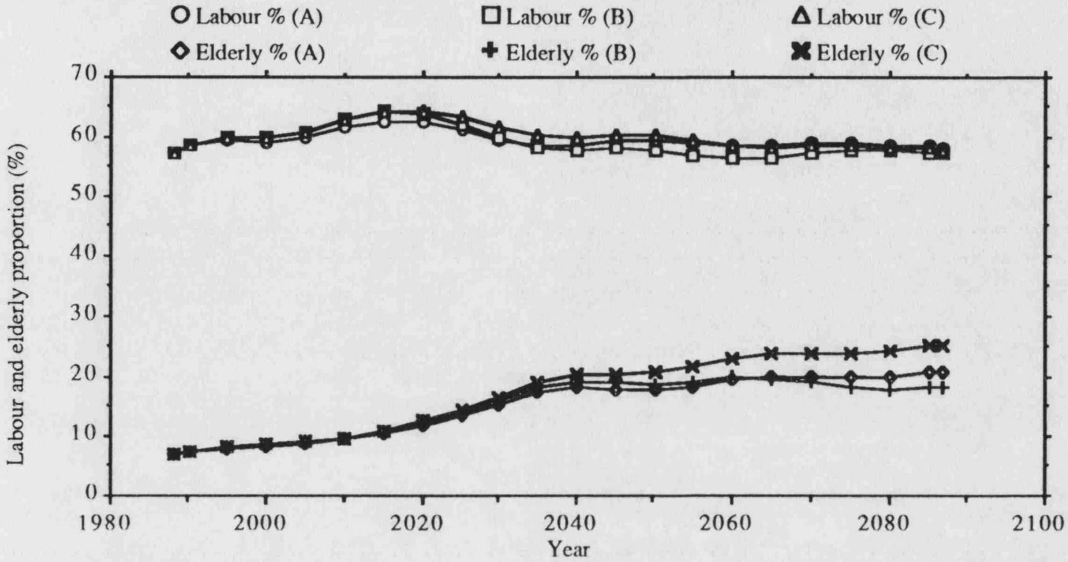

Figure 4-19 Percentage labour and elderly population projections (A, B, C) for China to 2087

Table 4-8 Relative projection errors of total population of China, 1988-1990

Year	Real population (millions)	Projection (A) Population (millions)	Projection (A) Error %	Projection (B) & (C) Population (millions)	Projection (B) & (C) Error %
1988	1110.26	1109.50	-0.068	1109.19	-0.096
1989	1127.04	1127.03	-0.001	1126.34	-0.062
1990	1143.33	1144.99	0.145	1143.73	0.035

Data source: Real population data from SSB (1991).
Note: All data refer to year-end.

Table 4-9 compares the results of population projections (A), (B) and (C) with the United Nations' medium variant projections (United Nations, 1991). It seems that the total population projection results of projection (B) are closest to the United Nations' figures.

As mentioned earlier, the urban population proportions of projections (A), (B) and (C) are similar. An urban-rural growth differences method is used to project the urban population proportions in the United Nations' projections by assuming different growth rates of urban and rural populations for each country (United Nations, 1989). Despite the entirely different projection methods, the urban population proportion projection results of projection (B) in this research, though a little smaller, are close to and confirm the United Nations' medium variant projections.

Table 4-9 Comparison of projection results (A, B and C) with the United Nations' medium variant projections for China

Year	Total population (millions)				Urban (%)	
	UN	A	B	C	UN	B
1990	1139.06	1144.99	1143.73	1143.73	33.4	32.84
1995	1222.56	1237.70	1230.80	1230.80	40.8	37.02
2000	1299.18	1319.06	1302.47	1302.47	47.3	40.92
2010	1395.33	1432.65	1392.12	1392.03	56.1	50.00
2020	1476.85	1534.92	1469.20	1456.75	62.8	58.49
2025	1512.59	1574.22	1499.22	1472.59	65.8	62.11

Data source: UN projections from the United Nations (1991)
Note: All data refer to year-end

4.5 Simulation of the effect of urbanization on population growth

This section attempts to assess the interaction between urbanization and population growth on the basis of the urban-rural population model in section 4.3.

According to classical demographic transition theory, the mortality and fertility of a population will decline from high to low levels as a result of socio-economic development. Population will grow slowly or be stable at the initial and final stages of the demographic transition. There is a stage of rapid population growth because the mortality rate declines earlier than the fertility rate. It is clear that the demographic transition is closely associated with economic development, industrialization, urbanization and social modernization (Woods, 1982). Many studies have been attempted to reveal the causes and underlying mechanism of the demographic transition especially the decline of fertility (Eberstadt, 1981).

Urbanization is an integrated socio-economic process. There is no doubt that urbanization has significant effects on fertility, mortality and population growth. It is often believed that government intervention is the main cause of the dramatic decline of fertility in China (Wolf, 1986; Peng, 1991). But the effect of urbanization on population growth is also clear. The fertility rate declines faster and earlier in urban areas than in rural areas. The urban-rural difference in the fertility rate is significant though fertility rates in both areas have been experiencing decline since the early 1970s.

The urban-rural population model in section 4.3 provides an opportunity to examine the interaction between urbanization and population growth in the future China and thus make a quantitative evaluation of the effects of urbanization on population growth. The essence of the approach is to compare the simulation results of the urban-rural population model with or without urban-rural migration and transition. This kind of dynamic system simulation has a significant advantage over simple static comparison in that the dynamic interactions of system components are taken into account. For example, a static comparison is unable to reveal the accumulative consequence of the effect of urbanization on population growth that can be found in the following.

As mentioned above, many factors affect population growth and have different significance in different times, regions and situations. There are also many interactions among factors. The influence of urbanization on population growth may be divided into a direct and an indirect effect. The direct effect is the result of the urban-rural population migration and transition as the urban and rural populations are subject to different fertility and mortality rates. The indirect effect results from the changes of other factors such as overall economic development in the urban and rural areas caused by urbanization. This section aims to estimate the direct effect of urbanization on population growth, i.e., the effect of urban-rural migration and transition on population growth.

In the previous section, three population projections (A), (B) and (C) have been made which take into account urban-rural population migration and transition. Three sets of simulations corresponding to projections (A), (B) and (C) have been carried out assuming no urban-rural migration and transition to estimate the effect of urbanization on the future population growth of China. They are called sets (A), (B) and (C) corresponding to three sets of the total fertility rate assumptions in projections (A), (B) and (C).

The relative effect of urbanization on population growth is defined as the difference between the projection and simulation results divided by the projection result. Table 4-10 shows the results of estimated effects of urbanization on total population and births in future China.

It seems clear that there are significant effects of urbanization on population growth. According to set (A), the relative effect of urbanization on total population is 0.84% in 2000, 10.93% in 2040 and 55.16% by 2087. The relative effect of urbanization on births is 6.29% in 2000, 39.39% in 2040 and 135.45% by 2087. It is also clear that the effect of urbanization on population growth is accumulative. If there was no urban-rural migration and transition, total population of China will be only 0.84% more than the normal projection in 2000, but it will be 55.16% more than the normal projection in 2087.

The extent of the effect of urbanization on future population growth depends on the extent of future urban-rural differences in the total fertility rate. The effects of urbanization in set (B) are much smaller than those in sets (A) and (C) as it is assumed that there will be no urban-rural difference in total fertility rate after 2030. According to set (B), the relative effect of urbanization on total population is 0.91% in 2000, 5.70%

Table 4-10 Urbanization effect on total population and births in China to 2087 (millions)

Year	Projection Population	Projection Births	Simulation Population	Simulation Births	Relative effect (%) Population	Relative effect (%) Births
Set (A)						
2000	1312.00	24.48	1322.96	26.02	0.84	6.29
2020	1530.22	24.14	1591.13	28.72	3.98	18.97
2040	1603.60	20.79	1778.93	28.98	10.93	39.39
2060	1540.42	17.91	1912.84	30.64	24.18	71.08
2087	1369.55	14.98	2125.03	35.27	55.16	135.45
Set (B)						
2000	1296.49	22.26	1308.34	23.97	0.91	7.68
2020	1465.62	21.63	1516.34	23.92	3.46	10.59
2040	1515.93	20.06	1602.41	22.24	5.70	10.87
2060	1469.19	19.38	1586.22	21.33	7.97	10.06
2087	1414.70	19.32	1542.80	21.10	9.05	9.21
Set (C)						
2000	1296.49	22.26	1308.34	23.97	0.91	7.68
2020	1454.35	19.43	1511.79	23.10	3.95	18.89
2040	1430.20	14.90	1574.30	20.68	10.08	38.79
2060	1250.47	11.38	1521.32	19.20	21.66	68.72
2087	951.61	8.08	1417.82	18.39	48.99	127.60

in 2040 and 9.05% by 2087. The relative effect of urbanization on births is 7.68% in 2000, 10.87% in 2040 and 9.21% by 2087.

The extent of the effect of urbanization on future population growth in set (C) is similar to set (A) as the urban-rural difference in the total fertility rate is assumed to exist over the whole projection period. According to set (C), the relative effect of urbanization on total population is 0.91% in 2000, 10.08% in 2040 and 48.99% by 2087. The relative effect of urbanization on births is 7.68% in 2000, 38.79% in 2040 and 127.60% by 2087.

4.6 Conclusion

An accounts-based urban-rural population model has been developed in this chapter. The urban-rural population migration and transition in this model is driven by a demo-economic model of urban and rural sectors. The demo-economic model is tested against agricultural and non-agricultural employment data in period 1979-1988 and urban and rural employment data in period 1979-1987. It was found that the general trend of urban-rural migration and transition is captured by the demo-economic model using average increase rates of productivity and income elasticity of consumption in the period. The total of projected urban-rural net labour migration and transition in the period 1979-1987 is close to the total of real net urban-rural labour migration and transition.

Three urban-rural population projections (A), (B) and (C) are made assuming different trends of urban and rural total fertility rates. The projection error of total population for the period 1988-1990 is small. It was found that the projections of total population and the urban population proportion are comparable with the United Nations' projections in the period 1990-2025 though different models are used.

Some major features of the anticipated urban-rural population growth in period 1988-2087 are revealed. According to projection (A) which assumes unchanged fertility rates, the total population of China will increase to 1603.60 million in 2040, then decline to 1369.55 million by 2087. According to projection (B) which assumes a U shaped trend in urban fertility rates and declining rural fertility rates before 2020, the total population of China will increase to 1519.00 million in 2035, then decline to 1414.70 million by 2087. According to projection (C) which assumes declining urban fertility rates reaching levels lower than replacement and declining rural fertility rates before 2020, the total population of China will increase to 1471.90 million in 2025, then decline to 951.61 million by 2087.

In summary, two major phases of future population growth of China can be identified with a division in the late 2030s. In the first phase before the late 2030s, the total population will continue to grow in most years. The urban population will increase rapidly from 334 million in 1988 to over 1000 million in 2040. The urban population proportion will increase from 30.38% in 1988 to about 70% in 2040. Total deaths will increase steadily in this phase. Net rural to urban migration and transition will be relatively large. The labour population will increase rapidly especially before 2020. The proportion of elderly population will increase at first slowly before 2010, then rapidly after 2010.

During this period, China will face three main challenges. The first is the rapid increase of its urban population. Its urban population will triple in about 50 years and reach about 1000 million in 2040. The second is the rapid expansion of its labour force. The total labour force will increase rapidly before 2020. China already faces problems of labour force surplus and capital shortage. It seems that these problems will become more severe in the next three decades. The third challenge is the rapid ageing of its population during the period 2010-2040. The proportion of elderly population will increase rapidly from 7% in 1988 to over 18% in 2040. It is clear that great efforts are needed to coordinate urbanization and socio-economic developments to face these challenges.

In the second phase after late 2030s, the total population of China may begin to decline. Total deaths will be relatively stable and will be greater than total births. Net rural to urban migration and transition will be relatively small and decreasing. The labour population will begin to decline. The proportion of elderly population will be relatively stable or increase only slowly.

The urban-rural population projection results depend on the assumptions used. Three sets of fertility assumptions have been used to show the effect of fertility trends on urban-rural population growth. However, urban-rural population growth is also sensitive to the parameters in the demo-economic model. Four main parameters of the demo-economic model are the annual growth rates of productivity in agricultural and non-agricultural sectors and income elasticity of consumption of agricultural and non-agricultural products. The averages of these parameters in the period 1979-1988 have been used for the whole projection period. The future proportion of urban population is sensitive to these parameters. Thus alternative simulations of urbanization in China are carried out assuming various trends of productivity growth rates. The results are presented in appendix B.

The urban-rural population model has also been used to simulate the significant effect of urbanization on future population growth in China. The extent of the effect of urbanization on future population growth is cumulative and depends in large measure on the extent of future urban-rural differentials in fertility. According to set (A), the relative effect of urbanization on total population is 0.84% in 2000, 10.93% in 2040 and 55.16% in 2087. The relative effect of urbanization on births is 6.29% in 2000, 39.39% in 2040 and 135.45% in 2087. According to set (B), the relative effect of urbanization on total population is 0.91% in 2000, 5.70% in 2040 and 9.05% in 2087. The relative effect of urbanization on births is 7.68% in 2000, 10.87% in 2040 and 9.21% in 2087.

Chapters two to three concern the population dynamics at the urban-rural level. The spatial population dynamics at a provincial level will be examined in the next four chapters. There are significant differentials in regional population dynamics among provincial regions in China. Multiregional population projections (provincial level) will be made in such a way that national totals are consistent with those of urban-rural population projections. The regional patterns of population dynamics will be revealed and their totals will be consistent with national trends.

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5
Spatial population dynamics

5.1 Multiregional population systems: theory and empirical studies

The urban-rural population system which was dealt with in chapter two to chapter four is a specific example of a multiregional population system. The mechanism of the urban-rural population system and the underlying forces determining its dynamics are relatively clear. A more general multiregional population system will be dealt with in chapter five to chapter eight. This multiregional population system consists of the provincial populations of China. The mechanism of this multiregional population system and the underlying forces determining its dynamics are much more complex. More difficulties will be faced with regard to the availability of systematic data, the behaviour of multiregional migrations and the modelling itself of the multiregional population system.

This section discusses multiregional population systems in general to provide a contextual basis of the empirical analysis in the rest of the thesis. It also briefly reviews studies on spatial population changes and projections.

A multiregional population system can be defined as a system consisting of a group of interacting regional populations. The regional populations are interrelated via internal population migrations. The population of a region may be disaggregated by age, sex, marital status, education, employment status and occupation amongst other features. The whole population system will become more complex when more dimensions are considered. In most studies of multiregional population modelling to date, a regional population is only disaggregated by age and sex.

The basic objectives of the study of a multiregional population system are to understand the mechanism of the multiregional population system evolution, to reveal trends in population redistribution, and to make consistent multiregional population projections for the future.

Assume a closed multiregional population system in that there is no external migration, then the evolution of the system is completely determined by its initial state and its schedules of fertility, mortality and internal migration. See section 3.1 for a brief review of the state of the art of multiregional population modelling. There are remarkably persistent regularities in age-specific fertility rates, mortality rates and migration rates (Rogers, 1984). It is convenient to separate the level of a component of change from its distribution across the ages (Rees, 1989). For example, population fertility may be expressed by the total fertility rate and by the normal age-specific fertility schedule. Population mortality may be expressed by the life expectation and by the normal age-specific mortality rate schedule. It is noted that regional birth rates, death rates, gross out-migration and gross in-migration are determined by the age composition, fertility rate, mortality rate and migration rate of the regional population concerned.

It seems that the evolution of a multiregional population system is determined by the system itself and the environment of the system --- namely, the social, political, economic and ecological systems. These factors may affect the demographic parameters of the multiregional population system especially the levels of components of change such as the total fertility rate, life expectation, gross out-migration and gross in-migration. The spatial variation of a multiregional population system is of great interest to population geography (Hu and Zhang, 1984). The regional difference in the population dynamics of various regions may be explained by population conditions and by the social, political, economic and ecological conditions in various regions. The study of the spatial variation in a multiregional population system is necessary to understand and explain the state and the evolution of such a system. The empirical analysis in subsequent sections and chapters is developed on the basis of this idea.

A brief review of studies of spatial population changes and projections in the world and in China in particular will be constructed first in what follows. The United Nations has published a series of world population surveys about the past trends and projections of populations of the main countries and regions in the world (United Nations, 1991). According to recent estimates, the population of more developed regions increased by 45% between 1950 and 1990, while the population of the less developed regions increased by 143% in the same period. According to the medium-variant projections, it is expected that the population of more developed regions will increase by 12% between 1990 and 2025, while the population of the less developed regions will increase by 75% in the same period. With regard to the economic consequences of such change in the third world, Kelley (1988) concluded that economic growth in many developing countries would have been more rapid in an environment of slower population growth, although in a number of countries the impact of population on development was probably negligible and in some it may have been positive. Population's adverse impact has more likely occurred where arable land and water are particularly scarce. In the case of China, a large amount of human and financial resources has been used to increase grain output to feed the ever growing population since 1949. These resources would have been used in other development projects if the population growth had not been so massive in China. This is the basic rational for the strict family planning programme which has been implemented in China since the early 1970s.

A number of studies of spatial population changes and projections have been made for various countries and regions. A comparative study of spatial population dynamics of IIASA nations was made using the techniques of multiregional mathematical demography (Rogers and Willekens, 1986). These IIASA (The International Institute for Applied Systems Analysis) nations include Austria, Bulgaria, Canada, FRG, Finland, France, former GDR, Hungary, Italy, Japan, Netherlands, Poland, former Soviet Union, Sweden, UK and USA. These nations have low levels of fertility. During the 1960-1980 period IIASA nations entered a period of transition to zero growth. Seventeen national multiregional population projections were made for years 2000 and 2030 with a same computer program. No international migration is assumed in these projections. The results are reasonably close to the United Nations' projections for the year 2000 except for Canada, UK and USA. IIASA used 1970 as the reference year which lead to the adoption of a high fertility level. By 1980, it already declined by over 25% in UK and USA. The use of the higher fertility levels raised the projected population totals.

Multiregional demographic models were termed ' transparent ' models by Rogers and Woodward (1991) and were used to assess state population projections made by the Bureau of the Census of the United States using a so-called ' black box ' model. The multiregional and the Census Bureau's projections produced a close projection that the population of USA is likely to be close to 267 million by the year 2000 and growing at an annual rate of less than 0.5 percent. The two projections differ in the spatial allocation of the projected national population totals. The net migration-based projections used by most State Demographers are likely to overproject the populations of states gaining net migrants and underproject the projections of states losing net migrants. It is argued that two innovations, multistate mathematical demography and parametric functional description of age-specific schedules are most useful for producing conceptually simple and operationally transparent population projections.

Plane (1992) decomposed age-specific interregional migration flows in USA into population base, mobility, and geographic distribution effects and found that age-composition change was a principal factor underlying the extraordinary acceleration of interregional population deconcentration in the USA in the 1970s. During the 1970s, the large baby-boom generation came of age, and the net out-flow of population from the Northwest and Midwest regions to the south and west regions increased precipitously. A spatial shift-share decomposition model was used to explore the ways that age-composition has influenced such regional trends. It is demonstrated that the larger cohorts of the baby boom generation provided a basis for the 1970's migration shifts, but the geography of the baby boom itself does not provide a sufficient explanation. Notable changes in age-specific mobility are also found and may help to explain the slowing of movement out of the south. However, the most interesting finding is that the largest contribution of age-composition change is the geographic distribution effect. The differential ability of regional economies to absorb new entrants seems to serve as the triggering mechanism for the population deconcentration in the USA in the 1970s.

Champion et al. (1987) made a detailed analysis of spatial changes in Britain in demographic as well as in social and economic dimensions using a functional regions framework. They found that relatively few places in Britain have experienced little or no change in their population size despite the fact that virtually zero growth in the national population was recorded for the period 1971-1981. The most consistent features are that the population in smaller places grew faster than in large ones and the population in the places of comparable size and status grew faster in the South than in the North. The most interesting features of population redistribution over this period are the small extent of areas from which the majority of ' net migrants ' were drawn - essentially the built-up areas of six major cities - and the very broad spread of the destination areas, going far beyond the suburban ring and going into relatively remote and rural localities. These massive shifts have important implications for regional balance, regional policy and strategic land-use planning ranging from inner city decay to pressurized rural areas.

Many studies have been carried out on China's population. Most studies have concentrated on the national population as a whole (Feeney, Zhou and Xiao, 1989; Yang, 1991; Coale, 1984; Jiang and Lan, 1987). Hu and his groups carried out research on the recent regional population distribution of China and its relationship to economic development. Hu identified the major features of population distribution by a three level regionalization of China (Hu, 1986; Hu and Wu, 1988). Firstly, China was divided into Eastern and Western parts with a significant difference in population density. Secondly, regional demo-economic analysis related to economic development was carried out using a division of three economic zones put forward by the State Planning Commission of China. Thirdly, China was divided into eight demographic regions according to natural and demo-economic conditions. The prospects for population and economic development in the different regions and zones were discussed in this research. Regional case studies were also made in Hu et al. (1989). Peng (1991) undertook an analysis of the fertility transition for China as a whole and for each of its 28 provinces except Tibet since 1950s. He examined the provincial patterns in the timing and pace of fertility transition. China's fertility transition is a process of diffusion. Sustained fertility decline started in a few large municipalities and some eastern provinces, with Shanghai leading the way. They were then followed by the northern provinces and the transition gradually spread to the interior provinces of China. The implications of these fertility trends on the regional population distribution in future will be revealed by the multiregional population projection in this research.

Studies of internal migration in China are few due mainly to lack of migration data at least until recently. The population migration flow has greatly increased with the economic reform and development since 1978. Many people especially farmers leave their local districts and seek employments in other regions. It has been reported that the size of the population flow amounted to 50 millions in early 1989. This substantial flow constitutes a great pressure on the social-economic and transportation systems in the relevant regions especially in large urban areas. The government is concerned about this problem. Much research effort has been expended in this field (Tien and Zhang, 1989). It is recognized that the western part of China is rich in many kinds of natural resources but is sparse in population. The possibility of migration from the east of China to the west has received much attention. However, there are severe disagreements on this matter (Hu et al., 1989). Yang has estimated aggregated interprovincial migrations under the assumption of equal natural increase rates among provinces (Yang, 1989).

A number of population projections have been made for China. Most of them are for China as a whole or for specific regions (Jiang and Lan, 1987; Shen, 1987a). Zeng and Vaupel (1989) used a multiregional (urban-rural) population model to study the impact of urbanization and delayed childbearing on population growth and ageing in China. Their model did consider urban-rural population migration. However, it seems that the various demographic rates used in the model were not consistently estimated using an accounts-based model.

At the moment, there is no consistent multiregional population model for provincial populations of China. One major aim of this research is to construct such an operational accounts-based multiregional population model and make consistent multiregional population projections of China.

The rest of this chapter will systematically study the regional trends in birth, death and migration rates, and population density since 1950s. Section 5.2 will analyze the spatial variation of China's population at provincial level using the 1987 one percent population sampling data and 1990 census data (DPS, 1988a; SSB, 1990a; 1990b).

Section 5.3 to 5.6 attempt to carry out an analysis of the trends in regional population dynamics in the period 1954-1990 in China. The spatial population distribution and the dynamics of change are the main topics in spatial demography and population geography. An empirical analysis of this problem in terms of the past evolution of population over space will have many implications for the projection of future trends.

Here an attempt is made to answer three basic questions with regard to the trend and stability of the population distribution in the period 1954-1990 in China. Firstly, what are the trends of spatial variation in the population birth rate, death rate, migration rate and population density? Secondly, are the spatial patterns of these population features stable or unstable over time? Thirdly, what are the typical spatial patterns of the population birth rate, death rate, natural increase rate, migration rate and population density if their spatial patterns are stable? Some well known statistical measures and approaches are used in the analysis which follows. Coefficients of variation are calculated for various spatial series to answer the first question. The spatial variation of a population indicator is increasing if its coefficient of variation increases and *vice versa*. Correlation matrices of spatial series are calculated for each population indicator and typical spatial patterns in terms of factor scores are extracted using a factor analysis approach to answer the second and third questions. If the spatial series of a population indicator in various years are significantly and positively correlated and there is only one dominant factor, then its spatial pattern must be stable. If the spatial series of a population indicator in different time periods are significantly but negatively correlated, then its spatial pattern must have been reversed in the period. If a number of factors are extracted and each of them is correlated with the spatial series of the population indicator in specific periods, then the spatial pattern of the population indicator may have undergone some gradual change from one pattern to another as described by the factors.

Spatial series of regional population birth rate, death rate, in-migration rate, out-migration rate, net migration rate and population density are analyzed in this chapter as they are directly related to the understanding of spatial population dynamics and the evolution of population distributions.

All population data are from Department of Population Statistics (DPS, 1988a, 1988b), State Statistical Bureau (SSB, 1989, 1990a) and Hu and Zhang (1984). With regard to the population birth rate and death rate, spatial series in 1954, 1957, 1965, 1972, 1978, 1981, 1986, 1988, 1990 are used. With regard to the in-migration rate, out-migration rate and net migration rate, spatial series in 1955, 1960, 1965, 1975, 1980, 1985, 1987 are used. With regard to population density, spatial series in 1957, 1965, 1970, 1975, 1980, 1985, 1990 are used.

The trends of regional birth, death, and migration rates are analyzed in section 5.3 to 5.5 respectively. The trend and stability of population distribution in terms of population density are analyzed in section 5.6. The major findings are summarized in section 5.7.

5.2 Spatial variation of China's population

This section will make a systematic analysis of the spatial variation of China's population at the provincial level using a series of indicators from the 1987 one percent population sample survey and the 1990 census (DPS, 1988a; SSB, 1990a; 1990b). There are 31 provincial regions including three municipalities, five autonomous regions and arguably Taiwan in China as shown in figure 5-1. Taiwan is not included in this research. Hainan province which was founded in 1988 is included in Guangdong province as its data before 1988 are not available. Therefore, the spatial analysis is carried out on the basis of 29 provincial regions. These regions were divided into three economic zones, namely, the east, middle and west by the Chinese government in 1986 (Hu et al., 1989) as shown in figure 5-2. This division roughly reflects the differences over space in the levels of economic development in China. The eastern economic zone includes twelve more developed coastal provinces from north to south as follows: Liaoning, Hebei, Beijing, Tianjin, Shandong, Jiangsu, Shanghai, Zhejiang, Fujian, Guangdong, Hainan and Guangxi. This eastern economic zone is given priority of development, construction, economic reform and international co-operation by the government. The middle economic zone includes nine less developed regions which are as follows: Heilongjiang, Jilin, Inner Mongolia, Shanxi, Henan, Anhui, Hubei, Jiangxi and Hunan. The western economic zone includes the nine least developed regions which comprise the following: Shaanxi, Ningxia, Gansu, Sichuan, Guizhou, Yunnan, Qinghai, Tibet and Xinjiang. Shen (1987b) has proposed a division into four economic zones, namely, east, north, middle, and the economic zone of Tibet on the basis of a detailed analysis of 22 demographic and economic indicators using an optimal partitioning method. It is argued that this division may reflect the reality of the China's space economy more realistically. Economic regionalization of China has been further discussed in Zhang and Shen (1991).

Fifteen demographic indicators will be used here to display the spatial variation of China's population in various dimensions. These indicators are defined as follows:

x_1 population density in 1990, persons per km^2;

x_2 population proportion of national minorities in 1987, %;

x_3 proportion of elderly population (aged 65+) in 1987, %;

x_4 average household scale in 1987, persons per household;

x_5 proportion of urban population in 1990, %;

x_6 proportion of agricultural employees in 1987, %;

x_7 proportion of illiterate and semi-illiterate population (aged 15+) in 1990, %;

x_8 birth rate in 1990, ‰ (one per thousand);

Figure 5-1 Provincial regions of China

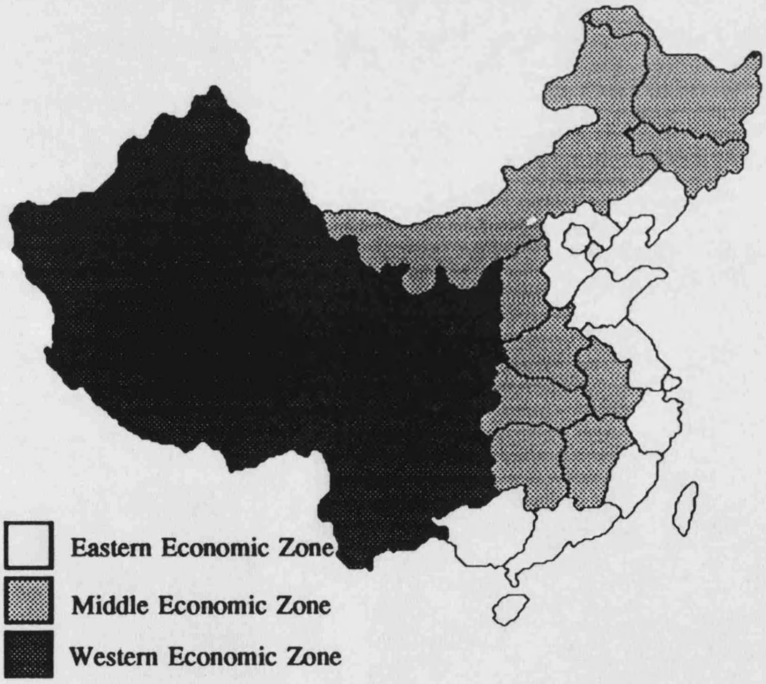


Figure 5-2 Three Economic zones of China

x_9 death rate in 1990, ‰;

x_{10} natural increase rate in 1990, ‰;

x_{11} inter-provincial in-migration rate in 1987, ‰;

x_{12} inter-provincial out-migration rate in 1987, ‰;

x_{13} inter-provincial net migration rate in 1987, ‰;

x_{14} population growth rate 1982-1990, %;

x_{15} population density change 1982-1990, persons per km^2.

Indicator x_1 is population density. Indicators x_2, x_3, x_5, x_6 and x_7 are used to describe population composition. Urban population is based on the official 1990 census definition. Indicator x_4 is average household scale. Indicators x_8, x_9 and x_{10} are used to describe natural population change. Indicators x_{11}, x_{12} and x_{13} are used to describe the migration component of population change. Indicators x_{14} and x_{15} are used to describe the population change between two censuses in 1982 and 1990.

The extent of regional variation is different for different demographic indicators. The well known coefficient of variation is used to measure the spatial variation of various demographic indicators. Table 5-1 presents the coefficients of variation of these indicators except the inter-provincial net migration rate in 1987. It is noted that the coefficient of variation of inter-provincial net migration rate is not defined if external migration is negligible. The coefficients of variation of population proportion of national minorities in 1987, population density in 1990, population density change

Table 5-1 Coefficients of variation of demographic indicators (%)

Indicator		Coefficient of variation
x_2	population proportion of national minorities in 1987	154
x_1	population density in 1990	124
x_{15}	population density change 1982-1990	112
x_{11}	inter-provincial in-migration rate in 1987	109
x_5	proportion of urban population in 1990	54
x_{12}	inter-provincial out-migration rate in 1987	50
x_7	proportion of illiterate and semi-illiterate population in 1990	46
x_6	proportion of agricultural employees in 1987	31
x_{10}	natural increase rate in 1990	26
x_3	proportion of elderly population in 1987	22
x_{14}	population growth rate 1982-1990	22
x_8	birth rate in 1990	19
x_9	death rate in 1990	13
x_4	average household scale in 1987	12

1982-1990 and inter-provincial in-migration rate in 1987 are over 100%. These four indicators have substantial variation over space. The coefficients of variation of proportion of urban population in 1990, inter-provincial out-migration rate in 1987, proportion of illiterate and semi-illiterate population in 1990 and proportion of agricultural employees in 1987 range from 31% to 54%. These four indicators have moderate spatial variation. The coefficients of variation of natural increase rate in 1990, proportion of elderly population in 1987, population growth rate 1982-1990, birth rate in 1990, death rate in 1990 and average household scale in 1987 range from 12% to 26%. These six indicators have much less spatial variation than other indicators. However, this does not mean that their spatial variation is not important.

The demographic characteristics of the eastern, middle and western economic zones and the differences between them will be discussed first. Then the spatial variation of various demographic indicators at the provincial level will be examined using a series of maps. Table 5-2 presents the demographic indicators and intra-zonal coefficients of variation of three economic zones in China. Basic demographic characteristics of these zones can be readily identified.

Table 5-2 Demographic indicators and intra-zonal coefficients of variation of eastern, middle and western economic zones in China

	Demographic indicator			Coefficient of variation		
	Eastern	Middle	Western	Eastern	Middle	Western
Population density	559	237	88	95	66	88
National minorities %	7	5	36	189	130	88
Proportion of elderly	6	5	4	15	16	16
Average household scale	4.1	4.3	4.8	13	5	10
Urban population %	38	28	22	56	41	28
Agricultural employees %	53	70	80	46	16	12
Illiterate and semi-illiterate %	13	15	24	27	30	38
Birth rate	18	22	23	22	13	11
Death rate	5.8	6.2	6.9	6	9	17
Natural increase rate	12	16	17	34	16	15
In-migration rate	2.8	1.3	1.5	113	43	70
Out-migration rate	1.4	1.5	2.2	38	44	51
Net migration rate	1.4	-0.3	-0.7	206	247	194
Population growth rate	14	12	14	23	19	22
Population density change	61	28	12	85	72	94

The eastern economic zone is the most densely populated, most urbanized and industrialized. This zone has a moderate proportion of national minority population (7%), but the highest proportion of elderly population. The eastern economic zone also has the smallest household scale, the lowest birth, death and natural increase rates.

However, the eastern economic zone had the greatest absolute increase in population density in the period 1982-1990 due to its already high level of population density. As mentioned before, the spatial variation of the population density is much greater than the spatial variation of the population growth rate. Thus the population density is the decisive factor in determining the absolute change in population density. Despite its low natural increase rate, this zone also had a high population growth rate of 14% in the period 1982-1990 due to its substantial net in-migration. This high growth rate is almost comparable with the western economic zone which has the highest natural increase rate.

The middle economic zone is moderately populated with a population density of 237 persons per km^2 in 1990, less than half of the population density in the eastern economic zone. Its levels of urbanization and industrialization are much lower than those in the eastern zone. The proportion of urban population was 28% in the middle zone compared with 38% in the eastern zone. About 70% of its labour force were still employed in the agricultural sector. In the eastern zone, a substantial proportion of the labour force has shifted to non-agricultural sectors. Only 53% of the labour force in the eastern zone remains in the agricultural sector.

The middle economic zone has the lowest proportion of national minority population of 5%. Its proportion of elderly population is slightly lower than that of the eastern zone while its average household scale and the proportion of illiterate and semi-illiterate population are slightly greater. The birth, death and natural increase rates in the middle zone are higher than in the eastern zone but lower than in the western zone. However, the middle economic zone had the least population increase of 12% in the period 1982-1990 probably due to its significant net out-migration.

The western economic zone is sparsely populated. It had the smallest population density of 88 persons per km^2 in 1990. Most national minority population reside in this zone and account for 36% of the total population there. Other demographic indicators show its position as the least developed economic zone in China. It has the lowest levels of urbanization and industrialization, the highest proportion of illiterate and semi-illiterate population, the highest birth, death and natural increase rates. Its average household scale is the largest but its proportion of elderly population is the lowest due to the presence of the highest natural increase rate among three economic zones. The western zone had a high population growth rate of 14% in the period 1982-1990 though there were net out-migrations. However, this zone had the smallest absolute population density increase of 12 persons per km^2 in the period 1982-1990 due to its lowest level of population density.

In summary, the picture of the spatial variation among three economic zones and their demographic characteristics is quite clear. The distributions of the total population and the national minority population are two fundamental features in China. They reflect the vital effects of natural conditions on the growth and distribution of human populations. The eastern economic zone is rich in agricultural resources and has been able to sustain a high level of population density. The distribution of national minority population is the result of historical evolution. The national minority population in the western part of China may have been subjected to less influence of the mainstream culture in the eastern and middle parts of China and are able to maintain their own identities.

The spatial variations of other demographic indicators are related with the difference in the levels of economic development. The eastern economic zone is the most developed zone in China. Thus its urbanization and industrialization levels are the highest. Its population has good education but low mortality rate. Its birth and natural increase rates are low. Thus its proportion of elderly population is relatively high and the average household scale is small. The situation is reversed in the western economic zone. The middle economic zone has exactly the middle situation between the eastern and western zones. One important exception is that the eastern zone has net in-migrations while the other two zones have net out-migrations.

There are also significant intra-zonal differentials among three economic zones. Population density, population proportion of national minorities, inter-provincial in-migration and net migration rates, and population density change have greater intra-zonal spatial variation than other demographic indicators. Their coefficients of variation are over 50% as are shown in table 5-2. Nine out of fifteen demographic indicators have the largest intra-zonal coefficients of variation in the eastern zone indicating the significant differentials among its twelve relatively developed regions. These demographic indicators include population density, population proportion of national minorities, average household scale, proportion of urban population, proportion of agricultural employees, birth rate, natural increase rate, inter-provincial net migration rate and population growth rate. The intra-zonal differentials in the level of industrialization, population proportion of national minorities, average household scale, birth rate and natural increase rate are much more significant in the eastern economic zone than in the middle and western zones. The coefficient of variation of the proportion of agricultural employees is 46% in the eastern zone while it is only 16% in the middle zone and 12% in the western zone. The coefficient of variation of birth rate is 22 % in the eastern zone while it is only 13% in the middle zone and 11% in the western zone. This means that some regions in the eastern economic zone still have relatively high fertility rates and much efforts are needed to implement family planning there.

The eastern economic zone does have the smallest intra-zonal coefficient of variation for death rate (6%). In the middle and western zones, the coefficients of variation are 9% and 17% respectively. The eastern zone has been relatively successful in reducing its mortality rate uniformly. Many cities with the most advanced science and technolodge are located in the eastern zone. It is obvious that many regions in this zone have benefited from their easy access to these cities. The western economic zone has been less successful in reducing its mortality rate uniformly in its member regions. Great efforts are needed to improve the medical system and health services in those regions with high mortality rates.

The above discussion about intra-zonal variation is quite general. Detailed regional variation of various indicators will be considered in map form in the following. These maps are shown in figure 5-3(a)-(o). All demographic indicators are divided into five equal intervals except that population density in 1990, in-migration rate, out-migration rate, net migration rate in 1987 and population density change 1982-1990 are divided such that each interval includes equal number of regions. For this group of variables, the last interval only includes five regions as there are only 29 regions to be divided into five groups.

Figure 5-3 (a) shows the spatial variation of population density in 1990. Six regions, namely, Heilongjiang, Inner Mongolia, Gansu, Xinjiang, Qinghai and Tibet in the northern and north-western parts of China have a population density below 84 persons per km^2 while five regions, namely, Beijing, Tianjin, Shandong, Jiangsu and Shanghai in the eastern part of China have a population density over 526 persons per km^2. The difference of population density between the north-west part and the south-east part of China is clear. This characteristic of population distribution in China was recognized by Hu in 1935 (Hu, 1935; 1986). It is noted that there are significant intra-zonal variation in population density in three economic zones. In the eastern economic zone, Guangxi has the least population density which is even less than Sichuan in the western economic zone.

Figure 5-3 (b) shows that the eight regions with a population proportion of national minorities over 20% are in the sparsely populated north-western and south-western parts of China. Most are located in the middle and western economic zones. Only Xinjiang and Tibet have an impressive population proportion of national minorities over 60%. Note that Guangxi in the eastern zone also has a proportion of national minorities over 40%.

Figure 5-3 (c) shows that the proportion of the elderly population is relatively low in the north-western part of China and is relatively high in the eastern part of China. This character confirms that demographic transition process started in some eastern

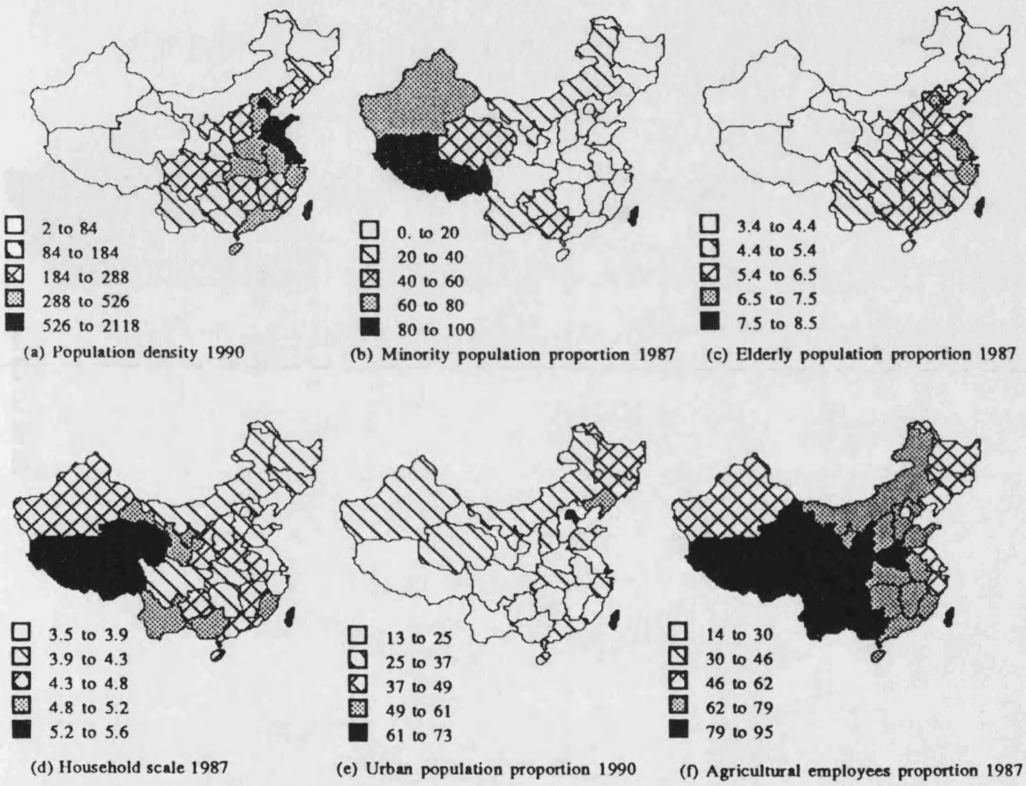


Figure 5-3 **Regional variations in aspects of China's population**

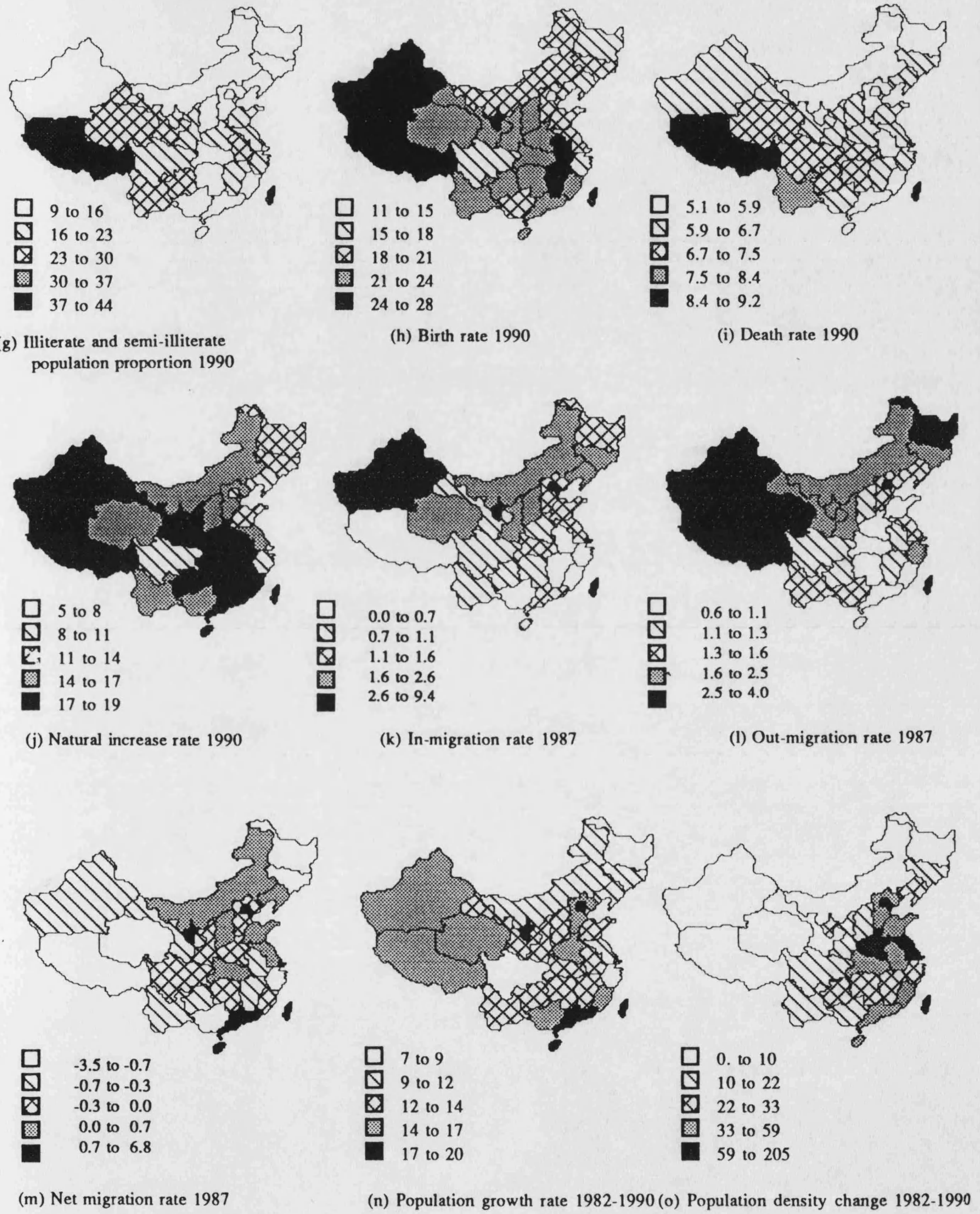


Figure 5-3 **Regional variations in aspects of China's population (continued)**

municipalities and provinces which has then spread to the interior provinces of China (Peng, 1991).

Figure 5-3 (d) shows that Liaoning, Beijing, Tianjin, Shanghai, Jiangsu and Zhejiang in the eastern part of China have average household scales under 3.9 persons per household while Tibet and Qinghai in the west a much larger household scale is the norm (5.2 persons per household and over). Note that Guangxi and Fujian in the eastern zone also have a relatively large household scale (over 4.8 persons per household). Actually, these two regions are the least developed in the eastern zone.

Figure 5-3 (e) shows that the northern part of China generally has more than 25% of its population urban while in the south the urban proportion is usually under 25%. This character is the result of combined effects that the eastern China has a more developed economy and that especially the south-east also has a more developed agriculture with a favourable natural environment. This characteristic is also confirmed by figure 5-3 (f) which shows the spatial pattern of the proportion of agricultural employees. Most regions except Xinjiang in the western zone have a proportion of agricultural employees over 79%. Rapid industrialization has taken place in Jiangsu and Zhejiang provinces in the eastern economic zone since the late 1970s. These two provinces have made most use of the economic reforms. Collective and private owned enterprises constitute a substantial proportion of their economies. Their proportions of agricultural employees in the total labour force are well below 50%. Three municipalities (Beijing, Tianjin and Shanghai) and Liaoning province in the eastern zone are the traditional industrial bases of China and also have small proportions of agricultural employees below 50%.

Figure 5-3 (g) shows that Tibet, Qinghai, Gansu, Yunnan and Guizhou in the western zone and Anhui in the middle zone have proportions of illiterate and semi-illiterate population over 23%. In the least developed region, Tibet, the proportion of illiterate and semi-illiterate population is over 37%. Such low level of education may have adverse éffect on its development.

Figure 5-3 (h) shows the spatial variation of the birth rate in 1990. Most regions except Sichuan in the western zone have birth rates over 21‰. It is interesting to note that Sichuan has the largest provincial population of 107 million in China in 1990, and that its birth rate has been successfully kept at a low level. Six out of nine regions in the middle zone also have birth rates over 21‰. Birth rates are not uniformly low in the eastern economic zone. Fujian and Guangdong have birth rates over 21‰ while the rest regions below 18‰. These two provinces have been most influenced by the open door policy. The traditional administrative system has been weakening much faster than in other provinces. It may become more and more difficult to implement family programme effectively there. It is of concern that such adverse effect on family planning may spread into other regions with the further transition of China's economy into a market economy.

The spatial variation of death rate in 1990 is shown in figure 5-3(i). The death rates are normally below 6.7% in the eastern zone. Most regions in the western zone have death rates over 6.7%. Tibet and Yunnan in that zone have high death rates over 7.5‰ However, in Heilongjiang, Hebei, Anhui and Inner Mongolia in the middle zone, and Ningxia in the western zone the death rate does not climb above 5.9‰ as in Beijing, Tianjin, Fujian and Guangdong in the eastern economic zone.

Figure 5-3 (j) shows the spatial variation of natural increase rate. By definition, natural increase rate is the difference between the birth rate and the death rate. Currently, the birth rate is much greater than the death rate in China. Comparing the spatial patterns of birth, death and natural increase rates in figures 5-3(h), (i) and (j), it seems that the spatial pattern of natural increase rate mainly reflects that of birth rate. All those regions with natural increase rates over 17‰ have birth rates over 21‰. These regions can be found in the western, middle and eastern economic zones. All those regions with natural increase rates below 14‰ have birth rates below 21‰. Most of these regions locate in the eastern zone (Liaoning, Beijing, Tianjin, Shandong, Shanghai and Zhejiang). Two regions, Heilongjiang and Jilin, are in the middle economic zone. Sichuan in the western zone also has a natural increase rate below 14‰.

Figure 5-3 (k) shows that Liaoning, Beijing, Tianjin and Shanghai in the eastern zone, Jilin, Inner Mongolia, Shanxi in the middle zone, and Xinjiang, Qinghai, Ningxia, Shaanxi in the western zone, have in-migration rates over 1.6‰. These regions are either sparsely populated or more urbanized and industrialized regions in China. Two kinds of in-migration flows can be identified. The first one is the migration flow toward sparsely populated regions in the north-western part of China. The second one is the migration flow toward most urbanized and industrialized regions in the eastern economic zone. However, most of those regions except for Shanxi receiving the fist kind of migration flow also have high out-migration rates as are shown in figure 5-3(l). Only Beijing which receives the second kind of migration flow has high out-migration rates. Beijing, as the capital of China, has huge exchange of persons with the rest of the country. Besides, another three traditional in-migration regions, Heilongjiang, Gansu and Tibet also have out-migration rates over 2.5‰. It is interesting to note that Zhejiang also has a high out-migration rate over 2.5‰. The economy in Zhejiang has been growing rapidly since the late 1970s. A number of people with various skills have migrated to other regions all over the country to engage in various kinds of small business such as retailing and catering.

Net migration rate is the difference between the in-migration and out-migration rates. Figure 5-3 (m) shows that a number of regions in the eastern and middle zones have net in-migrations. Specifically Beijing, Tianjin, Shanghai and Guangdong in the eastern zone have a net migration rate over 0.7‰. In the western zone, only Ningxia has such a high net migration rate. The economy in Guangdong is booming in recent years with the implementation of a series of policies aiming to attract capital from Hong Kong and abroad. Such rapid growth has attracted substantial migrants all over the country. Zhejiang has net out-migrations due to a high out-migration rate mentioned before. It should be noted that some traditional net in-migration regions such as Guangxi in the eastern zone, Heilongjiang and Jilin in the middle zone, Qinghai and Tibet in the western zone have been subjected to net out-migration rates over 3.5‰. This change in the inter-provincial migration direction is the result of changes in a variety of political, social and economic situations as well as government policies in China since the late 1970s. See chapter seven for a more detailed discussion.

Figure 5-3 (n) shows the spatial pattern of the population growth rate over the period 1982-1990. Regional population growth is the combined result of the effects of natural population increase and net population migration. Beijing, Ningxia and Guangdong have a growth rate over 17% in the period 1982-1990. It seems that high net in-migration is the main cause of the high rate of growth in Beijing, while both high net in-migration rates and substantial natural increase rates have contributed to the high population growth rates in Ningxia and Guangdong. Heilongjiang, Zhejiang and Sichuan have a growth rate under 9% in the period 1982-1990. It seems that high net out-migration is the best explanation of low population growth rate in Heilongjiang while low natural increase rate is the main cause of low population growth rate in Sichuan. Both a low natural increase rate and a high net out-migration rate seem to have contributed to the low population growth rate in Zhejiang.

Spatial population change is a long term process. It often takes many years to change the spatial pattern of population distribution. The standard deviation of the natural increase rate is 4‰ in 1990, and that of the net migration rate is 2‰ in 1987 while the coefficient of variation of the population density is 124% in 1990. It seems that, on average, the effect of the natural increase rate on population redistribution is two times more than that of the net migration rate in late 1980s. Assuming that region A has a population density of 1.24 times more than region B, and a natural increase rate of 14.7‰, that region B has a natural increase rate of 4‰ more than region A, and that there is no migration between two regions, simple calculation shows that it will take 1225 years for region B to catch up with region A to reach a same population density.

Figure 5-3 (o) shows the spatial pattern of population density change in the period

1982-1990 which is almost identical to the spatial pattern of population density in 1990 as shown in figure 5-3 (a). This is because the population density is the main factor determing the change of population density as its spatial variation is much greater than the spatial variation in the rates of population change. Six sparsely populated regions, namely, Heilongjiang, Inner Mongolia, Gansu, Xinjiang, Qinghai and Tibet in the northern and north-western parts of China have a population density increase under 10 persons per km^2 while five densely populated regions, namely, Beijing, Tianjin, Shanghai, Jiangsu and Henan have increases of over 59 persons per km^2.

It should be noted that the spatial patterns of most demographic indicators discussed above are highly correlated. Table 5-3 presents their correlation coefficients which are significant at 0.05 level. The out-migration rate, death rate, population growth rate and population proportion of national minorities have more unusual patterns compared to other indicators as they have more insignificant correlation coefficients than the others.

Table 5-3 Correlation coefficients among demographic indicators

	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	x_{11}	x_{12}	x_{13}	x_{14}
x_1	1													
x_2	-0.4	1												
x_3	0.8	-0.5	1											
x_4	-0.6	0.7	-0.7	1										
x_5	0.5	*	0.4	-0.6	1									
x_6	-0.7	*	-0.5	0.7	-0.9	1								
x_7	*	0.6	-0.4	0.7	-0.6	0.6	1							
x_8	-0.6	0.4	-0.6	0.8	-0.8	0.8	0.6	1						
x_9	*	0.6	*	0.4	-0.4	0.4	0.6	0.4	1					
x_{10}	-0.6	*	-0.6	0.7	-0.8	0.8	0.5	1.0	*	1				
x_{11}	0.6	*	0.4	-0.5	0.8	-0.8	-0.4	-0.6	*	-0.6	1			
x_{12}	*	0.7	-0.5	*	*	*	*	*	*	*	*	1		
x_{13}	0.8	-0.4	0.6	-0.6	0.7	-0.8	-0.5	-0.6	-0.4	-0.6	0.9	*	1	
x_{14}	*	*	*	0.5	*	*	*	0.5	*	0.5	*	*	*	1
x_{15}	1.0	-0.4	0.8	-0.6	0.6	-0.7	*	-0.6	*	-0.6	0.7	*	0.8	*

Note: * not significant at 0.05 level. For key to entries see text.

Except for these four indicators (x_2, x_9, x_{12}, x_{14}), most of the rest of the demographic indicators are significantly correlated with two exceptions. The correlation coefficients of the proportion of illiterate and semi-illiterate population (x_7) with population density (x_1) and population density change (x_{15}) are insignificant at 0.05 level. Two groups of demographic indicators can be identified. The demographic indicators within each group are positively and significantly correlated. The first group consists of population density, proportion of elderly population, proportion of urban population, inter-provincial in-migration rate, inter-provincial net-migration rate and population density change. The second group consists of average household scale, proportion of agricultural employees, proportion of illiterate and semi-illiterate population, birth rate and natural increase rate. The demographic indicators in one group are negatively and significantly correlated with the demographic indicators in another group, with two exceptions mentioned above. Thus a typical region with a high population density in China usually has high levels of urbanization and industrialization, large increase in population density, high rates of inter-provincial in-migration and net migration, high proportion of elderly population, but low birth and natural increase rates, small household scale, small proportion of illiterate and semi-illiterate population. The situation is reversed for a typical region with a low population density.

Now consider the four demographic indicators with lower correlation with other indicators. The distribution of the national minority population is a fundamental feature in China. The population proportion of national minorities is positively and significantly correlated with average household scale, proportion of illiterate and semi-illiterate population, birth rate, death rate and inter-provincial out-migration rates, but negatively and significantly correlated with population density, proportion of elderly population, inter-provincial net migration rate, population density change. Thus a typical region with a high proportion of national minorities usually has a low population density, small population density change, high birth and death rates, large household scale, high proportion of illiterate and semi-illiterate population, low proportion of elderly population, high inter-provincial out-migration rate and low net migration rate.

The death rate is positively and significantly correlated with the population proportion of national minorities, average household scale, proportion of agricultural employees, proportion of illiterate and semi-illiterate population and birth rate, but negatively and significantly correlated with the proportion of urban population, inter-provincial net migration rate. Thus a typical region with a high death rate may look like this: high proportions of national minorities and illiterate and semi-illiterate population, low levels of urbanization and industrialization, a high birth rate, a large household scale, and small inter-provincial net migration rate.

The inter-provincial out-migration rate is only significantly correlated with two demographic indicators. It has a positive correlation with the population proportion of national minorities and a negative correlation with the proportion of elderly population. A region with a high proportion of national minorities and a low proportion of elderly population is more likely to have a high out-migration rate.

The population growth rate is positively and significantly correlated with only three demographic indicators: the birth rate, natural increase rate and average household scale. Here, it shows that the birth rate and natural increase rate do play a decisive role in the regional population growth rate. A region with high birth and natural increase rates is likely to have a high population growth rate. Of course, the household scale in such a region may be large. It is interesting to note that the urbanization level is not significantly correlated with the population growth rate. A region may have a high population growth rate whether its urbanization level is high or low. For example, Beijing has a high proportion of urban population. It has a low birth rate. But it still has a high population growth rate due to a high net in-migration rate. For another example, Tibet has a low urbanization level. It has a high birth rate. Thus its population growth rate is also high. Here, two different factors, migration and fertility, help to keep high population growth rates in Beijing and Tibet respectively.

5.3 Trends in regional birth rates

China's population has experienced a demographic transition process in the last three decades. The current spatial patterns of regional birth and death rates are the results of such process. Subsequent sections in this chapter will examine the main features of such trends in the regional birth and death rates as well as regional migration rates and population densities.

The trends in birth, death and natural increase rates for China as a whole in the period 1949-1990 are shown in figure 5-4 and will be examined first. The birth rate increased slightly from 36‰ in 1949 to 38 ‰ in 1954 as China entered a peaceful period. The birth rate began to decline after 1954. However, this process was speeded up by a 'Socio-economic crisis' around the year 1960. There was severe shortage of food and the birth rate declined to 21‰ by the year 1960. In the mean time, the death rate increased to over 25‰ by 1960. In that year, China had a negative natural increase rate of -4.6‰. The birth rate reached the bottom of 18‰ in 1961. To compensate for the loss of population and the low birth rates during the crisis, the birth rate recovered to a highest level of 43‰ by the year 1963. The birth rate began to decline slowly after 1963 and rapidly after 1970. Because the family planning was gradually introduced in urban areas in 1960s and rural areas in areas in 1970s. The widespread implementation of family planning in the rural areas where majority of Chinese people live play a vital role in the dramatic decline of fertility in China. By the year 1980, the birth rate in China was as low as 18‰. With the introduction of economic reforms, the family planning policy has been somewhat relaxed. The birth rate increased slightly to around 21‰ by the year 1990 with small fluctuations.

Except for a sharp increase of the death rate during the socio-economic crisis around

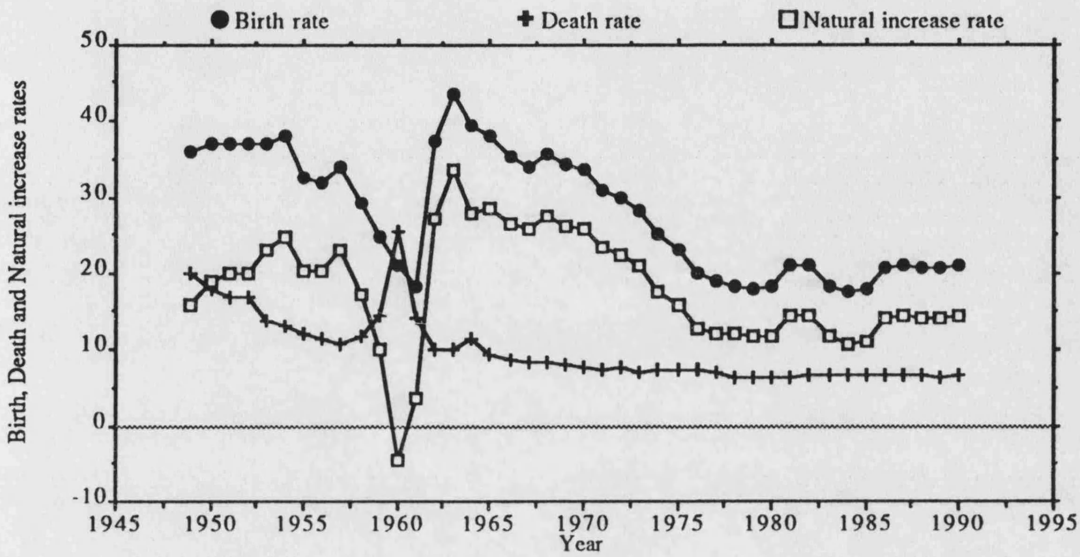


Figure 5-4 Trends in birth, death and natural increase rates in China, 1949-1990 (‰)

1960, the death rate has declined from 20‰ in 1949 to 6.7‰ by 1990. In the period 1949-1957, after the foundation of the People's Republic, the death rate declined rapidly from 20‰ to 11‰, nearly a 50% decrease due to significant improvements in peoples' life compared to the war times before 1949. The further decline of the death rate in the period has been achieved rather slowly. The death rate has been almost stable around 6.7‰ since 1982.

In figure 5-4, the natural increase rate almost follows the trend of the birth rate. It increased from 16‰ to 25‰ in the period 1949-1954. A sharp decline of natural increase rate occurred in the period 1958-1960. By the year 1960, it reached the bottom of -4.6‰. It was quickly recovered and climbed to a new high level of 33‰ by the year 1963. Following the decline of the birth rate, it was declined slowly to 26‰ by the year 1970, then rapidly to 13‰ by the year 1976. It was further declined, though slowly, to 12‰ by the year 1980. With the increase of the birth rate in 1980s, the natural increase rate increased to a level around 15‰ in the 1980s.

These national trends are the combined results of regional trends. Figure 5-5 presents trends in the regional birth rates for 29 provincial regions in selective years. The national birth rate began to decline in 1955, reached the bottom in 1961 and recovered to a high level in 1963 as mentioned above. Though detailed annual regional data for

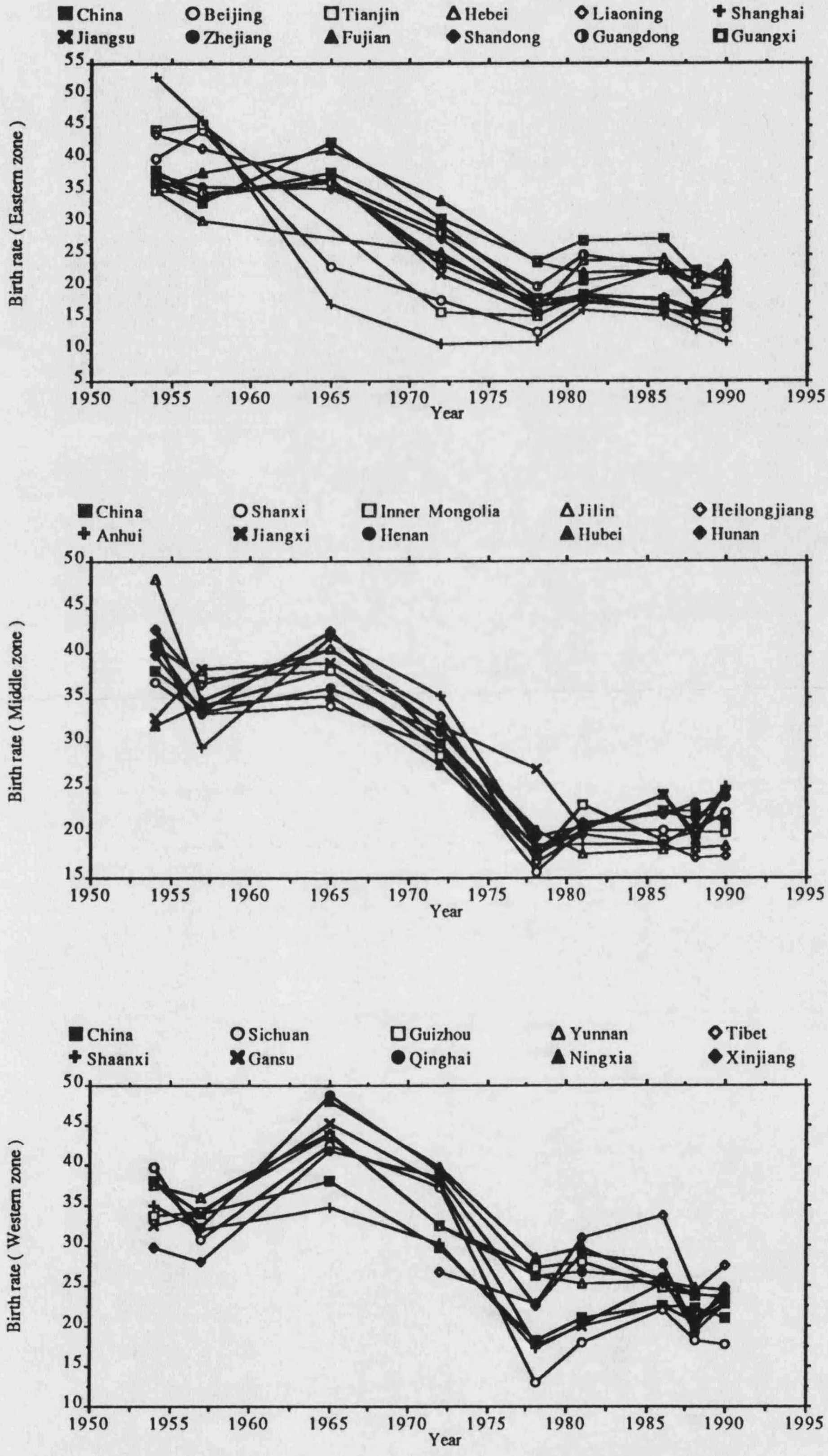


Figure 5-5 Trends in regional birth rates in China, 1954-1990

this period are not available, figure 5-5 does show the regional trends using data for 1954, 1957 and 1965. In the eastern economic zone, not all regions followed the national trend. Birth rates in Shanghai and Liaoning declined continuously in the period 1954-1965. Birth rates in Beijing and Tianjin increased from 1954 to 1957 contrary to the national trend. Their birth rates then declined in the period 1957-1965. The birth rate in Fujian also increased in the period 1954-1957, and climbed to a peak in 1965. The remaining regions in the eastern economic zone have similar trends to the national one.

The regional trends in the middle and western economic zones show much clear V shapes in the period 1954-1965. In the western economic zone, the recovery of birth rates was very strong in the first half of the 1960s. Most regions climbed to high birth rates in 1965 which were significantly greater than those ever before reached. A few regions did not show a decline in birth rate from 1954 to 1957. These include Jiangxi and Hubei in the middle economic zone, Guizhou and Gansu in the western economic zone.

The decline of birth rates took place in all regions in the period 1965-1978. For China as a whole, this declining period covers 1963-1979. The available regional data only cover the period 1965-1978. According to figure 5-5, it is quite clear that Beijing, Tianjin and Shanghai in the eastern economic zone lead the way in the decline of birth rate. By 1965, Shanghai already had a birth rate as low as 17‰ while the national average was 38‰. In some regions such as Sichuan, Shaanxi and Xinjiang in the western economic zone, Shanxi and Henan in the middle economic zone, significant decline of birth rates did not happen until 1972. In eastern economic zone, the rates of the birth rate decline were close in the period 1965-1972 and 1972-1978. However, in most regions in the middle and western economic zone, birth rates declined much faster in the period 1972-1978 than in the previous period 1965-1972. It is in line with the much wider implementation of family planning all over the country in the 1970s. However, birth rates in Tibet, Guizhou and Yunnan in the western economic zone, and Jiangxi in the middle economic zone did not decline fast even in the 1970s.

More flexible family planning policy has been adopted in China since the early 1980s. For China as a whole, its birth rate reached a bottom in 1979 and then slightly increased. According to figure 5-5, most regions recorded increases in birth rats from 1978 to 1981. It seems that some regions had much greater increases than other regions. For examples, birth rates increased from 16‰ to 24‰ in Hebei in the eastern zone, from 16‰ to 20‰ in Shanxi, from 17‰ to 23‰ in Inner Mongolia in the middle zone, from 23‰ to 31‰ in Tibet, from 23‰ to 29‰ in Xinjiang and from 13‰ to 18‰ in Sichuan in the western zone in the period 1978-1981. Sichuan experienced the greatest decline of the birth rate, from 37‰ to 13‰, in the period 1972-1978. It had a steady increase in the birth rate from the bottom (13‰) in 1978 to a new peak (22‰) in 1986. However, its birth rate declined again to 18‰ by the year 1990. In the period 1981-1990, all regions in the eastern zone except for Fujian, plus Inner Mongolia, Heilongjiang in the middle economic zone and Guizhou, Yunnan, Qinghai, Ningxia and Xinjiang in the western zone had slight decreases in their birth rates. The birth rates in the remaining regions either increased slightly or were stable in the same period.

The trends of regional birth rates described above are quite different among various regions. It is of interest if the spatial variation of birth rates is increasing or decreasing in this whole process. Coefficients of variation are used to examine whether the trend in the spatial variation is increasing or declining. In most years, data samples include the 29 mainland provinces with the new province, Hainan, included in Guangdong. Two sets of calculations are made as the data of Tibet and Ningxia for 1954 and 1957 and Tianjin, Hebei and Tibet for 1965 are, unfortunately, not available. As many samples as available are used in the set A calculations. A group of 25 samples, excluding Tianjin, Hebei, Tibet and Ningxia, is used in the set B calculations for comparison. Table 5-4 presents the results of these calculations.

Table 5-4 Coefficients of variation of the regional birth rates

Year	A (29 samples) Mean (‰)	Standard deviation (‰)	Coefficient of variation (%)	B (25 samples) Mean (‰)	Standard deviation (‰)	Coefficient of variation (%)
1954[a]	38.29	5.17	13.49	38.19	5.19	13.58
1957[a]	35.35	4.52	12.78	35.15	4.12	11.73
1965[b]	38.49	6.81	17.68	38.11	6.65	17.46
1972	29.42	6.87	23.37	29.81	6.49	21.76
1978	19.41	4.64	23.92	19.20	4.48	23.36
1981	21.88	4.16	19.01	21.25	3.62	17.04
1986	22.13	4.22	19.06	21.61	3.65	16.90
1988	19.60	3.01	15.37	19.32	2.81	14.55
1990	20.93	4.01	19.13	20.79	3.87	18.63

Note: a 27 samples in set A as the data for two regions are not available
b 26 samples in set A as the data for three regions are not available

According to table 5-4, the trends of the spatial variation of set A and set B are quite similar. According to the set A result, coefficients of variation were low in 1954 and 1957 (13.49% and 12.78% respectively) and increased to their highest values in 1972 and 1978 (23.37% and 23.92% respectively). It seems that the spatial variation increased from 1957 to 1978, decreased from 1978 to 1981, and was stable at about 19% in the period 1981-1990. The relatively fast and early decline of the birth rate in the more developed regions, such as Shanghai and Zhejiang, compared to the less developed regions, such as Guizhou, may be the reason for the increase in variation from 1957 to 1978. The decrease in the spatial variation of the birth rate from 1978 to 1981 may be due to the significant increase of birth rate in those regions which achieved rapid decline of birth rates in the previous period as the overall national birth rate increased over the period. This phenomenon is particularly clear in the western economic zone. Several regions including Guizhou, Yunnan, Qinghai and Ningxia which had the highest birth rates did not have significant increase in birth rates in the period 1978-1981. Regional birth rates changed slowly in the period 1981-1990. Thus the spatial variation was stable in this period. Table 5-5 presents the birth rates in Shanghai, Zhejiang, Guizhou and Qinghai in selective years.

In 1988, the coefficient of variation was quite small (15.37%). In that year, Tibet, Shaanxi, Gansu, Qinghai and Xinjiang in the western economic zone which normally have high birth rates reported low birth rates. This significantly reduced the spatial variation in that year.

Table 5-5 Birth rates in the regions of Shanghai, Zhejiang, Guizhou and Qinghai ($\%_0$)

Region	1957	1978	1981	1986	1988	1990
Shanghai	46.00	11.31	16.14	15.45	13.20	11.32
Zhejiang	34.62	16.90	17.93	16.18	15.54	14.84
Guizhou	34.27	27.37	27.89	24.79	23.81	23.77
Qinghai	32.18	26.15	26.65	25.99	19.27	22.65

Data source: Hu and Zhang (1984) pp.101, DPS (1988b), and SSB (1990a)

A correlation matrix of the spatial series of birth rates has been calculated to examine the stability of the spatial pattern. The greater the correlation coefficient, the more stable the spatial pattern of birth rate. Table 5-6 presents the correlation matrices. Set A uses 29 samples. Set B uses 25 samples, excluding Tianjin, Hebei, Tibet and Ningxia. All correlation coefficients, except in one case, are significant at 0.05 level. There was a change of the spatial pattern of birth rate between 1957 and 1965 as indicated by negative correlation between those spatial series before 1957 and those spatial series after 1965 (inclusive). The reason for this change in the spatial pattern of the birth rate is as follows. The birth rate was positively correlated with the development level before 1957 and was negatively correlated with the development level after 1965. The birth

Table 5-6 Correlation matrices of the regional birth rates

Year	1954	1957	1965	1972	1978	1981	1986	1988	1990
A (29 samples)									
1972				1					
1978				0.61	1				
1981				0.48	0.75	1			
1986				0.52	0.65	0.84	1		
1988				0.64	0.70	0.75	0.76	1	
1990				0.68	0.65	0.63	0.74	0.85	1
B(25 samples)									
1954	1								
1957	0.49	1							
1965	-0.44	-0.70	1						
1972	-0.46	-0.76	0.89	1					
1978	-0.45	-0.28*	0.65	0.56	1				
1981	-0.53	-0.42	0.55	0.53	0.75	1			
1986	-0.64	-0.53	0.57	0.66	0.69	0.79	1		
1988	-0.44	-0.56	0.66	0.65	0.65	0.66	0.73	1	
1990	-0.62	-0.68	0.64	0.70	0.62	0.56	0.71	0.84	1

Note: * not significant at 0.05 level

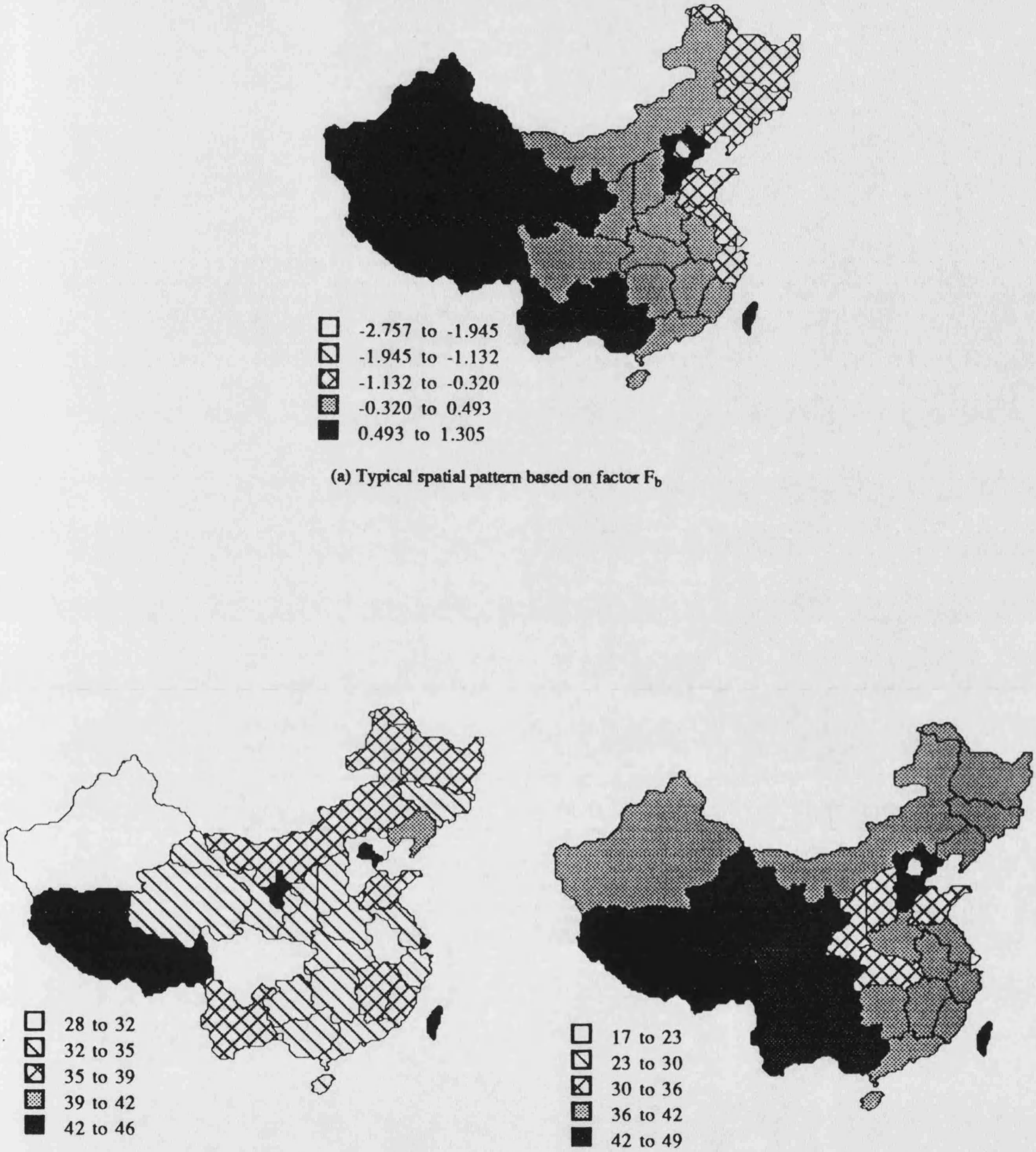
rate began to decline faster in the more developed regions after 1965. It seems that the spatial pattern of the birth rate has been quite stable since 1965 as indicated by significant correlations among the spatial series of birth rates.

An orthogonal varimax factor analysis has been used to examine the typical spatial pattern of birth rates based on the data set of 25 samples. Table 5-7 presents the factor loadings of the first factor (correlation coefficient of a factor with the birth rate at a specific year in this case) . Figure 5-6 show the typical spatial pattern of regional birth

Table 5-7 Factor loadings of regional birth rate factor F_b

Year	1954	1957	1965	1972	1978	1981	1986	1988	1990
Factor loading	-0.682	-0.741	0.840	0.855	0.777	0.793	0.867	0.854	0.875

rates as described by regional factor scores of factor F_b. The original variance contribution of factor F_b is 65.9%. According to table 5-7, factor F_b describes the typical spatial pattern of birth rate as it is significantly correlated with the birth rate every year. A region may have a low birth rate before 1957 and a high birth rate after 1965 if its factor score of F_b is high. According to figure 5-6(a), Beijing and Shanghai have



(a) Typical spatial pattern based on factor F_b

(b) Birth rate in 1957

(c) Birth rate in 1965

Figure 5-6 Spatial patterns of birth rates in China the smallest scores of factor F_b. Heilongjiang, Jilin, Liaoning, Shandong, Jiangsu and Zhejiang in the east of China also have small factors. On the other hand, Xinjiang, Qinghai, Gansu, Shaanxi, Yunnan, Guizhou and Guangxi in the west and south-west parts of China have the largest scores. It is noted that two contrasting patterns of birth rate before 1957 and after 1965 are described by factor F_b. Figure 5-6 (b) and (c) show the contrasting spatial patterns of the birth rate in terms of raw data in 1957 and 1965. Beijing, Tianjin, Shanghai and Liaoning in the more developed eastern zone had a high birth rate, over 39%₀, in 1957 while Guangxi in the eastern zone and Gansu, Ningxia, Qinghai, Sichuan, Guizhou, Yunnan in the western zone had a high birth rate over 42%₀ in 1965.

5.4 Trends in regional death rates

The national death rate of China decreased gradually from 20 %₀ in 1949 to 6.7%₀ in 1990 except for an upturn during the 'Socio-economic crisis' around 1960. Following this national trend, death rates in most regions also declined in this period as are shown in figure 5-7. The great decline of the death rates occurred in early years after the foundation of the People's Republic in 1949. A number of regions recorded a rapid decline of death rates in the first period 1954-1957. These regions include Jiangsu (from 12%₀ to 10%₀), Zhejiang (from 11%₀ to 9%₀), Guangdong (from 13%₀ to 9%₀) and Guangxi (from 15%₀ to 12%₀) in the eastern zone, Shanxi (from 15%₀ to 13%₀), Anhui (from 25%₀ to 16%₀), Jiangxi (from 14%₀ to 11%₀), Hubei (from 16%₀ to 10%₀) and Hunan (from 18%₀ to 10%₀) in the middle zone, and Sichuan (from 15%₀ to 12%₀) in the western economic zone. Regional death rates declined more slowly in most regions over the period 1957-1978 and have been stable since 1978. Death rates in Guizhou, Ningxia and Gansu were still high in 1965, probably due to the delayed recovery from the 'Socio-economic crisis' in early 1960s. By the year 1954, Shanghai already had a low death rate of 7.12%₀, it further declined to 5.57%₀ in 1972, then increased slowly to 6.36%₀ by 1990 mainly due to the ageing of its population. For China as a whole, such a process may take place in the next century.

The same methods and data for the same period are used to analyze the trends in the spatial variation of the death rates in the following. Table 5-8 presents the coefficients of variation for regional death rates. It seems that the spatial variation of death rates has a decreasing trend over the period 1954-1990. With regard to data set A, the coefficient of variation of the death rate was 23.56% in 1954, 14.31% in 1978 and 13.04% in 1990. The decreasing trend is clearer in data set B where the coefficient of variation of the death rate was 22.49% in 1954, 13.14% in 1978 and 9.52% in 1990. The reason

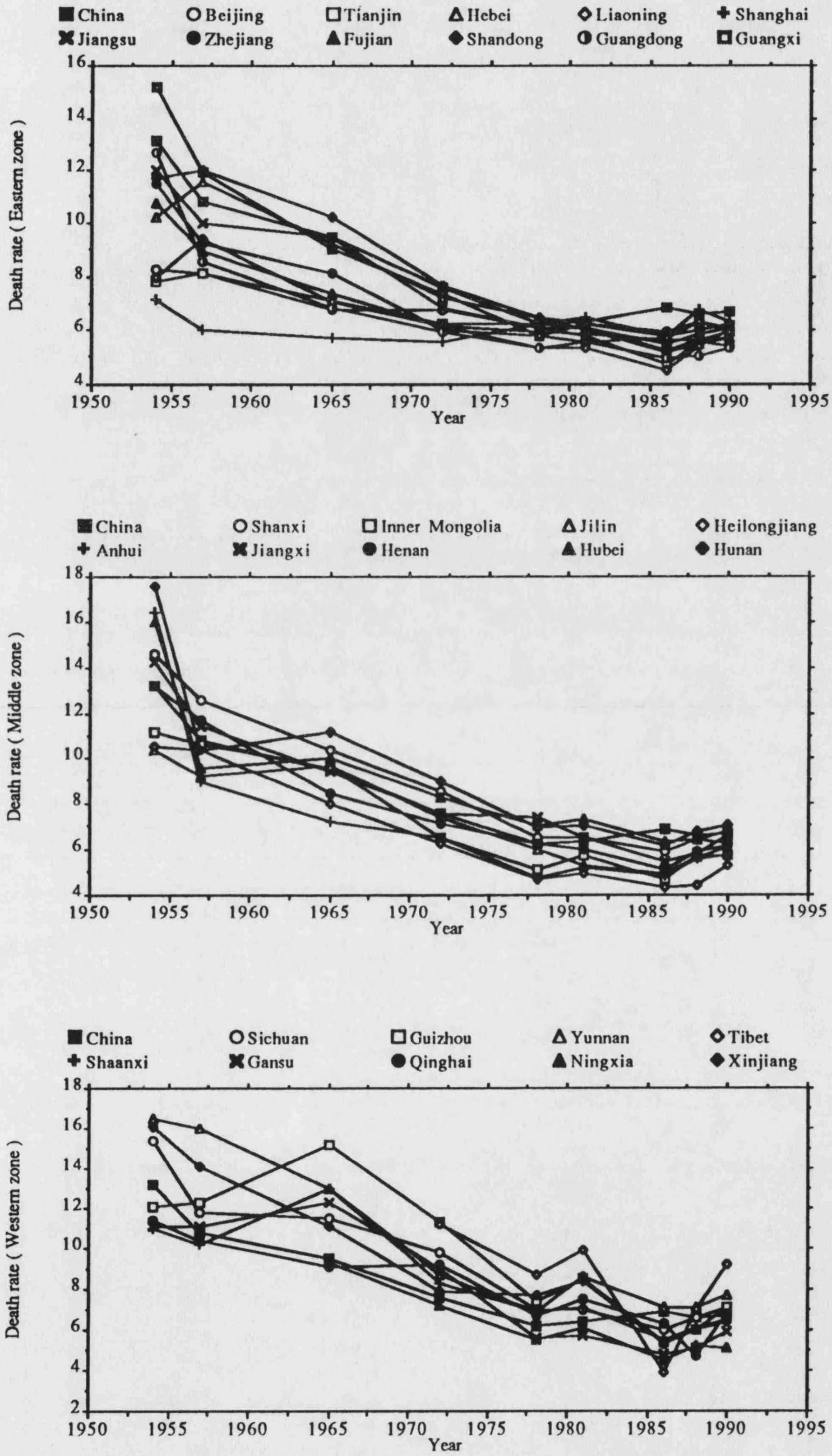


Figure 5-7 Trends in regional death rates in China, 1954-1990

Table 5-8 Coefficients of variation of the regional death rates

Year	A (29 samples) Mean (‰)	Standard deviation (‰)	Coefficient of variation (%)	B (25 samples) Mean (‰)	Standard deviation (‰)	Coefficient of variation (%)
1954[a]	12.33	2.90	23.56	12.60	2.83	22.49
1957[a]	10.55	2.02	19.12	10.60	2.03	19.13
1965[b]	9.57	2.24	23.42	9.58	2.29	23.86
1972	7.66	1.49	14.50	7.61	1.41	18.48
1978	6.32	0.90	14.31	6.25	0.82	13.14
1981	6.51	1.16	17.88	6.43	1.03	16.06
1986	5.38	0.70	13.08	5.49	0.66	12.06
1988	5.89	0.66	11.27	5.90	0.66	11.18
1990	6.30	0.82	13.04	6.27	0.60	9.52

Note: a 27 samples in set A
b 26 samples in set A

for this trend lies in the effective spread of medical facilities and services to less developed regions in China. The decline of regional death rates has taken place gradually since the early 1950s. As a result, the spatial variation of the death rate was less than that of birth rate in the period 1972-1990. This confirms part of the demographic transition theory that mortality declines ahead of fertility.

There are some fluctuations around the overall trend. In 1957, a number of regions in the middle and western economic zones, which normally had high death rates, recorded low death rates as were shown in figure 5-7. Thus the spatial variation of the death rate was lower in 1957 than in 1954 and 1965. In 1981, a number of regions in the western economic zone recorded higher death rates than in the previous and following years, Thus the difference in death rates between these regions and other developed regions was increased. The coefficient of variation was as high as 18% in 1981. In 1990, the coefficient of variation was a little higher than in 1988 based on the results of data set A. In that year, Tibet recorded a high death rate of 9.2‰. Based on the results of data set B, which excludes Tibet, the coefficient of variation did reach its smallest value in 1990.

Table 5-9 presents the correlation matrices of regional death rates. Most correlation coefficients are significant at 0.05 level. It seems that the spatial pattern of the death rate was also relatively stable in the period 1954-1990. However, it may well be less stable than the spatial pattern of the birth rate as the birth rate had a greater number of significant correlation coefficients than the death rate. This may be due to the fact that all regional death rates have been reduced to low levels as well as the differences among them. Also some random factors may play more active role in the spatial pattern of death rates. Thus spatial patterns of the death rate are less significantly correlated.

One factor F_d is again extracted using the factor analysis methodology to examine the typical spatial pattern of death rates. The data set of 25 samples is used. Table 5-10 presents the factor loadings of the first factor. The original variance contribution of factor F_d is 62.2%. Factor F_d describes the typical spatial pattern of death rate as it is significantly correlated with the death rate every year. This typical pattern in terms of regional factor scores of factor F_d is shown in figure 5-8. A region may have a high death rate if its factor score of F_d is high. According to figure 5-8, Xinjiang, Sichuan, Guizhou and Yunnan in the western zone, Hubei and Hunan in the middle zone usually have high death rates. Liaoning, Beijing and Guangdong in the eastern zone, Heilongjiang and Anhui in the middle zone usually have low death rates. Shanghai is not a typical region of low death rate as its death rate has been increasing with the ageing of its population. Its trend in death rates is quite different from other regions.

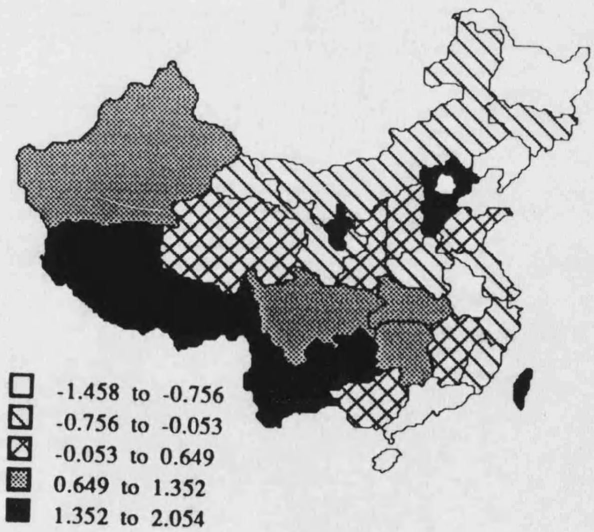


Figure 5-8 Typical spatial pattern of death rates based on factor F_d in China

Table 5-9 Correlation matrices of regional death rates

Year	1954	1957	1965	1972	1978	1981	1986	1988	1990
A (29 samples)									
1972				1					
1978				0.72	1				
1981				0.76	0.89	1			
1986				0.16*	0.29*	0.28*	1		
1988				0.36*	0.61	0.58	0.47	1	
1990				0.76	0.82	0.87	0.26*	0.68	1
B(25 samples)									
1954	1								
1957	0.60	1							
1965	0.42	0.70	1						
1972	0.43	0.58	0.87	1					
1978	0.39	0.46	0.59	0.66	1				
1981	0.42	0.58	0.68	0.69	0.86	1			
1986	0.49	0.38*	0.37*	0.43	0.63	0.69	1		
1988	0.43	0.28*	0.31*	0.23*	0.54	0.50	0.69	1	
1990	0.48	0.53	0.67	0.73	0.77	0.84	0.79	0.63	1

Note: * not significant at 0.05 level

Table 5-10 Factor loadings of regional death rate factor F_d

Year	1954	1957	1965	1972	1978	1981	1986	1988	1990
Factor loading	0.636	0.715	0.802	0.808	0.849	0.902	0.772	0.635	0.924

5.5 Trends in regional migration rates

The migration data available are in-migration rates and out-migration rates of various regions which include intra-provincial migrations and inter-provincial migrations (DPS, 1988b). These data are produced by the residence registration system administrated by the Ministry of Public Security of China. Net migration rates are calculated from in-migration rates and out-migration rates and, theoretically, they are net inter-provincial migration rates as external migration is negligible. It is noted that there is a significant statistical error of migration registration in China. For example, the national out-migration rate was 15.75‰ while the national in-migration rate was 18.59‰ in 1987. The in-migration rate is thus significantly greater than the out-migration rate. The difference cannot be explained by net external migrations. According to the 1% population sample survey in 1987, the external in-migration rate was only 0.09‰ in 1987. The in-migration rates and out-migration rates of various regions may have the same statistical errors. As a result, most regional net migration rates are positive and may have been affected by these types of statistical errors. The net migration rates must be used with caution and they are used in this section only to reveal the general trend of regional net migration patterns. Two sets of calculations are made as the data for Tibet in 1955, 1960, 1965 are not available. As many samples as available are used in the set A calculation. A group of 28 samples excluding Tibet is used in the set B calculation. The new province Hainan is included in Guangdong.

After the foundation of the People's Republic of China, the government gradually introduced a series of measures to control migration especially the rural to urban migration (see section 2.3). These measures have become more rigid and effective after the 'Socio-economic crisis' in the early 1960s when many urban residents were sent back to rural areas. In addition, the government organized a number of people in the densely populated eastern provinces such as Shanghai, Shandong and Zhejiang to move to the sparsely populated middle and western provinces such as Heilongjiang, Ningxia and Xinjiang to develop arable land in the 1950s. Such organized migrations have stopped since the early 1960s. Therefore, the scale of migration flow has been significantly reduced since the early 1960s. For China as a whole, its in-migration rate was 42‰ in 1955, reached a peak of 50‰ in 1960, then declined dramatically to 23‰ by the year 1965. The in-migration rate in 1960 is exceptionally high as a result of the 'Great Leap Forward' movement when urban population was increased rapidly (see section 2.3.3). In the period 1965-1987, the in-migration rate decreased slowly to 19‰ by 1987.

Figure 5-9 shows the regional trends in in-migration rates. Most regions follow the national trend. But the most rapid decline of in-migration rates occurred in those regions which had high in-migration rates before 1960. These regions including Beijing and Liaoning in the eastern zone, Inner Mongolia, Jilin and Heilongjiang in the middle zone, Ningxia and Xinjiang in the western zone had massive in-migrations in the 1950s. The variation of regional in-migration rates has become small since 1960. Table 5-11 presents the coefficients of variation of the in-migration rate. According to data set A, the coefficient of variation decreased from 59.64% in 1955 to 25.96% by 1987.

Table 5-12 presents the correlation matrices of the in-migration rate data. It seems that the spatial pattern of the in-migration rate is relatively stable as most correlation coefficients are significant at 0.05 level though some changes have gradually taken place as revealed by factor analysis below.

Two factors F_{i1} and F_{i2} are extracted using the factor analysis method. The data set of 28 samples is used. Table 5-13 presents the factor loadings. The variance contributions of factor F_{i1} and F_{i2} are 51.7% and 48.3% respectively. Two spatial patterns of the in-

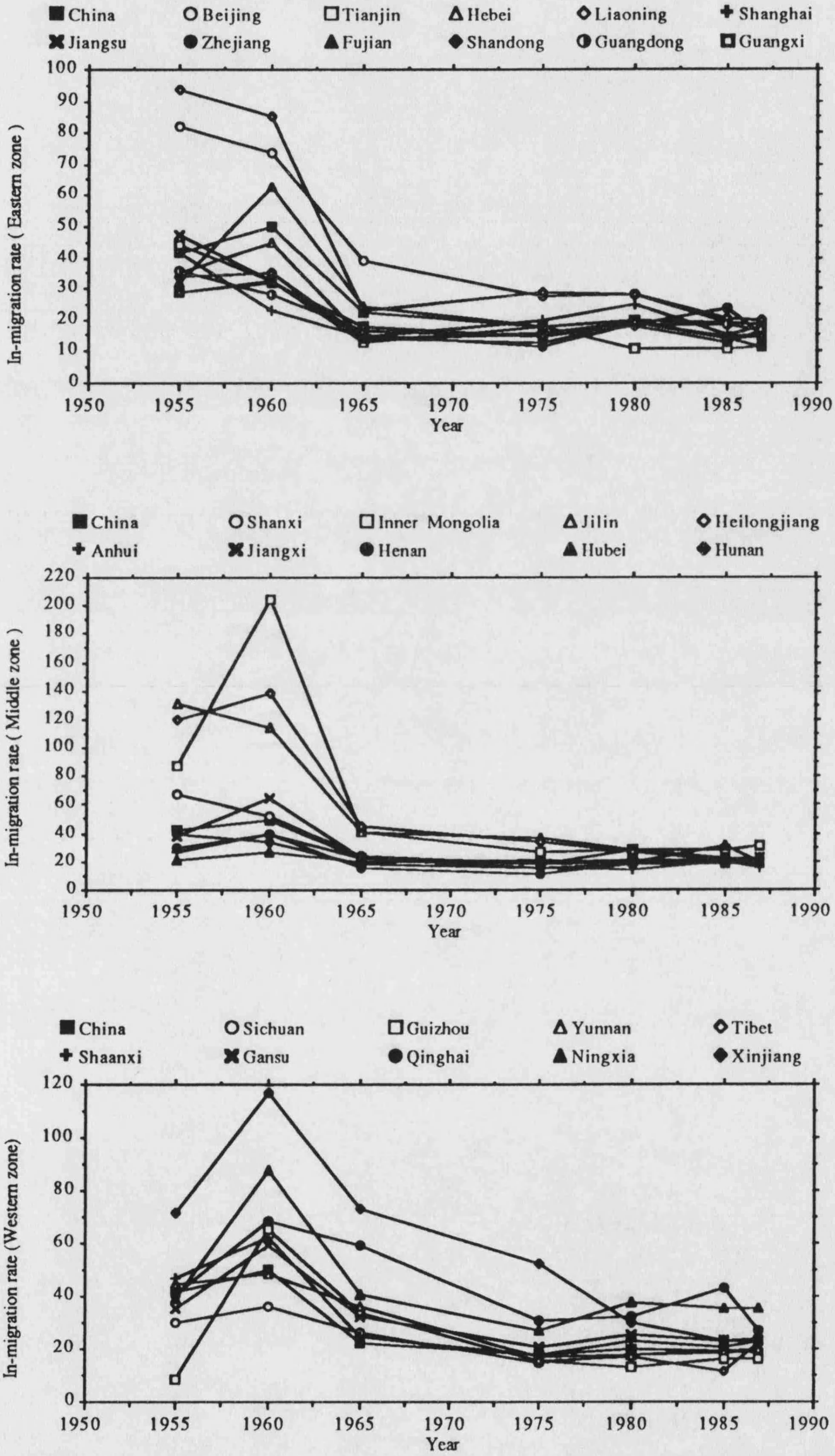


Figure 5-9 Trends in regional in-migration rates in China, 1955-1987

Table 5-11 Coefficients of variation of the regional in-migration rates

Year	A (29 samples)			B (28 samples)		
	Mean (‰)	Standard deviation (‰)	Coefficient of variation (%)	Mean (‰)	Standard deviation (‰)	Coefficient of variation (%)
1955[a]	49.35	29.44	59.64	49.35	29.44	59.64
1960[a]	62.15	40.55	65.24	62.15	40.55	65.24
1965[a]	27.94	14.73	52.72	27.94	14.73	52.72
1975	20.96	8.97	42.80	21.17	9.07	42.83
1980	22.12	6.33	28.60	22.32	6.36	28.48
1985	20.33	7.02	34.55	20.65	6.93	33.54
1987	19.85	5.15	25.96	19.76	5.22	27.28

Note: a 28 samples in set A excluding Tibet

Table 5-12 Correlation matrices of the regional in-migration rates

Year	1955	1960	1965	1975	1980	1985	1987
A (29 samples)							
1975				1			
1980				0.70	1		
1985				0.44	0.66	1	
1987				0.47	0.74	0.73	1
B(28 samples)							
1955	1						
1960	0.71	1					
1965	0.44	0.67	1				
1975	0.69	0.69	0.85	1			
1980	0.56	0.57	0.64	0.70	1		
1985	0.11*	0.38	0.59	0.43	0.65	1	
1987	0.28*	0.57	0.58	0.49	0.77	0.78	1

Note: * not significant at 0.05 level

Table 5-13 Factor loadings of the regional in-migration rates

Year	Factor loading	
	F_{i1}	F_{i2}
1955	0.925	-0.006
1960	0.808	0.335
1965	0.632	0.585
1975	0.829	0.391
1980	0.542	0.700
1985	0.075	0.940
1987	0.260	0.887

migration rate are revealed by factor F_{i1} and F_{i2} respectively. Factor F_{i1} describes a typical spatial pattern of the in-migration rate in 1955, 1960, 1965, 1975. Factor F_{i2} describes a typical spatial pattern of the in-migration rate in 1980, 1985, 1987. It seems that the spatial pattern of the in-migration rate has gradually changed from F_{i1} to F_{i2} in the period 1955 to 1987. Figure 5-10 shows the typical spatial patterns of the in-migration rate as described by regional factor scores of factor F_{i1} and factor F_{i2} respectively. According to figure 5-10, in the period 1955-1975, those regions with a high in-migration rate were Heilongjiang, Jilin, Inner Mongolia and Xinjiang. These regions are located in the north of China. They have low population densities and the most undeveloped arable land in China. A substantial proportion of the migrations to these regions were organized by the government to develop agricultural and natural resources there. In this period, Sichuan, Henan, Hubei, Hunan, Anhui and Zhejiang between the north and south of China had low in-migration rates. In the period 1980-

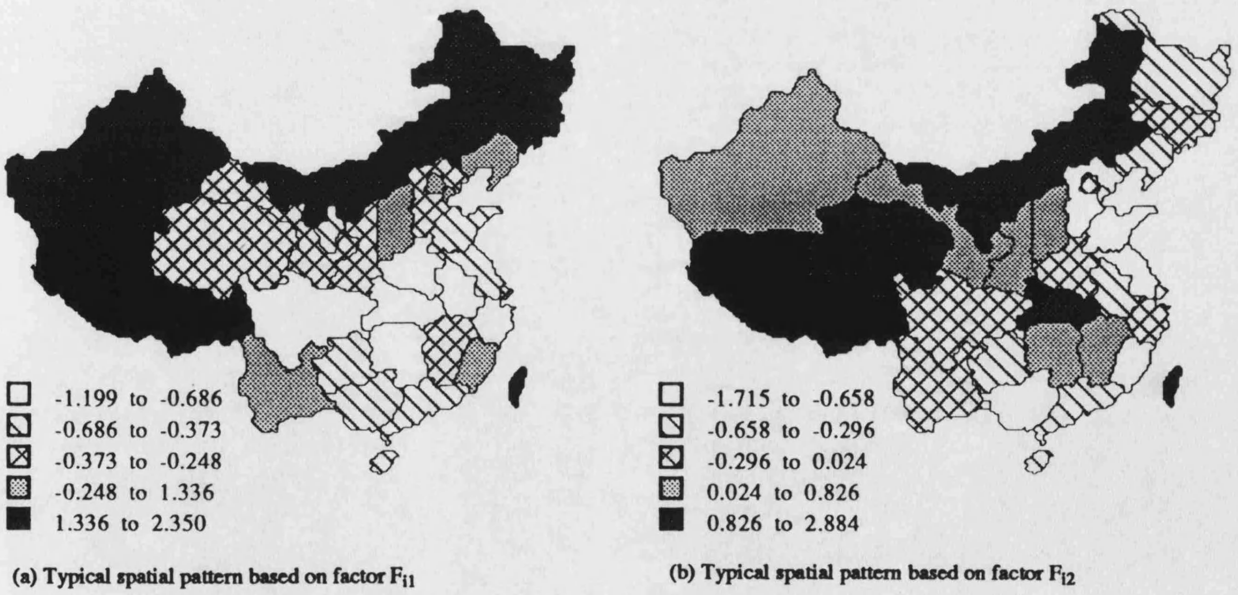


Figure 5-10 Spatial patterns of in-migration rates in China

1987, in-migrations to Heilonjiang, Jilin and Xinjiang become more moderate. Inner Mongolia still had a high in-migration rate. In addition, Hubei, Ningxia and Qinghai also had high in-migration rates. In the period 1980-1987, several regions along the coast had low in-migration rates. These regions are Hebei, Tianjin, Shandong, Jiangsu, Shanghai, Fujian and Guangxi. Note that Hebei, Tianjin, Jiangsu and Guangxi also have low out-migration rats as will be revealed in the following.

There is significant correlation between the in-migration rate and the out-migration rate. Table 5-14 presents their correlation coefficients which are all significant at 0.05 level. It is probably due to the fact that majority of these migrations are intra-provincial. These intra-provincial migrations contribute a similar significant value to the regional in-migration and out-migration rates (see chapter seven).

Table 5-14 Correlation coefficients of the in-migration and out-migration rates

Year	1955[a]	1960[a]	1965[a]	1975[b]	1980[b]	1985[b]	1987[b]
R	0.88	0.86	0.92	0.97	0.94	0.94	0.92

Note: a 28 samples
b 29 samples

Figure 5-11 shows the trends of the regional out-migration rates in the period 1955-1987. These trends are quite close to those of the regional in-migration rates (figure 5-9). Most regions had peaks of out-migration rates in the year 1960, then their migration rates declined to low levels in 1965. However, the out-migration rates in Beijing, Tianjin, Liaoning and Shanghai in the eastern zone, Shanxi, Jilin and Heilongjiang in the middle zone have declined since 1955. These trends are consistent with the national trend in the decline of the migration level. For China as a whole, the out-migration rate declined rapidly from 40‰ in 1955 to 23‰ in 1966, then decreased slowly to 16‰ by 1987. There is a similar decreasing trend of the spatial variation in out-migration rates. Table 5-15 presents the coefficients of variation of out-migration rates. The coefficient of variation declined rapidly from 62% in 1955 to 39% by 1965, then slowly to 27% in 1987 based on the results of set A. This is resulted from the fast decline of out-migration rates in those regions with high migration levels. It seems that the spatial pattern of the out-migration rate is stable as most correlation coefficients in table 5-16 are significant at 0.05 level. All insignificant correlation coefficients are related to the year 1955. It seems that the current spatial pattern of the out-migration rates have been formed since 1960.

One factors F_0 is extracted using the factor analysis method. The data set of 28

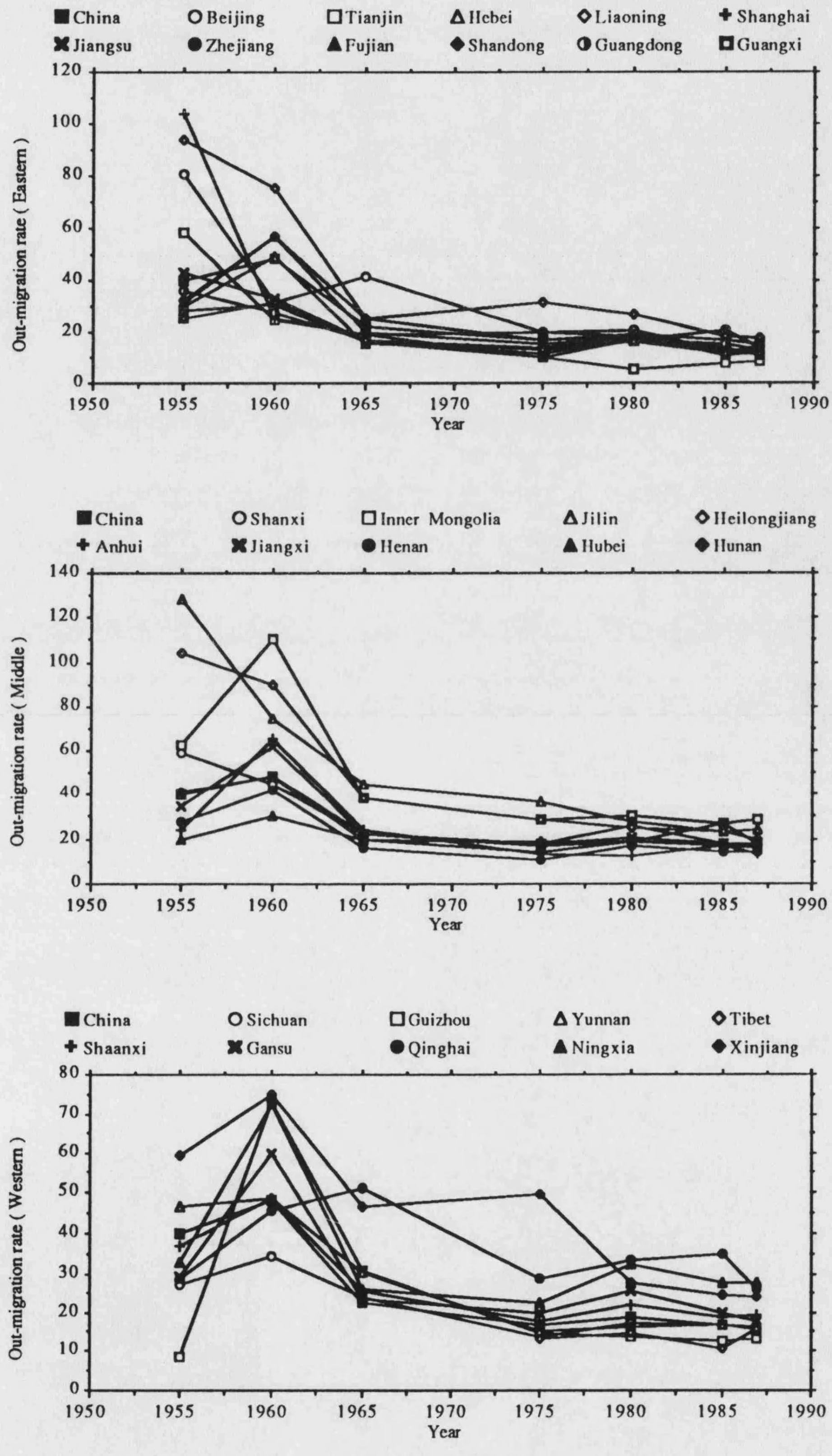


Figure 5-11 Trends in regional out-migration rates in China, 1955-1987

Table 5-15 Coefficients of variation of the regional out-migration rates

Year	A (29 samples) Mean (‰)	Standard deviation (‰)	Coefficient of variation (%)	B (28 samples) Mean (‰)	Standard deviation (‰)	Coefficient of variation (%)
1955[a]	47.71	29.45	61.73	47.71	29.45	61.73
1960[a]	52.36	21.41	40.89	52.36	21.41	40.89
1965[a]	26.28	10.22	38.91	26.28	10.22	38.91
1975	19.32	8.95	46.33	19.54	9.03	46.23
1980	20.57	6.30	30.64	20.76	6.33	30.48
1985	17.80	6.26	35.16	18.04	6.23	34.54
1987	16.87	5.17	26.71	16.90	5.26	31.11

Note: a 28 samples in set A

Table 5-16 Correlation matrices of the regional out-migration rates

Year	1955	1960	1965	1975	1980	1985	1987
A (29 samples)							
1975				1			
1980				0.73	1		
1985				0.60	0.79	1	
1987				0.70	0.87	0.87	1
B(28 samples)							
1955	1						
1960	0.26*	1					
1965	0.42	0.53	1				
1975	0.56	0.60	0.78	1			
1980	0.32*	0.56	0.61	0.73	1		
1985	0.05*	0.45	0.59	0.59	0.79	1	
1987	0.21*	0.64	0.65	0.70	0.88	0.88	1

Note: * not significant at 0.05 level

Table 5-17 Factor loadings of the regional out-migration rate factor F_o

Year	1955	1960	1965	1975	1980	1985	1987
Factor loading	0.439	0.725	0.822	0.886	0.898	0.819	0.920

samples is used. Table 5-17 presents the factor loadings. Figure 5-12 show the typical spatial pattern of out-migration rates as described by regional factor scores of factor F_o. The original variance contribution of factor F_o is 64.3%. Factor F_o describes the typical spatial pattern of out-migration rates as it is significantly correlated with out-migration rates every year. A region may have a high out-migration rate if its factor score of F_0 is high. According to figure 5-12, Jilin and Inner Mongolia in the middle zone, Xinjiang and Qinghai in the western zone usually have high out-migration rates. Actually, these regions usually have high in-migration rates too. Tianjin, Hebei, Jiangsu, Guangdong and Guangxi in the eastern zone, and Henan in the middle zone usually have low out-migration rates.

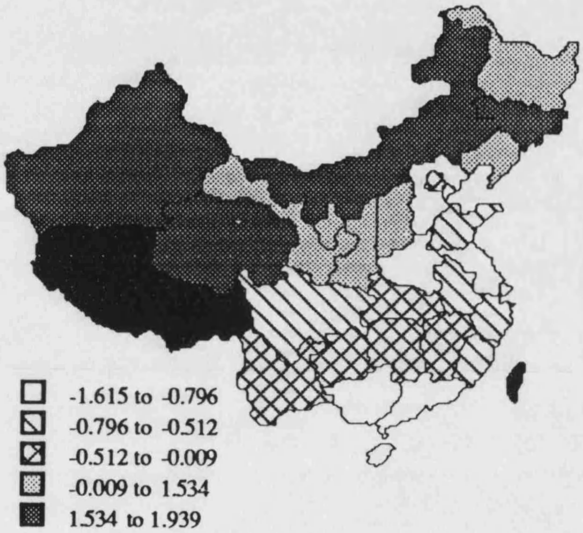


Figure 5-12 Typical spatial pattern of out-migration rates based on factor F_0 in China

Unlike the spatial pattern of the in-migration rate, there is no gradual change of the spatial pattern of the out-migration rate. The fact is compatible with the findings of other migration studies that in-migration is susceptible to economic opportunities while the out-migration is mainly determined by the demographic state of the population concerned (Lowry, 1966).

Figure 5-13 shows the rends in regional net migration rates in the period 1955-1987. It is quite clear that net migrations have been reduced to low levels in most regions since 1965 along with the decline of the in-migration and out-migration rates. The absolute regional differentials in net migration rates have been quite small since then.

The trend of the spatial variation of net migration rate will be analyzed in terms of its standard deviation. The mean net migration rate weighted by population is theoretically

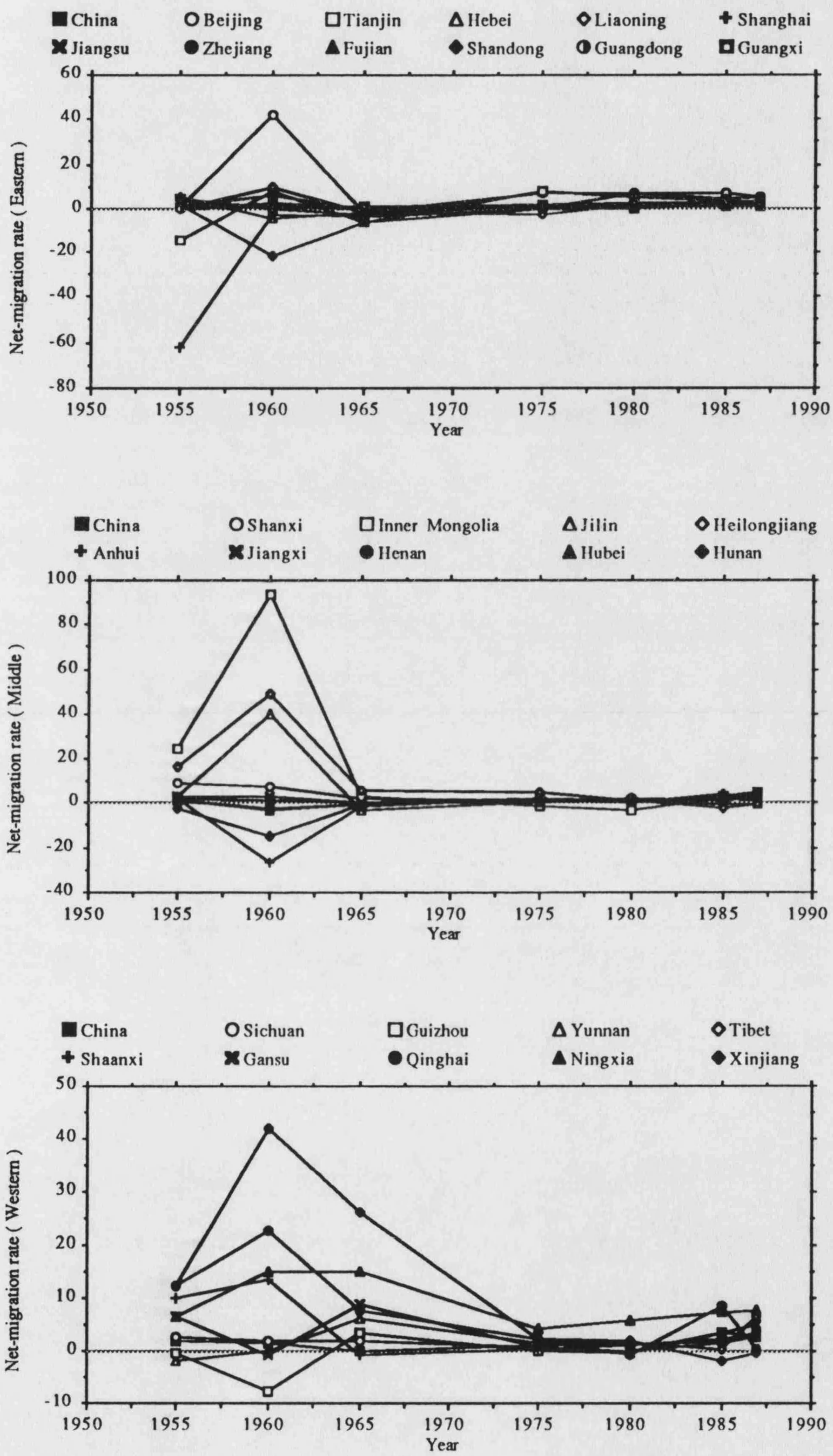


Figure 5-13 Trends in regional net migration rates in China, 1955-1987

zero if the external migration is negligible. Thus its coefficient of variation cannot be calculated. Table 5-18 presents the standard deviation of the net migration rates over time. It seems that there is a decreasing trend of the spatial variation of the net migration rate. The standard deviation of the net migration rates declined dramatically from 25‰ in 1960 to 7‰ in 1965, and has remained at about 2‰ since 1975. However, it may be more interesting to examine the regional net migrations in the period 1955-1965. In 1955, Tianjin and Shanghai had high net out-migration rates when many skilled people there moved out to support construction projects in other parts of the country. In 1960, many regions had significant in-migrations. These regions include Beijing in the eastern zone, Inner Mongolia, Jilin and Heilongjiang in the middle zone, Qinghai and Xinjiang in the western zone. On the other hand, Shandong in the eastern zone, Anhui and Hunan in the middle zone, and Guizhou in the western zone had significant net out-migrations in 1960. In 1965, Xinjiang maintained a high net in-migration rate while net migration rates in other regions had already declined to low levels.

Table 5-18 Standard deviation of the regional net migration rates (‰)

Year	A (29 samples)	B (28 samples)
1955[a]	14.29	14.29
1960[a]	24.62	24.62
1965[a]	6.68	6.68
1975	2.15	2.19
1980	2.24	2.28
1985	2.35	2.35
1987	2.05	1.97

Note: a 28 samples in set A

Table 5-19 is composed of the correlation matrices of the net migration rate. The spatial pattern of the net migration rate is not stable as most correlation coefficients are not significant at 0.05 level. In addition, no dominant typical spatial pattern of net migration rates can be extracted using the factor analysis method. This is similar to the case of the regional death rates. The net migration rate is the difference between the in-migration and out-migration rates. The spatial pattern of net migration rates may change from time to time under the influences of various factors including random factors.

Previous discussions on regional trends in migrations are based on migration data including both intra- and inter-provincial migrations. Migration data collected by 1% population sample survey in 1987 separated the inter-provincial migrations from the intra-provincial migrations. These data are used next to examine the recent trends in the

Table 5-19 Correlation matrices of the regional net migration rates

Year	1955	1960	1965	1975	1980	1985	1987
A (29 samples)							
1975				1			
1980				0.57	1		
1985				0.23*	0.27*	1	
1987				0.16*	0.41	0.52	1
B(28 samples)							
1955	1						
1960	0.41	1					
1965	0.37	0.33*	1				
1975	0.03*	0.10*	0.10*	1			
1980	-0.56	-0.04*	-0.05*	0.57	1		
1985	-0.22*	-0.17*	-0,06*	0.24*	0.28*	1	
1987	-0.37	-0.37	-0.09*	0.16*	0.44	0.62	1

Note: * not significant at 0.05 level

Table 5-20 Coefficients of variation of the inter-provincial in-migration rates (%)

Year	1983	1984	1985	1986	1987
Coefficient of variation	90.33	93.91	102.46	100.11	103.98

inter-provincial in-migration rates. The in-migration rates of 28 mainland provinces except Tibet in 1983, 1984, 1985, 1986 and 1987 are calculated. Here 1983 refers to the period from mid-1982 to mid-1983 , and so on. Table 5-20 presents the coefficients of variation of the inter-provincial in-migration rate. It seems that there is little increase of the spatial variation of the inter-provincial in-migration rate in this short period from mid-1982 to mid-1987. Table 5-21 presents the correlation matrix. It is clear that the spatial pattern of the inter-provincial in-migration rate is stable as all correlation coefficients are significant at 0.05 level.

One factor F_{im} is extracted using the factor analysis method. Table 5-22 presents the factor loading. The original variance contribution of factor F_{im} is 89.3%. Factor F_{im} describes the typical spatial pattern of the inter-provincial in-migration rate in the period from mid-1983 to mid-1987. Regional factor scores of factor F_{im} are used in figure 5-14 to display the typical spatial pattern of the inter-provincial in-migration rate in the period from mid-1982 to mid-1987. According to figure 5-14, a number of regions in

Table 5-21 Correlation matrix of the inter-provincial in-migration rates

Year	1983	1984	1985	1986	1987
1983	1				
1984	0.80	1			
1985	0.81	0.93	1		
1986	0.83	0.85	0.97	1	
1987	0.76	0.77	0.94	0.98	1

Table 5-22 Factor loadings of the inter-provincial in-migration rate factor F_{im}

Year	1983	1984	1985	1986	1987
Factor loading	0.887	0.921	0.986	0.983	0.943

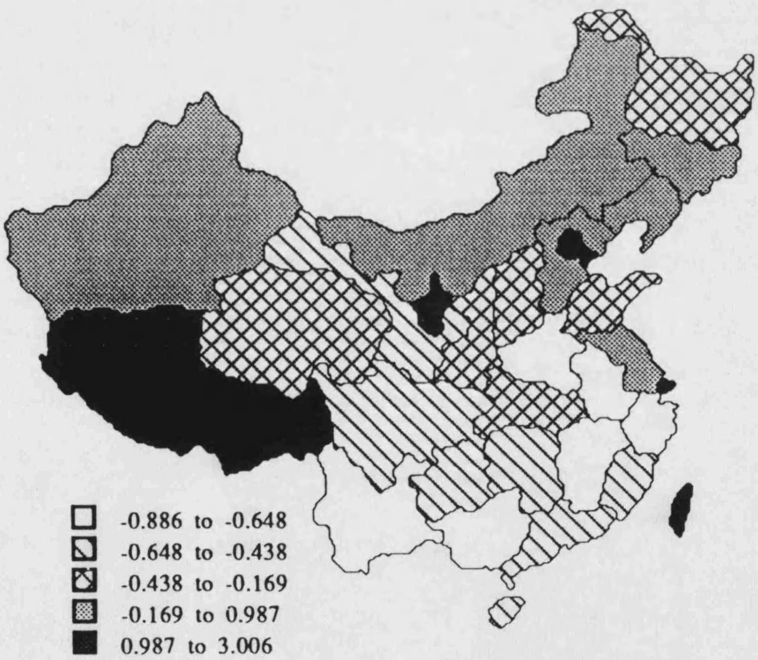


Figure 5-14 Typical spatial pattern of inter-provincial in-migration rates based on factor F_{im} in China

the east and north of China have high inter-provincial in-migration rates. These regions include Beijing, Tianjin, Hebei, Liaoning, Shanghai and Jiangsu in the eastern economic zone, Inner Mongolia and Jilin in the middle economic zone, Ningxia and Xinjiang in the western economic zone. On the other hand, Zhejiang and Guangxi in the eastern zone, Henan, Anhui and Jiangxi in the middle zone, and Yunnan in the western zone have low inter-provincial in-migration rates. This pattern is different from the pattern based on the in-migration factor F_{i2} which includes both inter- and intra-provincial migrations for the period 1980-1987. Their difference lies in the effects of intra-provincial in-migration rates.

5.6 The trend and the stability of population distribution 1957-1990

This section discusses the population distribution trend and stability in period 1957-1990 in terms of population density. Regional population density data for 1957, 1965, 1970, 1975, 1980, 1985 and 1990 are used. All spatial series except 1957 consist of 29 mainland provinces. The population density of Ningxia in 1957 is not available so that there is only 28 samples in 1957. All data are used in the set A calculation. The same group of 28 samples except Ningxia is used in the set B calculation.

Figure 5-15 shows the trends in regional population density in China in the period 1957-1990. Population density has been increasing in most regions over this period. However, there is little change in the ranks of regional population density. Shanghai remains the region with the highest population density while Tibet, Qinghai and Xinjiang have the lowest population density.

Table 5-23 presents the coefficients of variation of population density. The trends of the spatial variation of set A and set B are quite similar. According to set A result,

Table 5-23 Coefficients of variation of the regional population density

	A (29 samples)			B (28 samples)		
Year	Mean	Standard deviation	Coefficient of variation (%)	Mean	Standard deviation	Coefficient of variation (%)
1957[a]	179	212	118.4	179	212	118.4
1965	219	321	146.3	225	325	144.1
1970	237	315	133.0	244	319	131.0
1975	263	325	123.6	270	328	121.7
1980	279	346	123.7	287	350	121.9
1985	297	367	123.6	305	371	121.9
1990	324	402	124.2	332	407	122.5

Note: a 28 samples in set A

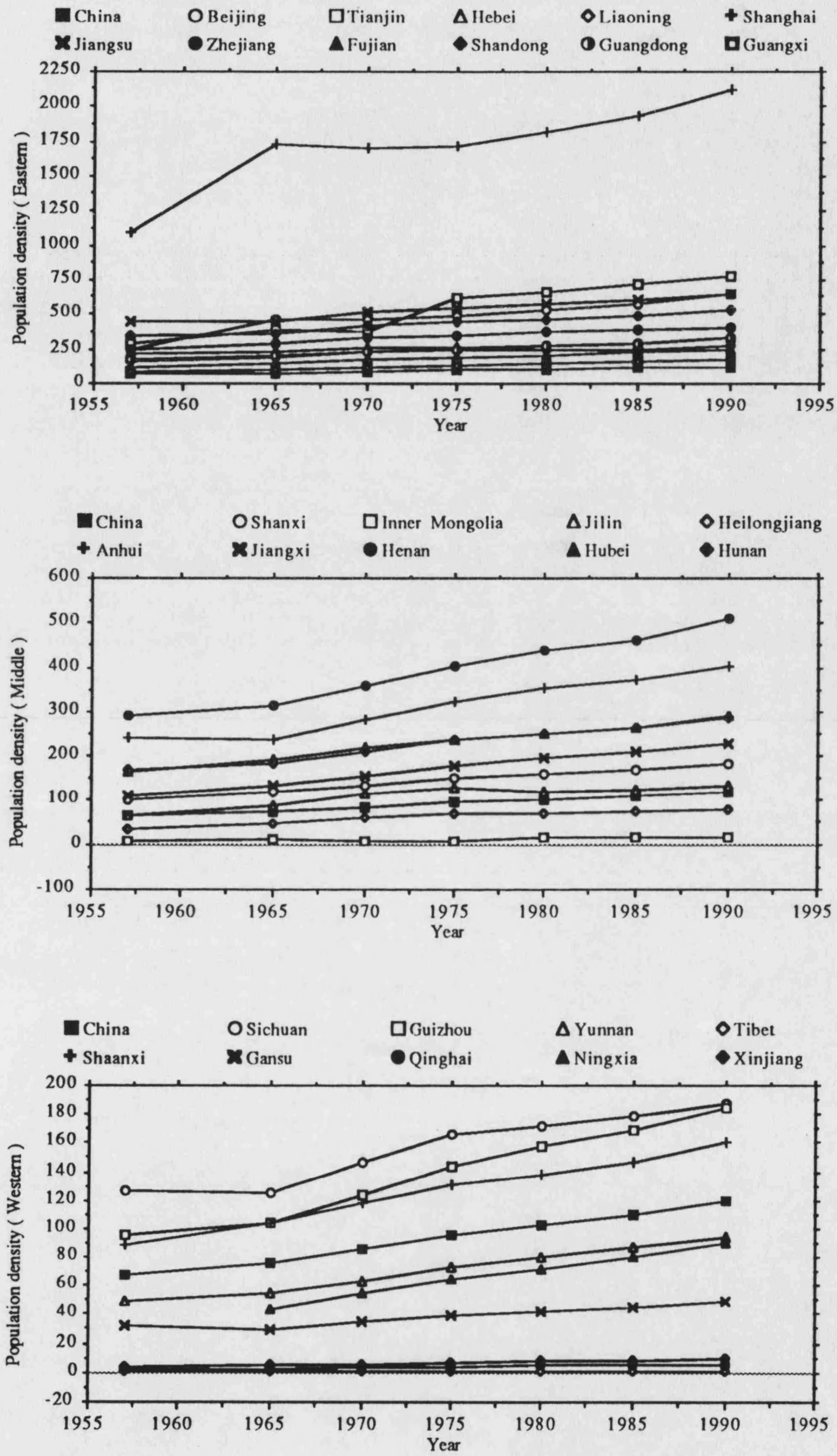


Figure 5-15 Trends in regional population density in China, 1957-1990

the coefficient of variation of population density increased from 118.4% in 1957 to 146.3% in 1965, decreased to 123.6% in 1975 and changed little afterwards. The spatial variation of population density is five to ten times more than those of birth rate, death rate and natural increase rate. The spatial variation of population density increased from 1957 to 1965 probably due to the rapid increase of population density in Shanghai in that period. It decreased gradually in period 1965-1975 as some developed regions with high population density slowed down their population growth rates. The spatial variation of population density has changed little since 1975 as the decline of fertility spread into other parts of the country.

Table 5-24 presents the correlation matrices of population density. It seems, as expected, that the spatial pattern of population distribution is stable as spatial series of population density are correlated significantly. The spatial pattern of population density is much more stable than any of the other spatial patterns of birth rate, death rate and natural increase rate as these indicators have less spatial variation and have only limited effects on the change of the spatial distribution of population which has greater spatial variation.

Table 5-24 Correlation matrices of the regional population density

Year	1957	1965	1970	1975	1980	1985	1990
A (29 samples)							
1965		1					
1970		0.99	1				
1975		0.99	0.99	1			
1980		0.99	0.99	1	1		
1985		0.99	0.99	1	1	1	
1990		0.99	0.99	1	1	1	1
B(28 samples)							
1957	1						
1965	0.98	1					
1970	0.99	1	1				
1975	0.99	0.99	0.99	1			
1980	0.98	0.99	0.99	1	1		
1985	0.98	0.99	0.99	1	1	1	
1990	0.98	0.99	0.99	1	1	1	1

One major factor F_p is extracted using the factor analysis to describe the typical spatial pattern of population distribution. The data set of 29 samples in 1965, 1970, 1975, 1980, 1985 and 1990 is used. Table 5-25 presents the factor loading. The original variance contribution of factor F_p is as high as 99.5%. Factor F_p is correlated significantly with population density every year. Regional factor scores of factor F_p are used in figure 5-16 to display the typical spatial pattern of population distribution in China, which is almost identical to the spatial pattern of population density in 1990 (figure 5-3a).

Table 5-25 Factor loadings of the regional population density factor F_p

Year	1965	1970	1975	1980	1985	1990
Factor loading	0.995	0.995	0.999	0.999	0.999	0.999

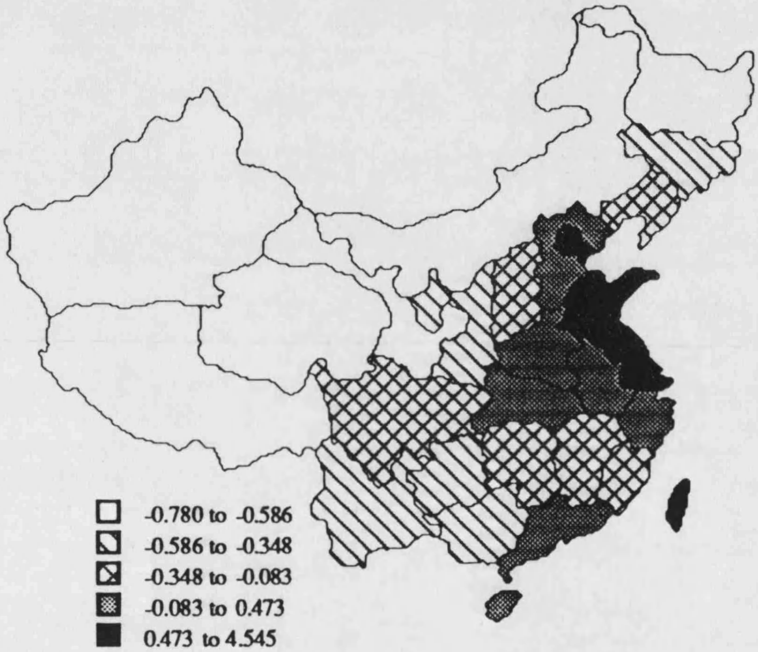


Figure 5-16 Typical spatial pattern of population density based on factor Fp in China

5.7 Conclusion

A brief discussion of the theory of multiregional population systems and a brief review of empirical studies of spatial population changes and projections in the world and in China in particular introduced this chapter. In section 5.2, the spatial variations of China's population have been examined in various dimensions: population distribution, household scale, population composition, components of population change.

The distributions of the total population and the national minority population are two fundamental features in China. They reflect the vital effects of natural conditions on the growth and distribution of human populations. The eastern economic zone has been able to sustain a high level of population density due to its rich agricultural resources. The distribution of national minority population is the result of historical evolution. The national minority population in the western part of China may have been subjected to less influence of the mainstream culture in the eastern and middle parts of China and are able to maintain their own identities. As a result, the eastern economic zone has high population density but a low proportion of national minorities. The western economic zone has low population density but a high proportion of national minorities.

The spatial variations of other demographic indicators are related to the differences in the levels of economic development. The eastern economic zone is the most developed zone in China. Thus its urbanization and industrialization levels are the highest. Its population has good education but low mortality rate. Its birth and natural increase rates are low. Thus its proportion of elderly population is relatively high and the average household scale is small. The situation is reversed in the western economic zone. The middle economic zone has exactly the middle situation between the eastern and western zones. One important exception is that the eastern zone has net in-migrations while the rest two zones have net out-migrations. Detailed regional variations of various demographic indicators are also examined in map form.

Family planning was gradually introduced in urban areas in the 1960s and rural areas in the 1970s in China. The birth rate of China began to decline slowly after 1963 and rapidly after 1970. By the year 1980, the birth rate in China was as low as 18‰. With the introduction of economic reforms, the family planning policy has been somewhat relaxed. The birth rate increased slightly to around 21‰ by the year 1990 with small fluctuations.

The decline of birth rates took place in all regions in the period 1965-1978. Beijing, Tianjin and Shanghai in the eastern economic zone lead the way in the decline of the birth rate. In some regions such as Sichuan, Shaanxi and Xinjiang in the western economic zone, Shanxi and Henan in the middle economic zone, significant decline of birth rates did not happen until 1972. In the eastern economic zone, the rates of the birth rate decline were close in the period 1965-1972 and 1972-1978. However, in most regions in the middle and western economic zone, birth rates declined much faster in the period 1972-1978 than in the previous period 1965-1972. However, birth rates in Tibet, Guizhou and Yunnan in the western economic zone, and Jiangxi in the middle economic zone did not decline fast even in the 1970s.

More flexible family planning policy has been adopted in China since the early 1980s. Most regions recorded increases in birth rate from 1978 to 1981. In the period 1981-1990, all regions in the eastern zone except for Fujian, plus Inner Mongolia, Heilongjiang in the middle economic zone and Guizhou, Yunnan, Qinghai , Ningxia and Xinjiang in the western zone had slight decreases in their birth rates. The birth rates in other regions either increased slightly or were stable in the same period.

The national death rate of China decreased gradually from 20 ‰ in 1949 to 6.7‰ in 1990 except for an upturn during the 'Socio-economic crisis' around 1960. A number of regions recorded a rapid decline of death rates in the first period 1954-1957. These regions include Jiangsu, Zhejiang, Guangdong and Guangxi in the eastern zone, Shanxi, Anhui, Jiangxi, Hubei and Hunan in the middle zone, and Sichuan in the western economic zone. Regional death rates declined more slowly in most regions over the period 1957-1978 and have been stable since 1978. By the year 1954, Shanghai already had a low death rate of 7.12‰, it further declined to 5.57‰ in 1972, then increased slowly to 6.36‰ by 1990 mainly due the ageing of its population. For China as a whole, such process may take place in the next century.

After the foundation of the People's Republic of China, the government gradually introduced a series of measures to control migration especially the rural to urban migration. The scale of migration flow has been significantly reduced since the early 1960s. Most regions follow the national trend. But most rapid decline of in-migration rates occurred in those regions which had high in-migration rates before 1960. These regions including Beijing and Liaoning in the eastern zone, Inner Mongolia, Jilin and Heilongjiang in the middle zone, Ningxia and Xinjiang in the western zone had massive in-migrations in the 1950s.

The trends of the regional out-migration rates in the period 1955-1987 are quite close to those of the regional in-migration rates. Most regions had peaks of out-migration rates in the year 1960, then their migration rates declined to low levels by 1965. Net migrations have been reduced to low levels in most regions since 1965 along with the decline of the in-migration and out-migration rates. The absolute regional differentials in net migration rates have been quite small since then.

In the period 1957-1990, population density has been increasing in most regions. However, there is little change in the ranks of regional population density. Shanghai remains the region with the highest population density while Tibet, Qinghai and Xinjiang have the lowest population density.

A systematic study of the trends of the spatial variation and the stability of the spatial patterns of major population indicators of China since 1950s has also been carried out. A number of findings are obtained with regard to the trends of the spatial variation and stability of spatial patterns of regional birth rates, death rates, migration rates and population density in China.

Firstly, the coefficient of variation is used to measure spatial variation. The spatial variation increases in order from death rate, birth rate, natural increase rate to inter-provincial out-migration rate, inter-provincial in-migration rate and finally to population density using various data in 1987 and 1990 respectively. The spatial variation of population density is the greatest of all these population indicators.

Secondly, the spatial variation of the birth rate increased in the period 1957-1978 as some regions were leading the way in the decline of fertility. It decreased from 1978 to 1981 and has been stable over the period 1981-1990. The spatial variation of the death rate decreased in the period 1954-1990 as death rates decreased all over the country. The spatial variation of the in-migration rate, the out-migration rate and the net migration rate decreased in the period 1955-1987 with the overall decline of the migration levels since 1960. The spatial variation of the inter-provincial in-migration rate was stable in the period from mid-1982 to mid-1987. The spatial variation of population density increased from 1957 to 1965, decreased gradually in the period 1965-1985 and changed a little from 1985 to 1990.

Thirdly, correlation matrices are used to examine the stability of spatial patterns. There is a change of the spatial pattern of birth rates between 1957 and 1965. The spatial pattern of birth rates has been stable since 1965. The spatial pattern of death rates is stable in the period 1954-1990. There is a gradual change of the spatial pattern of in-migration rates between 1975 and 1980. The spatial pattern of out-migration rates is stable in the period 1955-1987. The spatial pattern of the net migration rate is not stable in the period 1955-1987. However, the spatial pattern of population density is stable in the extreme in the period 1957-1990.

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6
Fertility and mortality analysis

6.1 Introduction

This chapter attempts to analyse the causes of the regional differences in fertility and mortality with an emphasis on fertility.(Fertility is a most active factor in determining population growth and distribution in the process of population development. It is also a most direct and important measure of population control.) Taking the national population of China as an example, here the birth rate has been greater than the death rate and migration rate since 1949 which accounts for the continuous trend of population growth in China.

(The natural increase rate of China decreased from 23‰ (one per thousand) in 1953 to 10.81‰ in 1984. The decline of birth rate plays a major role. It was decreased by 1.95 percent points in this period. The direction of the death rate effect is opposite to that of the birth rate. It was decreased by only 0.731 percent points. The positive effect of the birth rate change is much greater than the negative effect of the death rate change in the decline of the natural increase rate. The natural increase rate rose from 10.81‰ in 1984 to 14.39‰ in 1987. The effect of the birth rate change was 0.354 percent points while that of the death rate change was only 0.004 percent point (DPS, 1988b).

With regard to the regional differences in the population dynamics within China, the birth rate also plays a major role. In 1987, natural increase rate was the greatest in Ningxia (23.57‰) while it was the least in Shanghai (9.70‰). The difference in natural increase rate between these two regions was 1.387 percent points. The difference in birth rate was 1.351 percent points while the difference in death rate amounted to only 0.036 of a percent point.

The birth rate is mainly determined by the fertility level though it is also affected by the age and gender compositions of the population concerned. There is no doubt that the fertility level is a major factor and measure in population control. In fact, a number of studies on China's population have been concentrated on China's fertility and birth control policy. Tien (1991) made a detailed analysis on the formation and implementation of family planning policies in China.

Birdsail and Jamison (1983) analyzed the effects of income and other factors on fertility in China. They used three sets of data at province-level, prefecture-level and county-level respectively for the 1970s. It was concluded that differences in level of development across regions of China are associated with differences in fertility levels. Fertility is lower in high-income regions. A rural income variable alone accounts for as much as 45% of the variation in crude birth rates within one province. They suggested that income is highly correlated with a number of other variables, such as the educational level, wage rates and employment opportunities for women, which influence fertility more directly by raising the 'price' of children to parents.

A time series of fertility data in provinces of China 1940-1982 has been made available (Coale and Chen, 1987). These data were used by Yang (1991) in an analysis of fertility change in rural China. Peng (1991) made a detailed documentation and analysis of fertility change in urban and rural China as well as in each province also using these data. He pointed out that China's fertility decreased by more than 50% in the 1970s. But changes did not occur homogeneously across the country. The fertility in urban areas generally began to decline around the mid-1960s in all provinces. The fertility in rural areas in most provinces only began to decline in the early 1970s. Peng further considered the major determinants of China's fertility transition. He concluded that China's fertility transition has been, by and large, not a natural process, but rather an induced one. The overall fertility decline was brought about, or at least speeded up, by the government's determined efforts on population control. Furthermore, it was found that fertility transition was closely associated with socio-economic development. But the impact of socio-economic development on fertility differs over time. This may be due to the increasing strength of the government intervention over the 1970s.

Feeney, Wang, Zhou and Xiao (1989) discussed the recent fertility trends in China using the 1% population sampling survey data in 1987. It seems that most studies are about the fertility trend and its spatial variation in China (Hull, 1990). However, few studies have been made to analyze the effect of various factors on fertility in China.

A log-linear additive model was used by Peng (1991) to examine the effects of various factors on mean parity (the number of children produced by a woman) in China using the 1982 national fertility survey data. Two types of models were fitted. Three variables including educational level, type of residence (urban or rural) and province location were considered in the first type of models. In the second type of models, occupation, type of residence and province location were considered. Theoretically, the effect of one variable can be separated from other variables in each type of models. Two sets of estimations of the effects of the type of residence and the province location on fertility were estimated by two types of models. They are generally close. However, these models were not able to separate the effects of educational level and occupation on fertility. His main findings are that mean parities of women with higher middle school plus education are 29% lower than those illiterate ones for the 35 age cohort and that urban women aged 35 are estimated to have 30% fewer children than rural women.

An in-depth fertility survey was carried out in Shaanxi, Hebei and Shanghai in 1985 and detailed data were collected (DPS, 1986a). The main findings from this survey were summarized in a report (DPS, 1986b). The report covers various topics including nuptiality, fertility, child survivorship and child health care, fertility preferences and contraception. With regard to fertility, the report focused on the description and discussion of a variety of measures of fertility obtained from the detailed birth and marriage history information collected during the surveys. It does reveal long standing differences in fertility between Shaanxi, Hebei and Shanghai. Women began childbearing in the early 1950s (these women now aged 45-49) have an average of 5.0 children in Shaanxi, 4.5 in Hebei and only 2.8 in Shanghai. Fertility decline took place earlier in Shanghai than in Hebei and Shaanxi. By the year 1970, Shanghai already had a total fertility rate below 2.0. Dramatic decline of fertility in Hebei and Shaanxi only took place in the 1970s. In the early 1980s (1980-1983), fertility has fluctuated around the low levels achieved in the last decade.

The span of childbearing has become much narrower. In the 1980s, 75-80% of the total fertility took place in the age group 20-29 in these regions. The age of first birth has also been increased. The incidence of having first birth before the age of 20 has significantly decreased to 7% in Shaanxi, 4% in Hebei and to negligible level in Shanghai. More and more women are foregoing or at least postponing their second birth. Among the women who married in the second half of the 1970s, 80% didn't have a second birth in Shanghai and 20% in Shaanxi and Hebei.

Section 6.2 attempts to use the detailed fertility data collected during this survey to make an analysis of the effects of various factors---social, economic, cultural and education, geographic factors and the family planning policy on the fertility level in order to understand the determinants of population growth and distribution in China. In section 6.2.1, some theoretical considerations will be discussed with regard to the measures of the fertility level and the variety of approaches in fertility analysis. An empirical comparative analysis of fertility levels will be carried out subsequently. Cross-sectional analyses of the regional birth rate and the death rate will be undertaken in sections 6.3 and 6.4 respectively and some conclusions follow.

6.2 Comparative analysis of fertility levels

6.2.1 Theoretical considerations of fertility level analysis

This section discusses some theoretical considerations with regard to the measures of the fertility level and the approaches of fertility analysis. Theoretically, the fertility level can be measured by the total number of children produced by a woman in her whole life. Nevertheless, this measure is difficult to use in practice. First, data of this kind of fertility level are difficult to collect. Second, they cannot represent the fertility level at any specific time as the total number of children of a woman is achieved accumulatively in her whole life. Hence, more commonly used indicators of the fertility level are the total fertility rate and the gross reproduction rate. In the current practice of population survey and statistics provision in China, detailed data on the total fertility rate are not available. In this chapter, the total number of children ever produced by a married woman (NCMW) is used as the indicator of the fertility level. Detailed data on this indicator were collected in the in-depth fertility survey in 1985. There are two shortcomings in using this indicator. First, those woman below age of 49 have not completed their childbearing process. Second, this indicator cannot represent current fertility level completely as some childbearing events actually occurred many years ago. Nevertheless, the indicator NCMW is valid enough to be used in a comparative analysis to reveal the effects of various factors on fertility level.

Many population studies have found that populations with different socio-economic characters have different fertility level. Day (1983) used a set of detailed Australian data to examine the fertility differences among population groups and the forces that underlie fertility behaviour in general. The prime indicator of fertility in his inquiry is the number of children born within the current marriage to married women 40 or more years of age at the date of the census whose current marriage began before age 26. This indicator represents the desired levels of fertility --- or at least of the levels of fertility individual married women have been willing to accept. It excludes the effects of proportions marrying, age at marriage (a proxy for involuntary infecundity) and duration of marriage on fertility differences among population groups. His main findings are as follows. First, fertility differences by generation exist within each sector of the Australian population. Among the Australian-born, the median issue (number of children) declined from the birth cohort of the early 1870s to that of the turn of this century. Then there was a period of leveling off. The median issue increased from the cohort of 1922-6 to that of 1927-31. British-born followed the same pattern though the changes were less extensive. There were continued fertility declines among Italian- Dutch-, Greek- and Yugoslav-born and modest fluctuation around a low level among the German-born from the cohort of 1907-11 to that of 1927-31. Second, there are significant differences among sectors within cohorts. Rural-dwellers have more children than city-dwellers; Catholics more than non-Catholics, the Dutch-born more, and the German-born fewer, than those born elsewhere. Those with more schooling have fewer children than those with less schooling. However, there have been changes in the nature of these differences. The differences by the years of schooling, by residences and by husband's occupation had narrowed due to the diffusion of control over children.

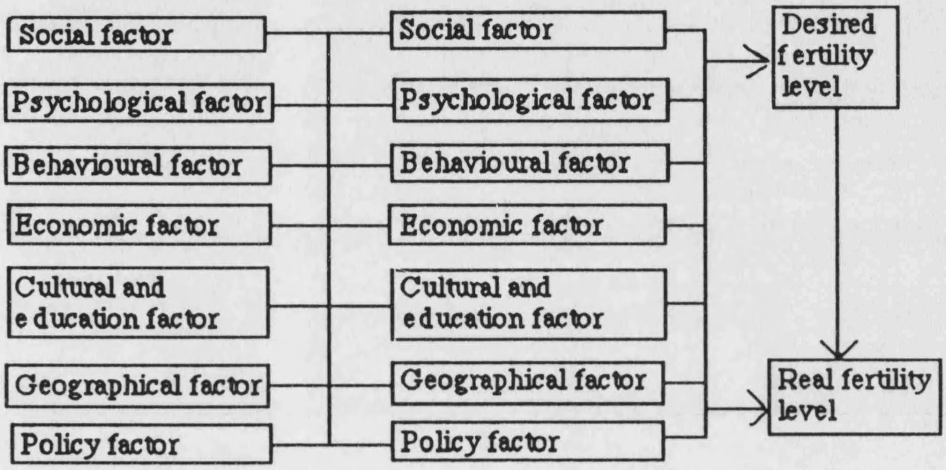
Hu and Zhang (1984) discussed the fertility differentials in China based on population data available in the early 1980s. They pointed out that the rural fertility has always greater than the urban fertility. This is due to the significant difference between the urban and rural societies in China. The rural economy is usually family based and involves much manual labour. Rural people are influenced by the old idea of having large family, having many sons in particular. Hu and Zhang also found significant differentials between people with different educational levels or occupation.

There are many factors which may affect general fertility levels such as social characteristics, psychological and behavioural traits, economic conditions, cultural and educational levels as well as geographical factors and policy effects. Each factor may has some effect on the fertility level. But the strength and the effect of a factor can be different in different regions at different times. There are significant interactions among various factors. The effect of a factor on the fertility level may be constrained by other factors. For example, the effect of family planning policy on fertility in China is constrained by the socio-economic development level in different regions. The family planning policy meets stronger resistance and longer delay of policy implementation in the less developed regions. On the other hand, the family planning policy can be implemented more successfully in more developed regions. As a result, the effect of the family planning policy on fertility levels depends on socio-economic factors as well as other determinants.

The effects of various factors are also influenced by the current fertility level. At the moment, the desired fertility level of a woman (number of children per couple) in China is close to the critical replacement level of total fertility rate which is approximately 2.2 (DPS, 1986b). The family planning policy will have greater effect when the fertility level is substantially over the critical level of total fertility rate.

The collinear problem should also be noted when attempting to analyze the effects of various factors on the fertility level respectively. There may be significant correlation among various factors. For example, in terms of a time series, the social development level and educational level will be raised with increasing levels of economic development. In terms of spatial series, those regions with higher economic levels often have higher social development and educational levels. In this case, it is difficult to distinguish the effects of social, economic and educational factors respectively as they are intercorrelated and affect the fertility level in the same direction. Figure 6-1 is a possible model of factors influencing the fertility level. All factors are interacting each other. The effect of a factor on the fertility level consists of two parts which may be termed direct and indirect components. The former acts on fertility level, or more precisely proximate determinants (see below), directly. The indirect effect takes place via its relation with other factors.

It should be noted that no socio-economic variable can affect fertility directly. Socio-economic variables operate through 'proximate determinants' such as marriage and contraceptive use which have direct effects on fertility. Some significant advances have already been made in the analysis of the effects of proximate determinants on fertility (Hobcraft and Little, 1984). This section is only concerned with the effects of various socio-economic factors on fertility.



Note: the left part of the diagram represents the interaction among various factors

Figure 6-1 A model of the effects of various factors on fertility level

In empirical studies, there are no purely independent indicators of social, economic and geographic conditions. In population statistics, the effects of various factors on fertility levels are often represented by the fertility level (NCMW) difference by urban and rural residence, by region, by education, by occupation, by age at first marriage, by years since first marriage and by age of married women. The relation between statistical indicators and factors affecting fertility levels is not a one to one relation but a multilateral relation. Of course, some relations are much clearer than others and some hypotheses can be postulated. The NCMW difference by urban and rural residence reflects the effects of social, economic and education factors on fertility level. The NCMW difference by region reflects the effects of social, economic, education and geographic factors on fertility level. The NCMW difference by educational level reflects the effect of cultural and education factor directly and the effect of economic factor indirectly. The NCMW difference by age at first marriage reflects the effects of social, education, psychological, behavioural and economic factors. The NCMW difference by years since first marriage reflects social, economic, education and policy factors on fertility level.

6.2.2 NCMW difference by region

Shaanxi is a less developed inland province in west China. Hebei is a medium developed coastal province in north China. Shanghai is a most developed coastal municipality in east China. The populations of Shaanxi and Hebei have similar educational level and age composition. The population of Shanghai has a relatively high educational level and relatively high proportion of elderly population. A comparative analysis of fertility levels in Shaanxi, Hebei and Shanghai will be made in sections 6.2.2-6.2.7 using NCMW as an indicator of fertility level. The NCMW difference by region will be discussed first in this section.

The most developed region (Shanghai) has the smallest number of children per married woman while the least developed region (Shaanxi) has the largest number of children per woman. The NCMW is 2.80 in Shaanxi, 2.45 in Hebei and 1.54 in Shanghai as shown in table 6-1. It is clear that the higher the economic level, the lower the fertility level. The NCMW difference between Shaanxi and Hebei is 0.35. NCMW difference between Hebei and Shanghai is 0.91. As most women aged over 40 have completed their childbearing process, the NCMW difference between cohort 40-44 and cohort 45+ of married women can reflect the scale of fertility level change. This NCMW difference between the two cohorts is larger in the two regions Shaanxi and Hebei with higher fertility level, and smaller in Shanghai with the lowest fertility level. The theoretical discussion in the previous section is confirmed that the lower the fertility level, the smaller the scale of the decline of the fertility level between these age cohorts. With regard to the fertility difference by region, it can be concluded that the higher the

Table 6-1 NCMW by region and urban-rural residence

	Shaanxi	Hebei	Shanghai
Urban	2.38	2.29	1.32
Rural	2.92	2.49	1.82
Total	2.80	2.45	1.54
NCMW difference between cohorts 40-44 and 45+			
Urban	0.48	0.85	0.60
Rural	0.78	0.59	0.38
Total	0.63	0.61	0.49

economic level, the lower the fertility level and that the lower the fertility level, the smaller the scale of fertility level decrease with age.

6.2.3 NCMW difference by urban and rural residence

The variation in regional differences are also clear for urban and rural areas. Table 6-1 also presents the NCMW of urban and rural married women in Shaanxi, Hebei and Shanghai. An average urban married woman in Shanghai has only 1.32 children while the number of children per married woman is well over 2.2 in Shaanxi and Hebei. The NCMW difference of urban married women is 0.09 between Shaanxi and Hebei and 0.97 between Hebei and Shanghai. The NCMW of rural married women in Shaanxi, Hebei and Shanghai are 2.92, 2.49 and 1.82 respectively. The regional difference in fertility level between the two less developed regions Shaanxi and Hebei is more significant in rural areas than in urban areas. The NCMW difference of rural married women is 0.43 between Shaanxi and Hebei and 0.67 between Hebei and Shanghai. The NCMW difference between Hebei and Shanghai of urban married women is greater than that of rural married women. It is noted that the NCMW of urban married women is relatively high in Shaanxi and Hebei ---- even higher than the NCMW of rural married women in Shanghai.

With regard to NCMW difference between cohort 40-44 and cohort 45+ of married women, it is greater in urban areas than in rural areas in Hebei and Shanghai. It means that fertility level decreases more in urban areas than in rural areas. The difference is 0.85 in urban Hebei and 0.59 in rural Hebei. In Shanghai, the difference is 0.60 in urban and 0.38 in rural. Shaanxi is exceptional. The difference is 0.48 in urban and 0.78 in rural areas.

The NCMW difference by urban and rural residence is large in Shaanxi (0.54) and Shanghai (0.50) and small in Hebei (0.20). The urban population proportion data are used to separate the effect of the urbanization level on the fertility level. The proportions of urban and rural populations in Hebei are applied to the urban and rural NCMW in Shanghai respectively. A hypothetical NCMW for Shanghai can be obtained assuming a low urbanization level in Shanghai. This hypothetical NCMW is then compared to the real NCMW in Shanghai. Their difference roughly represents the effect of the urbanization level on the fertility level. It is found that, of the NCMW difference between Hebei and Shanghai, 0.19 resulted from the high urban population proportion in Shanghai. This means that some 20.9% of the regional difference in fertility level between Hebei and Shanghai is explained by the urbanization level and 79.1% is explained by other factors. This figure is close to the estimate of 30% urban-rural difference by Peng (1991) based on the 1982 national fertility survey data in 28 provinces.

6.2.4 NCMW difference by education

Table 6-2 presents the fertility level of women with various educational levels. There is a near perfect negative correlation of fertility level with educational level. In Shaanxi, the NCMW of married women with no education is 3.42, with primary school education it is 2.96, with middle school plus education it is reduced to only 1.67. In Hebei, the NCMW are 2.89, 2.60 and 1.52 for those women with no education, primary school education and middle school education plus respectively. In Shanghai, the NCMW are 2.66, 2.00 and 1.16 respectively. It is clear that education has important effect on fertility level. Those married women with middle school plus education have significantly lower fertility level than those with less education. Compare in addition the women with primary school education and the women with no education, the NCMW is lowered by 0.46 in Shaanxi, 0.29 in Hebei and 0.66 in Shanghai. Compare the women with middle school plus education and the women with primary school education, the NCMW falls impressively by 1.27 in Shaanxi, 1.08 in Hebei and 0.84 in Shanghai. It is clear that the higher the educational level the more the fertility will be decreased. The fact that Shanghai has a low fertility level has much to do with the high educational level of its population. In the case of the women with no education, the NCMW is 2.66 in Shanghai which is quite close to the NCMW in Hebei (2.89). But NCMW of married women with primary school plus education is significantly lower in Shanghai than in Hebei and Shaanxi due to its high development level. It seems that the effect of the economic factor will be operative only when a certain educational level is achieved. If the educational level of Hebei is used to calculate the NCMW in Shanghai, it will be 2.06 which is 0.52 greater than the real NCMW in Shanghai. Thus 57% of the NCMW difference between Shanghai and Hebei is explained by the educational factor and no more than 43% may be explained by the economic factor. Similarly, if the educational level of Shanghai is used to calculate the NCMW in Hebei, it will decrease from 2.45 to 1.95.

Table 6-2 NCMW by educational level

educational level	Shaanxi	Hebei	Shanghai
No education	3.42	2.89	2.66
Primary school	2.96	2.60	2.00
Middle school +	1.67	1.52	1.16

6.2.5 NCMW difference by occupation

Table 6-3 presents the NCMW difference by occupation. It seems that there are significant fertility differentials among women with various occupations. Those women with a high status of occupation often have less children. The NCMW is increased from managers and professionals to industrial workers, service workers and peasants. The NCMW difference between the managers and professionals, and the peasants is 1.01 in Shaanxi, 0.63 in Hebei and 0.83 in Shanghai. With regard to regional differences in the fertility levels of various occupations, the NCMW difference between Hebei and Shanghai ranges from 0.56 in the managers and professionals class to 0.36 for peasants. It needs to be pointed out, of course, that the occupational difference is highly correlated with the differences in education and economic status.

Table 6-3 NCMW by occupation

Occupation	Shaanxi	Hebei	Shanghai	Difference between Hebei and Shanghai
Managers and professionals	2.06	1.86	1.30	0.56
Industrial workers	2.21	1.94	1.40	0.54
Service workers	2.61	2.05	1.54	0.51
Peasants	3.07	2.49	2.13	0.36
Difference between the managers and professionals, and the peasants	1.01	0.63	0.83	

6.2.6 NCMW difference by age at first marriage

The reasons for the NCMW differences by age at first marriage are complex. Elderly women often married at younger age and have experienced a longer childbearing process than younger women in China. Hence, those women who have younger age at first marriage often have greater NCMW. The other reasons for the NCMW difference by age at first marriage are the different social, economic, cultural and educational, and occupational backgrounds. Only the last mentioned factors may have effects on the current fertility level.

Table 6-4 presents the NCMW by age at first marriage. It is clear that the younger the age at first marriage, the greater the NCMW. The NCMW difference between two extreme groups <17 and 26+ of age at first marriage is 3.05 in Shaanxi, 2.83 in Hebei, and 2.16 in Shanghai. It is noted that the higher the fertility level, the larger the NCMW

Table 6-4 NCMW by age at first marriage

Age at first marriage	Shaanxi	Hebei	Shanghai
< 17	4.52	4.49	3.13
17-19	3.30	3.20	2.65
20-22	2.07	2.19	1.77
23-25	1.53	1.75	1.32
26+	1.47	1.66	0.97
Difference between groups <17 and 26+	3.05	2.83	2.16

difference. Hence, the effect of age at first marriage on the fertility level decreases with the fertility level.

6.2.7 Effects of family planning policy on fertility level

It is an interesting and controversial question as what role the family planning policy plays in the recent dramatic decline of fertility levels in China. This section attempts to estimate the effect of family planning policy on fertility level by comparing the desired numbers of children at first marriage whether or not taking into account the family planning policy. The desired number of children is the total number of children that a woman wants to produce in her life. The desired number of children at first marriage is 2.5 in Shaanxi, 2.2 in Hebei and 1.6 in Shanghai taking into account the family planning policy. If the family planning policy is disregarded, the desired number of children at first marriage is 2.7 in Shaanxi, 2.6 in Hebei and 1.8 in Shanghai. Their difference may be regarded as the direct effect of family planning policy on fertility level. It is only 0.2 in Shaanxi and Shanghai and 0.4 in Hebei. It seems then that the direct effect is not particularly significant. But it needs to be pointed out that the family planning policy may also have an indirect effect on the desired number of children at first marriage. This indirect effect may be estimated on the basis of desired numbers of children by various years since first marriage. Strong implementation of family planning in China began about twenty years ago. It may have more effect on those couples who have married more recently. Here, this indirect effect will be roughly estimated by comparing the desired number of children of those women first married in past five years with that of those women first married twenty five years ago. When the family planning policy is disregarded, the desired number of children of those women first married in the past five years is 2.3 in Shaanxi, 2.2 in Hebei and 1.6 in Shanghai. The desired number of children of those women first married twenty five years ago is 3.0 in Shaanxi, 3.6 in Hebei and 2.1 in Shanghai. The difference in fertility level between these two women groups is more impressive. It is 0.7 in Shaanxi, 1.4 in Hebei and 0.5 in Shanghai. The sum of direct and indirect effects of the family planning policy is 0.9 in Shaanxi, 1.8 in Hebei and 0.7 in Shanghai. It seems that the family planning policy has had a significant effect on fertility levels in China. In fact, the dramatic decline of fertility levels in China since 1970s has much to do with the intensive implementation of the family planning policy on a large scale.

Table 6-5 Desired number of children of women at first marriage

	Shaanxi	Hebei	Shanghai
Considering family planning policy			
All women	2.5	2.2	1.6
Disregarding family planing policy			
All women	2.7	2.6	1.8
Women married in past five years	2.3	2.2	1.6
Women married twenty years ago	3.0	3.6	2.1

6.3 Explanatory model of regional birth rate

Sections 6.3 and 6.4 attempt to make an explanatory analysis of regional birth and death rates in China. Explanatory models of regional birth and death rates will be estimated using the cross-sectional data of the 30 mainland provinces in China. Various socio-economic variables will be used in a step-wise regression analysis to establish optimal regression models. An explanatory model of the regional birth rate will be estimated first.

The following regional data for 30 provinces in China are obtained or calculated from the official sources (SSB, 1989; 1990a; 1990b; DPS, 1988a, 1988b). Most recent data in 1987, 1988 or 1990 are used.

b = birth rate, ‰, 1990

x_1 = GNP per capita, Yuan, 1988

x_2 = net income per peasant, Yuan, 1988

x_3 = total production value index in terms of 1986, 1987

x_4 = population density, persons per square km, 1990

x_5 = farmland per peasant, hectare, 1988

x_6 = foodstuffs production per peasant, kg, 1988

x_7 = proportion of agricultural production value in total production value, %, 1987

x_8 = proportion of agricultural employees in total employees, %, 1988

x_9 = proportion of urban population based on 1990 census definition, %, 1990

x_{10} = proportion of urban population based on 1982 census definition, %, 1987

x_{11} = proportion of population aged 15-29 in total population, %, 1987

x_{12} = birth index of education, 1990

There are 12 explanatory variables in total. Table 6-6 presents the correlation matrix of these 12 explanatory variables and the regional birth rate. The proportion of urban population based on 1982 census definition (x_{10}) and the proportion of population aged 15-29 (x_{11}) in 1987 are only available for Guangdong and Hainan as a whole. Thus correlation coefficients involved with these two variables are calculated using 29 regions. Guangdong and Hainan are treated as one region. Most correlation coefficients which are insignificant at the 0.05 level are omitted. The GNP per capita (x_1) and the net income per peasant (x_2) are used to describe the level of economic development. Both of them are significantly correlated with the regional birth rate at the 0.05 level. The correlation coefficients of the GNP per capita and the net income per peasant with the birth rate are -0.769 and -0.797 respectively. The GNP per capita and the net income per peasant are also significantly correlated with a correlation coefficient of 0.932. It seems clear that the higher the income per capita, the lower the birth rate.

The total production value index (x_3) is used to describe the growth rate of regional economies. The correlation coefficient of the total production value index with the birth rate is only -0.083 and is not significant at the 0.05 level. It seems that the birth rate is closely related with the level of development rather than the economic growth rate.

The population density (x_4), the farmland per peasant (x_5) and the foodstuffs production per peasant (x_6) are used to describe the relation of land use and foodstuffs production with the birth rate. There is some indication of the trend that the regional birth rate may be higher in regions with lower population density and more farmland per peasant as reflected by the negative and positive correlation coefficients of these two variables with the birth rate respectively. The correlation direction of the foodstuffs production per peasant with the birth rate is negative. The correlation direction is not correct in this case. A positive correlation is expected here if other things are equal. It seems that other factors are operating. It is found that the foodstuffs production per peasant has positive but insignificant correlation with the proportion of urban population based on the 1982 census definition. Those regions with more foodstuffs production per peasant may have a smaller proportion of rural population so that they may not necessary have high birth rates. The correlation coefficients of the farmland per peasant and the foodstuffs production per peasant with the birth rate are not significant at the 0.05 level. The correlation coefficient of the population density with the birth rate

Table 6-6 Correlation matrix of regional birth rates and potential birth rate explanatory variables

	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	x_{11}	x_{12}
x_1	1											
x_2	0.932	1										
x_3			1									
x_4	0.828	0.806		1								
x_5			-0.426	-0.386	1							
x_6					0.649	1						
x_7	-0.702	-0.672		-0.555			1					
x_8	-0.886	-0.838		-0.636			-0.875	1				
x_9	0.875	0.794		0.545			-0.750	-0.936	1			
x_{10}	0.589	0.634					-0.729	-0.753	0.769	1		
x_{11}	-0.380	-0.375		-0.594	0.601	0.656					1	
x_{12}	-0.766	-0.743		-0.588			0.772	0.869	-0.845	-0.758		1
Birth rate	-0.769	-0.797	-0.083*	-0.613	0.004*	-0.151*	0.751	0.805	-0.796	-0.598	0.127*	0.789

Note:
(a) for key to entries see text
(b) correlation coefficiens involved with variables x_{10} and x_{11} are calculated using 29 regions as Guangdong and Hainan are treated as one region
* not significant at the 0.05 level

is significant at the 0.05 level. It is argued again that this significant correlation may be due to the significant correlation of the population density with the GNP per capita. It seems that the birth rate of a region may depend more on its development level and socio-economic structure than on its regional population-land relation. On the other hand, birth rates in some regions with less foodstuffs production per peasant are not effectively checked. It may also be due to the fact that more developed regions may be more sensitive to population-land pressures than less developed regions. In this case, regional economic growth may have both positive and negative effects. It may promote the sense of environmental protection at certain stage while at others it may produce more environmental pollution.

The proportion of agricultural production value (x_7), the proportion of agricultural employees (x_8), the proportion of urban population based on 1990 census definition (x_9) and the proportion of urban population based on 1982 census definition (x_{10}) are used to describe the structures of regional economy and population. Here, two sets of most recent urban population data based on 1982 and 1990 census definitions are used. Basically, the 1982 census definition includes more population than the 1990 census definition. See chapter two and appendix A for details on urban population definition. They are significantly correlated with each other at the 0.05 level. They are also significantly correlated with the birth rate at the 0.05 level. The correlation coefficients of the proportion of agricultural production value, the proportion of agricultural employees, the proportion of urban population based on 1990 census definition and the proportion of urban population based on 1982 census definition with the birth rate are 0.751, 0.805, -0.796 and -0.598 respectively. The proportion of agricultural employees has the greatest correlation coefficient with the birth rate as it may be the best indicator in describing the structures of both the regional economy and population to some extent.

The proportion of population aged 15-29 (x_{11}) is used to describe the age composition of a regional population which may affect the birth rate. The direction of the correlation of the proportion of population aged 15-29 with the birth rate is positive and correct as anticipated, but their correlation coefficient of 0.127 is not significant at the 0.05 level. It seems that the age composition of a regional population has no significant effect on the birth rate. This result should only be interpreted in terms of cross-sectional analysis. There is no doubt that the age composition of a population is a crucial factor of population dynamics. However, in the case of cross-sectional analysis, what matters is what factors cause regional difference of the dependent variable concerned in statistical terms. In this case, the regional difference in age composition is so small that its effect on regional difference in the birth rate is submerged by the effects of other main factors.

The birth index of education (x_{12}) is used to describe the educational level of a regional population and its possible effect on the birth rate. The birth index of education is calculated by applying different total fertility rates to the proportions of population with university education, higher-middle school education, lower-middle school education, primary school education and the proportion of illiterate and semi-illiterate population. The total fertility rates of these populations with different educational levels in 1987 are used as weights in the calculation of the birth index of education. These weights are 1.243 for the population with university education, 1.706 for the population with higher-middle school education, 2.167 for the population with lower-middle school education, 2.575 for the population with primary school education and 3.015 for the illiterate and semi-illiterate population. The birth index of education is significantly correlated with the birth rate at the 0.05 level. The correlation coefficient is 0.789.

The step-wise regression method has been used to establish an optimal regression equation for the regional birth rate. The foodstuffs production per peasant is excluded from this analysis as its correlation sign with the regional birth rate is not correct. As some data are only available for Guangdong and Hainan as a whole, an optimal equation for 29 regions are estimated first while Guangdong and Hainan are treated as one region. It is found that all data of the two variables in the optimal equation are available for 30 regions. Thus the optimal equation is estimated again using the data of 30 original regions. The estimated multiple linear regression equation is as follows:

$$b = 19.595 - \underset{(2.125)}{0.007\, x_2} + \underset{(2.373)}{0.101\, x_8} \qquad (6\text{-}1)$$

$$R^2 = 0.698 \qquad \text{Adj. } R^2 = 0.676 \qquad F = 31.200$$

Only the net income per peasant and the proportion of agricultural employees appear in the equation. It is not surprising as they have the largest correlation coefficients with the birth rates. The signs of the regression coefficients are correct as anticipated. The t statistics of regression coefficients are significant at the 0.05 level. The F statistic of the regression equation is 31.2 and is also significant at the 0.05 level. Table 6-7 presents the fitted values and standardized residuals of regional birth rates.

Several regions have large standardized residuals. The birth rates in Zhejiang, Guangxi and Sichuan are significantly overpredicted by the model. Zhejiang is a developed region near Shanghai. It had a low birth rate of 14.84‰ in 1990 which is even smaller than in Tianjin. Sichuan is a less developed region in the western

Table 6-7 Fitted values and standardized residuals of regional birth rates (1990)

Region	Birth rate (‰)	Fitted birth rate (‰)	Standardized residual
Beijing	13.35	13.25	0.04
Tianjin	15.50	15.04	0.20
Hebei	19.66	21.44	-0.79
Shanxi	22.31	21.04	0.57
Inner Mongolia	20.12	21.53	-0.63
Liaoning	15.60	17.85	-1.00
Jilin	18.40	19.74	-0.59
Heilongjiang	17.51	19.43	-0.85
Shanghai	11.32	11.26	0.03
Jiangsu	20.54	18.37	0.97
Zhejiang	14.84	18.15	-1.47
Anhui	25.04	22.92	0.94
Fujian	23.45	21.06	1.06
Jiangxi	24.47	22.60	0.83
Shandong	18.86	21.44	-1.15
Henan	24.03	23.51	0.23
Hubei	24.32	21.91	1.07
Hunan	24.03	23.00	0.46
Guangdong	21.96	18.96	1.33
Guangxi	20.71	24.27	-1.58
Hainan	22.95	22.65	0.13
Sichuan	17.78	23.55	-2.57
Guizhou	23.77	24.58	-0.36
Yunnan	23.59	24.34	-0.33
Tibet	27.60	24.90	1.20
Shaanxi	23.49	22.98	0.23
Gansu	22.85	23.69	-0.37
Qinghai	22.65	21.90	0.33
Ningxia	24.56	22.42	0.95
Xinjiang	24.67	22.16	1.12

conomic zone but it has been successful in reducing its fertility since the early 1970s. Guangxi is the least developed region in the eastern economic zone. Its birth rate continued to decline in the 1980s while the birth rates in many other regions didn't decline significantly in that period.

The birth rates in Guangdong and Tibet are underpredicted by the model. Guangdong has experienced rapid economic growth since the late 1970s. However, its birth rate is relatively high compared to its high level of economic development. Tibet is the least developed region in China. It had the highest birth rate of 27.60% in 1990 which is significantly underpredicted by the model. It means that Tibet will have a higher birth rate than a region anywhere else in China which has the same level of economic development as Tibet. This is probably due to the fact that there has not been a strong government intervention in the family planning in Tibet compared to other regions in China.

In summary, the net income per peasant and the proportion of agricultural employees are the most important factors affecting regional birth rates. They account for over 67% of the regional variation in the birth rates in China.

6.4 Explanatory model of regional death rate

Similar regional data are used in the estimation of the regional death rate model. Some new variables related with the regional death rate are used in this section in addition to those variables used in the analysis of the regional birth rate in the previous section. All the variables are defined as follows:

d = death rate, ‰, 1990

x_1 = GNP per capita, Yuan, 1988

x_2 = net income per peasant, Yuan, 1988

x_3 = total production value index in terms of 1986, 1987

x_4 = population density, persons per square km, 1990

x_5 = farmland per peasant, hectare, 1988

x_6 = foodstuffs production per peasant, kg, 1988

x_7 = proportion of agricultural production value in total production value, %, 1987

x_8 = proportion of agricultural employees in total employees, %, 1988

x_9 = proportion of urban population based on 1990 census definition, %, 1990

x_{10} = proportion of urban population based on 1982 census definition, %, 1987

x_{13} = proportion of population aged 65 plus in total population, %, 1987

x_{14} = number of medical beds per capita, 1988

x_{15} = number of medical workers per capita, 1988

There are 13 explanatory variables in total. Table 6-8 presents the correlation coefficients of death rate and new variables x_{13}, x_{14}, x_{15} with other variables. The proportion of urban population based on 1982 census definition (x_{10}) and the proportion of population aged 65 plus (x_{13}) in 1987 are only available for Guangdong and Hainan as a whole. Thus correlation coefficients involved with those two variables are calculated using 29 regions. Guangdong and Hainan are treated as one region. The proportion of population aged 65 plus (x_{13}) is used to analyze the effect of the proportion of elderly population on the regional death rate. It is significantly correlated with the GNP per capita and other variables at the 0.05 level. It is clear that more developed regions have a greater proportion of elderly population. It is expected that the proportion of population aged 65 plus has a positive effect on the regional death rate.

Table 6-8 Correlation coefficients of regional death rates and potential death rate explanatory variables

	Death rate	x_{13}	x_{14}	x_{15}
x_1	-0.235*	0.659	0.737	0.886
x_2	-0.317*	0.748	0.587	0.720
x_3	-0.239*	0.412		
x_4	-0.128*	0.836	0.429	0.559
x_5	-0.176*	-0.657		
x_6	-0.224*			
x_7	0.388	-0.532	-0.535	-0.624
x_8	0.419	-0.496	-0.772	-0.857
x_9	-0.371	0.386	0.801	0.918
x_{10}	-0.542	0.368	0.540	0.562
x_{13}	-0.121*	1		
x_{14}	-0.150*		1	0.894
x_{15}	-0.230*		0.894	1

Notes:
(a) for key to entries see text
(b) correlation coefficients involved with variables x_{10} and x_{13} are calculated using 29 regions as Guangdong and Hainan are treated as one region
* not significant at the 0.05 level

However, it is negatively correlated with the death rate. But their correlation coefficient of -0.121 is not significant at the 0.05 level. This negative correlation may only be explained as indirect correlation due to the positive correlation of the proportion of population aged 65 plus with the GNP per capita.

The number of medical beds per capita (x_{14}) and the number of medical workers per capita (x_{15}) are used to analyze the effect of medical services on regional death rate. They are significantly correlated with the GNP per capita and some other variables at the 0.05 level. They are negatively correlated with the regional death rate. The direction of correlation is correct as anticipated. But the correlation coefficients are not significant at the 0.05 level.

The regional death rate is negatively correlated with the GNP per capita (x_1), the net income per peasant (x_2), the total production value index (x_3), the population density (x_4), the farmland per peasant (x_5), the foodstuffs production per peasant (x_6). But the correlation coefficients are insignificant at the 0.05 level. It is expected that the population density may have a positive effect on the regional death rate. However, its correlation with the regional death rate is negative and not correct. This negative correlation may be due to the significant correlation between the population density and the level of economic development. The regional death rate is significantly and positively correlated with the proportion of agricultural production value (x_7), the proportion of agricultural employees (x_8), the proportion of urban population based on 1990 census definition (x_9) and the proportion of urban population based on 1982 census definition (x_{10}) at the 0.05 level. It seems that those regions with higher proportions of non-agricultural population and urban population have lower death rates due to better living standards of non-agricultural and urban population in China.

The step-wise regression method is again used to establish an optimal regression equation for the regional death rate. The population density and the proportion of population aged 65 plus are excluded from this analysis as their correlation signs with the regional death rate are not correct. The proportion of urban population based on 1982 census definition (x_{10}) is only available for Guangdong and Hainan as a whole. For simplicity, this figure is used for Guangdong and Hainan respectively. The estimated optimal linear regression equation is as follows:

$$d = 7.494 - \underset{(3.739)}{0.025}\, x_{10} \qquad (6\text{-}2)$$

$R^2 = 0.333$ Adj. $R^2 = 0.309$ $F = 13.978$

Only the proportion of urban population based on the 1982 census definition appears in the equation. It does have the largest correlation coefficient with the regional death rate. The t statistic of the regression coefficient is significant at the 0.05 level. The F statistic of the regression equation is also significant at the 0.05 level. However, this explanatory model for the regional death rate is much weaker than the model for the regional birth rate. Only 30% of the regional variation in the death rate is explained by the model. It is clear that socio-economic variables have more significant effects on the birth rate than on the death rate. The death rate has decreased to a low level in China. Its regional variation is less predictable than that of the birth rate.

Table 6-9 presents the fitted values and the standardized residuals of regional death rates. The death rates in Tibet, Yunnan and Hubei are significantly underpredicted. Tibet and Yunnan are less developed regions in the western economic zone and they did have the highest death rates in 1990. Hubei recorded a high proportion of urban population of 71.71% in 1987 based on the 1982 census definition. This figure is quite unreliable as a number of rural population may have been counted as urban population in Hubei in particular. Thus the death rate in Hubei is significantly underpredicted.

The death rates in Anhui and Ningxia are significantly overpredicted by the model. In fact, Ningxia has the lowest death rate in 1990. Anhui had a lower death rate than

Jiangxi and Guizhou though they both have a proportion of urban population around 31%. This is probably due to better health services in Anhui. It has had a low death rate since the 1970s.

In summary, the proportion of urban population based on the 1982 census definition is the most important factor affecting the regional variation in the death rates. Some regions with the highest or lowest death rates often have large standardized residuals of the predicted death rates.

Table 6-9 Fitted values and standardized residuals of regional death rates (1990)

Region	Death rate (‰)	Fitted death rate (‰)	Standardized residual
Beijing	5.43	5.67	-0.34
Tianjin	5.98	5.69	0.42
Hebei	5.76	6.56	-1.16
Shanxi	6.25	6.05	0.29
Inner Mongolia	5.79	6.28	-0.71
Liaoning	6.01	5.70	0.44
Jilin	6.12	5.77	0.51
Heilongjiang	5.33	5.88	-0.80
Shanghai	6.36	5.88	0.69
Jiangsu	6.07	6.35	-0.40
Zhejiang	6.10	6.19	-0.13
Anhui	5.79	6.70	-1.32
Fujian	5.70	6.34	-0.93
Jiangxi	6.59	6.70	-0.16
Shandong	6.25	6.00	0.36
Henan	6.18	6.89	-1.03
Hubei	6.84	5.68	1.67
Hunan	7.07	6.51	0.81
Guangdong	5.34	5.32	0.03
Guangxi	5.96	6.53	-0.83
Hainan	5.22	5.32	-0.15
Sichuan	7.06	6.78	0.40
Guizhou	7.13	6.72	0.59
Yunnan	7.71	6.78	1.34
Tibet	9.20	7.18	2.93
Shaanxi	6.49	6.48	0.02
Gansu	5.92	6.48	-0.81
Qinghai	6.84	6.63	0.30
Ningxia	5.07	6.51	-2.08
Xinjiang	6.39	6.36	0.04

6.5 Conclusion

A comparative analysis of fertility levels in Shaanxi, Hebei and Shanghai has been completed. Cross-sectional analysis of regional birth and death rates of 30 provinces in China has also been undertaken. The main findings of the comparative analysis of fertility levels can be summarized as follows. First, the difference in the number of children ever produced by a married woman (NCMW) is 0.35 between Shaanxi and Hebei and 0.91 between Hebei and Shanghai. Of the fertility level difference between Hebei and Shanghai, 57% can be explained by cultural and educational factors, 20.9% can be explained by urban-rural differences, and no more than 43% may be explained by economic factors. Second, the NCMW difference by urban-rural residence is about 0.50 in Shaanxi and Shanghai and only 0.2 in Hebei. Third, the NCMW difference between those women with no education and those with primary school education is 0.46 in Shaanxi, 0.29 in Hebei and 0.66 in Shanghai. The NCMW difference between the women with the primary school education and the women with middle school plus education women is much greater --- 1.27 in Shaanxi, 1.08 in Hebei and 0.84 in Shanghai. Fourth, the NCMW difference between managers and professionals, and peasants is 1.01 in Shaanxi, 0.63 in Hebei and 0.83 in Shanghai. Fifth, the effect of the family planning policy on fertility is 0.9 in Shaanxi, 1.8 in Hebei and 0.7 in Shanghai.

In a word, the effects of cultural and educational influences and the family planning policy on the fertility level are the most critical. Each effect is about 1.0. The effect of occupation is about 0.8. The effect of urban-rural differences as well as the effect of regional differences is about 0.5 after excluding the indirect effects of other factors.

In the explanatory analysis of regional birth rates using cross-sectional data, it has been found that income and the proportion of agricultural employees are the two most important factors in determining regional differences in the birth rate. The effect of the level of economic development on the birth rate is firmly confirmed. In the explanatory analysis of regional death rates using cross-sectional data, it has been found that the proportion of urban population based on the 1982 census definition is the most important factor in determining the regional differences in the death rate. However, the model for the regional death rate is much weaker than the model for the regional birth rate. The socio-economic variables have more significant effects on the birth rate than on the death rate. The death rate has decreased to a low level in China. Its regional variation is less predictable than that of the birth rate.

These conclusions have great implications for regional and national development strategies and population policy. To control population growth effectively, social, economic and education developments need to be coordinated. Popular education and the dissemination of family planning policy and knowledge about the population are two useful measures in the implementation of population control.

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7
Migration analysis

7.1 Introduction

Migration is an important component of population change. In studies of urban and regional development, it is recognized that migration is a key link between demographic change and economic growth. Many demographic-economic studies have emphasized the role of migration as a cause and/or a consequence of development (Miron, 1979; Oosterhaven and Dewhurst, 1990; Greenwood, 1975; Greenwood et al., 1989; Cordey-Hayes, 1975; Isserman, 1985). There are some common laws of migration. For example, economic opportunities in destination regions have great effects on migration directions. The age composition of migration population is much younger than total population. The migration population generally has a higher educational level. The professionals are more mobile than ordinary workers (Lowry, 1966; ter Heide and Willekens, 1984; Rogers and Willekens, 1986).

Several studies have been carried out on migration problems in China in general. A brief review of these studies here will provide a contextual basis of the migration analysis in this chapter. Hu and Zhang (1984) examined the inter-provincial migrations in China. Two kinds of migrations were identified --- organized migration and unorganized (spontaneous) migration.

The first kind of migration is organized by the government. Firstly, several million people have been organized and moved from the eastern developed cities to new development areas and key construction areas in the north-eastern, western and south-western areas since the early 1950s. In the early 1950s, the main destination of such kind of migration was the north-eastern area which was regarded as the key construction area to consolidate the industrial base there. In the late 1950s and early 1960s, the north-eastern area and some newly industrialized cities such as Huhan and Lanzhou in the middle and western China became the main destinations. Sichuan and Guizhou in the south-western China have become the main destinations since the middle 1960s to facilitate the industrial development and transportation construction there.

Secondly, about two million people (urban residents and veterans demobilized from military service) were organized and moved from the eastern densely populated areas to sparsely populated areas to engage in agricultural development in 1950s. The main destinations were Inner Mongolia, Heilongjiang, Xinjiang, Hainan island and Yunnan. Such kind of organized migration for agricultural development has been stopped since the 1960s.

Thirdly, a number of graduates of the universities and colleges of higher education and the middle professional schools are allocated each year to key construction areas and less developed regions. Of course, many graduate are allocated to developed regions and may well be intra-provincial migrants. In addition, such kind of allocation mechanism has been weakening in the reform period since 1978.

Fourthly, over 2500 large and medium-sized hydroelectric power stations have been constructed in China since 1950. Over 100 thousand hectares of arable land have been submerged in water and over 1.2 million people have been relocated. Some of these moved to other provinces.

In addition to those organized migrations mentioned above, there have been significant spontaneous migrations, mainly by rural peasants. For example, these migrations account for over two thirds net in-migrations in Xinjiang. About 1.78 million spontaneous migrants moved into Heilongjiang over the period 1970-1978. It was argued that these spontaneous migrants may make positive contributions in their destination regions. However, there may be negative aspects. For example, some migrants may be more likely to commit crimes. Thus suitable measures are needed to control and settle these unorganized migrants. Local government may accept these migrants or persuade them to go back to their origin regions. In 1980, 0.92 million spontaneous migrants were accepted and settled in Heilongjiang and 0.49 million were persuaded to return to their origin regions.

Hu and Zhang estimated that there were some 25 million net inter-provincial migrations in China over the period 1950-1979. According to their estimations, seventeen regions including Beijing, Hebei, Shanxi, Inner Mongolia, Jilin, Heilongjiang, Jiangxi, Hubei, Guangxi, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia and Xinjiang had net in-migrations over this period. Inner Mongolia (3.1 million), Heilongjiang (6.5 million) and Xinjiang (2.8 million) account for half of the total net in-migrations. Eight regions include Shanghai, Jiangsu, Zhejiang, Shandong, Henan, Hunan, Guangdong and Sichuan had net out-migrations over the same period. About 40% net out-migrations were from Sichuan (9 million) which had the largest provincial population in China. This migration pattern is based on the estimation for a period of over 30 years. It is likely that some regions may have net in-migration in one period and net out-migration in other period as there have been significant changes in the level of migration over the period (see chapter five).

Sun (1984) briefly reviewed the urban and rural population changes and inter-provincial migrations in China up to the late 1970s. He pointed out that the main migration direction was from the densely populated central and eastern provinces to sparsely populated and remote border provincial regions in the northern and western parts of the country. Heilongjiang, Inner Mongolia, Xinjiang, Qinghai and Ningxia received large numbers of migrants while Yunnan, Guizhou, Shaanxi, Gansu, Jilin and Jiangxi received only small numbers of migrants from other provinces. For those spontaneous migrants, mainly peasants, there were two main destinations. One was from Shandong, Henan, and northern Anhui and Jiangsu to north-eastern, northern and north-western parts of China. Another was from Sichuan and Hunan to Yunnan and Guizhou in the south-west. This may be called the traditional migration pattern in the pre-reform period in China. The migration pattern has begun to change in the reform period since 1978. The newly emerged pattern of migration in the 1980s will be analyzed in this chapter.

A recent collective work edited by Tian and Zhang (1989) examined migration problems facing China today. Several case studies can be found in this work about inter-provincial and intra-provincial migrations. For example, one case study examined the rapid population growth and migration in Shekou in the Shenzhen special economic zone near Hong Kong. Shekou consists of three economic components: Shekou industrial district, Nanshan development corporation and Fishery, industry and trade corporation. It's population has increased rapidly from 3.8 thousand in 1979 when the Shekou industrial district was established to 33.5 thousand by 1986. Migrants account for over 98% of the population growth in this period. It's ordinary resident population increased from 3.7 thousand to 11.0 thousand in the same period. The temporary resident population, mainly of working age, increased dramatically from 0.15 thousand to 22.5 thousand in just seven years. They did not bring their dependents which significantly reduced the pressure for urban infrastructure and were usually from places nearby and employed as contract workers, replacement workers or temporary workers. Some 4.2% of total workers in the district were hired from other firms all over the country and also registered as temporary population. Some 18.4% of total workers were employed as normal workers registered as ordinary resident population. Most of them came from other provinces. Most clerks (or office workers similar to while collar workers in western countries) were employed from other provinces. Over 60% were normal clerks and registered as ordinary population. In summary, it was found that about 72% of new employees in the Shekou industrial district came from Guangdong province, while 28% came from from other provinces. As a result of huge in-migrations, Shekou industrial district has a young population. In 1984, 93% of its population were in the age range of 15-49 years. Another interesting feature is the high gender ratio in Shekou. The gender ratio of the ordinary population in Shekou increased from 97.9% in 1979 to 118% in 1986. It is likely that Shekou has absorbed more male migrants than female migrants. This case study has significant implications for the population dynamics in many rapidly growing cities in the coastal regions of China.

Yan (1991) examined the internal migration and migration policy in China since the 1950s. His analysis is based on the migration data collected via the resident registration system. Migration is defined as an authorized change in permanent residence of a person from the original city, county, town or township to a new place with a corresponding change in the resident register. It is well known that this registration system is not able to cover a substantial number of migrants who fail to get official approval to change their resident registration. Based on this data source, it is found that social, political and economic factors have critical effects on the direction and volume of internal migration in China since the 1950s. In the early 1950s, there was no policy to limit population movement. However, government policies on migration have become more explicit and systematic since the 1960s. Migrations from rural to urban areas and from inland to coastal provinces were strictly controlled while migrations in the reverse direction were generally encouraged. Some changes have taken place since the introduction of economic reforms in 1978. In 1984, the State Council issued a document that allows peasants and their families to get permanent registration in towns and townships as long as they conduct industrial or commercial activities. Peasants are allowed to get temporary registration in small and medium-sized cities. Migration to big cities is still strictly limited. Yang further argued that, under certain circumstances, the closed migration policy in China has advantages in securing public order and developing the economy in a planned way. But it also has negative effects on the overall socio-economic development by restraining exchanges of population. Therefore he argues that it is necessary to relax the control on population movement gradually.

Yan's study on the recent change of migration policy is useful to understanding the changing circumstances of migration in China in the reform period. Some new policies have also been proposed to serve the need of economic development. A most interesting example is that peasants can change their status from registered agricultural population to non-agricultural population if they contribute a certain amount of money to the local government to develop urban infrastructure. Previous resident registration of peasants in towns or cities did not involve this change. The state will become responsible for the provision of grain, job and living subsidies for a person who is registered as non-agricultural population. This has significant financial implications for the government.

Despite the studies mentioned above, detailed research on internal migration in China is scarce due primarily to lack of migration data, that is until recently. Yang (1989) interestingly made an estimate of aggregated inter-provincial migrations assuming equal natural increase rates among provinces. His results revealed the trends of net inter-provincial migrations in each provinces since the 1950s. However, his assumption of provincial natural increase rates may affect the preciseness of his estimations. The one percent sampling population data used in this research provide detailed information on the inter-provincial migration in China though it covers only a five year period from 1982 to 1987.

There are three basic questions involved in migration research --- who migrate, why and to where. This chapter attempts to answer these three questions with regard to migrations in China using 1982-1987 migration data (DPS, 1988a). In this set of migration data, migrants refer to those who changed their place of residence in the period 1982-1987. It is the first time that such kind of systematic migration data is available in China. The analysis below reveals that there is now clear evidence in China which confirm the common laws of migration found in other countries. The major features of multiregional migrations are revealed via a structural analysis. Two levels of population divisions are used. Firstly, the national population is divided into provincial populations. The geographic area of this research consists of 29 mainland provincial regions of China. Tibet is excluded in the provincial level analysis for most cases as only its county population was covered in the sampling survey in 1987. The population of the newly founded Hainan province is included in the population of Guangdong province. The difference between intra-provincial migrations and inter-provincial migrations and provincial differences in migration structure and migration rates are analyzed in the chapter. Secondly, the national or a provincial population is divided into city population, town population and county population as defined in 1987 (DPS, 1988a). The town population in a county is separated from and is not included in the county population. The migration data are tabulated for city, town and county populations respectively. It is recognized that migration patterns may be analyzed more clearly in terms of city, town and county populations rather than in terms of urban-rural populations. Thus, the migration data are not re-processed to derive tabulations for urban-rural populations. The migration structure among city, town and county populations is analyzed at the national level as well as at the provincial level. The results have great implications on the urbanization process in terms of migration.

In the following section 7.2, the migration causes in China will be analyzed first. In section 7.3, the selectivity of migration will be discussed. A structural analysis of migration will be made in section 7.4. Explanatory models for regional in-migration rates and out-migration rates will be estimated in sections 7.5 and 7.6 respectively to examine the factors determing the regional differentials in these in-migration and out-migration rates.

7.2 Migration causes

Eight potential causes of migration are distinguished in the 1982-1987 migration data. These causes together with an unidentified cause (other cause) were listed in the questionnaire and each migrant was asked to pick out one of them. These causes are grouped into five major causes in this research. These are employment (including job relocation, job assignment, and on business), study and training, joining family (including relatives and family), retirement, and marriage. Table 7-1 presents the migration proportions by causes of intra- and inter-provincial in-migrations in city, town and county populations.

Table 7-1 Proportions of migrations by various causes (%)

	Employment	Study and training	Joining family	Retirement	Marriage	Other causes
	Intra-provincial in-migration					
City	33.7	15.3	27.7	1.1	13.8	8.5
Town	31.5	6.6	26.3	1.8	25.4	8.4
County	9.9	0.3	13.9	4.3	65.2	6.3
Subtotal	27.2	8.0	23.9	2.2	30.8	7.9
	Inter-provincial in-migration					
City	41.6	16.4	32.2	1.8	4.8	3.2
Town	36.8	1.3	36.6	2.5	16.0	6.7
County	18.7	0.5	27.7	4.1	37.1	11.8
Subtotal	34.7	9.0	32.0	2.5	15.5	6.2
Total	28.8	8.2	25.6	2.3	27.7	7.6

Note: Migrations (transitions) refer to the period 1982-1987

For China as a whole, employment is a major cause of migration which accounts for nearly 30% of total migrations. Recent studies show that organized labour migration among a same institution plays a significant role in UK as well as in other western countries (Johnson and Salt, 1990; Salt, 1990). The China migration data show that 45.7% employment migrations are organized labour migration --- migration caused by organized job relocation. In the case of China, such job relocation may occur among various state-owned enterprises or state-run public organizations rather than just in one organization. For example, a manager or a technical expert in a large firm may be relocated to another firm to carry out a technical renovation project. It is interesting to note that marriage is the second major cause of migration in China which accounts for 27.7% of total migrations. The third major cause of migration in China is joining family which accounts for over one-fourth of total migrations. The remaining causes are less significant. Study and training is the fourth cause which accounts for 8.2% of total migrations. Retirement is the fifth cause which accounts for 2.3% of total migrations. The other 7.6% of migrations cannot be explained by five major causes discussed above.

Migrations for employment and joining family are critically important in city and town in-migrations. Migrations for employment account for over 30% of both city and town intra-provincial in-migrations respectively. Migrations for joining family account for over one-fourth of city and town intra-provincial in-migrations respectively. These two causes explain more than 55% intra-provincial in-migrations in the city and town populations. Migrations for employment and joining family are even more important in inter-provincial in-migrations. These two causes explain more than 70% inter-provincial in-migrations in the city and town populations. Study and training is the third major cause of in-migrations in the city population as cities are centers of science, technology and education in China. Study and training accounts for about 15% of intra-provincial and inter-provincial in-migrations in the city population respectively.

The causes of in-migration in the county population show a different pattern. The features of in-migration causes in town population take a middle position between the city and town populations. A striking feature in the county population is that marriage becomes the first major cause of in-migration. As a matter of fact, marriage migration is the most convenient and free migration form in China especially in rural areas. It accounts for over 65% of intra-provincial in-migration and much less but still significant proportion (37.1%) of inter-provincial in-migration in the county population. Employment and joining family are also important causes in inter-provincial in-migrations of the county population accounting for 18.7% and 27.7% respectively. It is interesting but perhaps not surprising to note that most marriage migrations are intra-provincial. As shown in table 7-2, inter-provincial marriage in-migration only accounts for about 10% of total marriage in-migrations while the remaining four causes for inter-provincial in-migration account for over 23% of total in-migrations of each cause respectively. This means that marriage migration is more sensitive to distance.

Table 7-2 Proportions of inter-provincial in-migrations in total in-migrations (%)

	Employment	Study and training	Joining family	Retirement	Marriage	Other causes
Proportion	24.9	22.8	25.9	23.3	11.6	16.8

Note: Migrations (transitions) refer to the period 1982-1987

Although retirement migration only accounts for 2.3% of total migrations, it is clear that it assumes a higher proportion in the county population in-migrations than in the city and town population in-migrations. This may indicate a trend of retirement migration from urban to rural areas as has occurred in most western countries. With regard to intra-provincial in-migrations, retirement migration accounts for 4.3% of the county population in-migrations while it only accounts for 1.1% and 1.8% of the city and town population in-migrations respectively.

To analyze the relations between in-migrations of different causes, a correlation matrix has been calculated using inter-provincial in-migration data of 28 mainland provinces of China excluding Tibet. According to table 7-3, the migrations of four causes except for study and training are significantly correlated each other at the 0.05 level. Migrations for study and training is only significantly correlated with migrations due to employment and retirement at the 0.05 level. It is clear that employment is a leading cause of inter-provincial in-migration as it is significantly correlated with all other causes for migration. For example, migrations for employment are usually followed by migrations for joining family. A regression analysis has been carried out to explain migration for joining family (y) by employment migration (x). The following regression equation is obtained:

$$y = 217.2 + \underset{(5.228)}{0.627}\, x \qquad (7\text{-}1)$$

$R^2 = 0.512$ Adj. $R^2 = 0.494$ $F = 27.330$

Table 7-3 Correlation matrix of migrations for different causes

	Employment	Study &training	Joining family	Retirement	Marriage
Employment	1.000				
Study &training	0.559*	1.000			
Joining family	0.716*	0.227	1.000		
Retirement	0.802*	0.493*	0.409*	1.000	
Marriage	0.706*	0.249	0.684*	0.623*	1.000

Note: * Significant at the 0.05 level

It seems that there will be 0.627 migration for joining family following one employment migration. This figure is smaller than the national average number of 0.827 dependent per employee. The reasons are that a significant proportion of migrants are unmarried youths and some dependents may not follow the migration of their family members.

Figure 7-1 presents the scattergram of the regression equation (7-1) with the 95%

confident bands for the true value of the migration for joining family. Several regions including Inner Mongolia, Liaoning, Heilongjiang and Shandong have large positive residuals. These regions have more induced migrations for joining family than other regions. Shanghai has a large negative residual. It is true that Shanghai has a more strict policy towards in-migration than other regions. As a result, its number of migrants for joining family is significantly less than the figure predicted by the regression model.

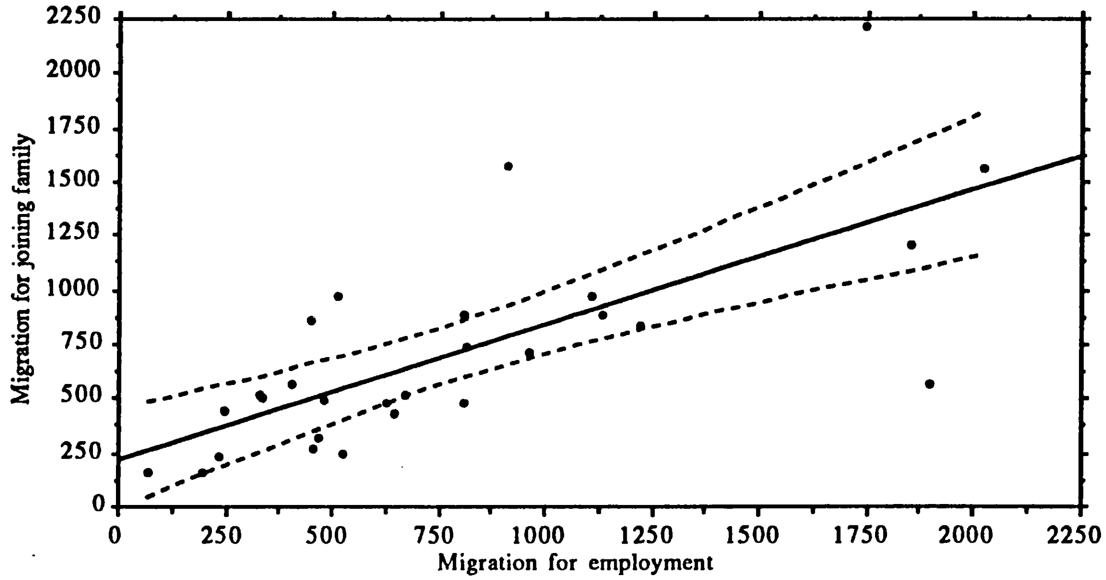

Figure 7-1 Regression scattergram of migrations for joining family and employment

7.3 Selectivity of migration

Only a proportion of population migrates in any period and they may have distinctive features compared with the population in their origin and destination regions. Thus migration is a selective process which may have important effects on both the origin and the destination regions of migration. Age and gender selectivity will be discussed first. Then labour skill selectivity will be considered.

Age and gender selectivity is a common phenomenon of migration in China and elsewhere and it often means that young adults move out while children and elderly people are left behind. As has been pointed out by many researchers, the main reason is that the young adults are less encumbered by family responsibility and job seniority. Most young adults are physically vigorous and spiritually adventurous. They are willing and able to move for a better life. In addition, as pointed out in the previous section, marriage is a major cause of migration in China. Undoubtedly most marriage migrations are made by young adults especially as will be discussed latter females.

According to the estimation results of age-specific out-migration rates of urban (city and town) and rural (county) populations in China in the period mid-1986 to mid-1987 in chapter three, it is the youth population aged 15-29 that have the highest out-migration rates. The out-migration rates of male urban population aged 50-64 is also high and it may reflect the retirement migration. Some of these migrants may move to rural areas to undertake some paid consultations for township and village industries after retirement. It is noteworthy that the urban female population and the rural population as a whole do not have significant retirement migration.

It would be useful to be able to compare the characteristics of the out-migration population with the population in its origin region. However, the migration data available in this research are such that migration populations are mainly tabulated according to their destination regions. Thus it is only possible, but is also equally interesting, to compare the in-migration population with the total population in its destination region. It should also be noted that a migrant may change some of his or her character (such as occupation and education level) after migration as the real migration in fact took place in a five-year period. Table 7-4 compares the age compositions of in-migration populations and total populations in their destination regions. The age-groups 15-19, 20-24, 25-29 have much higher proportions in the in-migration population than in the total population. The age-group 20-24 accounts for over 30% of in-migrations of city and town populations respectively. A much higher proportion, nearly 50%, of in-

Table 7-4 Age compositions of in-migration and total populations (%)

Age-group	In-migration population			Total population		
	City	Town	County	City	Town	County
0-4	2.58	2.77	3.21	7.92	9.05	9.76
5-9	4.92	5.07	3.38	7.50	8.77	9.62
10-14	6.00	6.43	3.12	8.02	9.90	11.22
15-19	<u>16.24</u>	<u>15.18</u>	8.05	10.43	11.93	12.46
20-24	<u>30.49</u>	<u>32.69</u>	<u>47.18</u>	11.67	11.73	11.19
25-29	<u>11.58</u>	<u>12.74</u>	<u>15.37</u>	9.00	7.31	6.28
30-34	7.81	7.27	5.12	9.85	8.67	7.90
35-39	5.34	5.02	3.05	7.33	6.94	6.42
40-44	3.65	3.35	2.09	5.26	5.06	4.80
45-49	3.02	2.63	1.84	5.10	4.50	4.16
50-54	2.33	2.15	2.06	5.11	4.32	4.09
55-59	1.73	1.58	2.19	4.20	3.62	3.58
60-64	1.38	1.17	1.41	3.12	2.86	2.99
65-69	1.01	0.75	0.75	2.30	2.19	2.28
70+	1.92	1.20	1.18	3.18	3.15	3.25

Note: Underlined figures indicating age-groups have higher proportions in the in-migration population than in the total population migrations to counties are in the age-group 20-24. It is likely that most of these migrations are for marriage. This age-group only accounts for 11-12% in total populations.

Table 7-5 compares the gender ratios (males per hundred females) of the migration populations with those of total populations. In this case, the direction of migration is also known. The gender ratios in three origin or destination regions (city, town and county) are close. On average, gender ratio of the migration population is lower than that of the total population. The gender ratio of the total migration population is only 77, much less than 104 in the total population. A striking feature is that the out-migration population from cities has a high gender ratio. The gender ratio of the city out-migration population is 152 which is much higher than that of the total population. The gender ratios are even higher in city to town and city to county migrations which are 198 and 188 respectively. This means that urban females are much less likely to move out of urban areas than urban males. On the other hand, the gender ratios of the town and county migration populations are much less than the gender ratio of the total population. This is because marriage migration, which is female dominated, is an important part of migrations in town and county populations. The gender ratios of town and county out-migrations are 75 and 65 respectively. The gender ratios of town and county in-migrations are 81 and 44 respectively. It is interesting to note that the gender ratio in the county to county migration is the least, as marriage is the dominated cause of migration, and that the gender ratio of county to city migration is much more balanced.

Table 7-5 Gender ratios of migration and total populations

	Migration population				Total
Destination\Origin	City	Town	County	Total	population
City	130	88	100	107	103
Town	198	89	68	81	104
County	188	50	34	44	104
Total	152	75	65	77	104

Note: Gender ratio is males per hundred females

The age and gender selectivity of migration in China discussed above may have significant demographic as well as economic effects in both the origin and destination regions of migration. Another important migration phenomenon is its labour skill selectivity which may also have direct effects on the economic development levels in the sending and receiving areas.

Labour skill is difficult to measure in practice. However, it is often assumed that labour skill can be represented by educational level, occupation and work experience. In this section, labour skill selectivity is analyzed via education and occupation selectivity of migration. It is only possible again to compare in-migration populations with the total populations in their destination regions.

Table 7-6 compares the proportions of the in-migration populations aged 6 plus with various educational levels with those of the total populations. Generally speaking, the city population has the highest educational level while the county population has the lowest. With regard to total populations, the percentage of the population with primary school plus education is 83.9% in city population, 77.6% in town population, and 69.3% in county population. There are in addition large differences in the proportions of populations with university education and middle school education respectively among city, town and county populations. The percentage persons having university education is 4.2% in the city population, only 0.8% in the town population and this is lowered further still to 0.1% for the county population. The percentage of middle school education is 49.3% in the city population, 36.5% in the town population, and 25.1% in the county population. There are similar differences in educational level among the city, town and county migration populations.

Table 7-6 Proportions of in-migration population and total population aged 6 plus with various educational levels (%)

	University	Middle school	Primary school	Primary school plus
	Intra-provincial in-migration population			
City	14.4	57.2	20.6	92.2
Town	3.9	59.5	27.1	90.5
County	0.6	43.5	38.1	82.2
Subtotal	6.5	54.7	27.7	88.9
	Inter-provincial in-migration population			
City	26.2	48.4	18.0	92.6
Town	3.7	57.1	28.7	89.5
County	0.5	42.2	36.6	79.3
Subtotal	14.8	48.5	25.1	88.4
	Total in-migration population			
	8.2	53.4	27.2	88.8
	Total population			
City	4.2	49.3	30.4	83.9
Town	0.8	36.5	40.3	77.6
County	0.1	25.1	44.1	69.3
Total	1.0	31.7	40.9	73.6

The most noteworthy feature is that the in-migration population has a generally higher educational level than the total population. On average, the percentage of population with primary school plus education is nearly 90% in the in-migration population while it is less than 75% in the total population. In the in-migration population, over 8% has university education. In the total population, that proportion is only 1%. The percentage of population with middle school education is over 50% in the in-migration population whereas it is only about 30% in the total population.

The educational level is similar between intra-provincial and inter-provincial in-migration populations of the town and the county populations. However, it is clear that the proportion of population with university education is significantly higher in the inter-provincial in-migration population than in the intra-provincial in-migration population of the city population. The former is over 25% while the latter less than 15%. This fact reflects the high mobility of the population with university education.

Table 7-7 presents the occupational compositions of city, town and county populations in China. As can be expected, the proportions of professionals and technicians as well as other non-agricultural occupations are highest in the city population and lowest in the county population. It is interesting to note that the proportion of professionals and technicians is higher in the city and town female populations than in the city and town male populations while it is higher in the county male population than in the county female population. The reasons may be that the educational opportunities of male and female populations are more equal in the city and town populations than in the county populations and that males are more likely to have leading posts of managers. It can be noted that the proportion of peasants is higher in

Table 7-7 Occupational compositions of city, town and county populations (%)

Occupation	Male			Female		
	City	Town	County	City	Town	County
Professionals & technicians	9.29	6.24	2.58	13.31	6.78	1.23
Managers	7.61	4.14	0.96	1.87	0.55	0.07
Clerks	5.13	2.90	0.38	3.52	1.21	0.07
Businessmen & Salespersons	4.89	4.41	1.42	6.94	5.65	0.73
Service workers	4.64	3.15	1.04	8.85	3.80	0.62
Industrial workers	41.71	24.62	10.63	33.66	18.50	5.72
Peasants	26.60	54.48	82.99	31.72	63.47	91.55
Unclassified	0.12	0.05	0.01	0.13	0.04	0.01

Table 7-8 Occupational compositions of migration populations (%)

Occupation	Male			Female		
	City	Town	County	City	Town	County
	Intra-provincial migration					
Professionals & technicians	15.68	19.22	11.82	15.84	11.44	2.26
Managers	6.44	7.12	3.90	1.11	0.37	0.06
Clerks	7.09	7.54	3.65	3.64	1.95	0.18
Businessmen & Salespersons	8.24	7.42	4.61	8.54	8.10	1.30
Service workers	6.48	6.22	3.21	12.69	6.03	0.95
Industrial workers	50.37	42.97	28.79	34.57	28.15	6.18
Peasants	5.33	9.42	43.98	23.44	43.91	89.06
Unclassified	0.37	0.10	0.04	0.16	0.04	0.01
	Inter-provincial migration					
Professionals & technicians	22.56	12.21	3.54	25.18	10.87	1.63
Managers	7.99	7.30	1.59	1.34	0.46	0.02
Clerks	8.98	10.22	1.95	5.88	2.74	0.10
Businessmen & Salespersons	6.72	5.78	3.42	8.51	8.82	1.39
Service workers	5.44	4.28	2.56	15.55	6.97	1.17
Industrial workers	43.73	43.16	31.57	30.11	29.86	8.84
Peasants	3.94	17.00	55.23	13.03	40.27	86.86
Unclassified	0.64	0.04	0.15	0.39	0.00	0.00

the female population than in the male population. This may be due to the fact that the male peasants are more likely to move to other occupations.

Most occupations, except peasants, have higher proportions in the in-migration population than in the total population as shown in table 7-8. The proportion of professionals and technicians is much higher in the in-migration population than in the total population. With regard to the city male population, this proportion is 15.68% and 22.56% in the intra-provincial and inter-provincial in-migration populations respectively while it is only 9.29% in the total population. With regard to the city female population, it is 15.84% and 25.18% in the intra-provincial and inter-provincial in-migration populations respectively while it is 13.31% in the total population. Conversely the percentage of peasants is much lower in the in-migration population than in the total population. This difference is clear in the city, town and county male populations, and the city female population. The difference is less clear in the town and county female populations as a significant part of in-migrations are marriage migrations often by peasants. With regard to the county male population, the proportion of peasants is 43.98% and 55.23% in the intra-provincial and inter-provincial in-migration populations respectively while it is some 82.99% for the total population. With regard to the county female population, the proportion of peasants is 89.06% and 86.86% in the intra-provincial and inter-provincial in-migration populations respectively while it is 91.55% in the total population. It seems that occupational selectivity of in-migration is less clear in the town and county female populations.

7.4 Structural analysis of migration

This section attempts to make a structural analysis of multiregional population migration in China using 1982-1987 migration data (DPS, 1988a). Migration structure among city, town and county populations at the national level will be analyzed first. A comparison of intra-provincial versus inter-provincial migration will be considered next. Then inter-provincial migration rates will be discussed and lastly inter-provincial migration direction and flows will be analyzed.

7.4.1 Migration structure among city, town and county populations

By the end of 1987, 24.4% of total population was city population, 22.1% town population and 53.4% county population in China (DPS, 1988b). The city population, town population and county population all have different migration patterns.

Table 7-9 presents the origin distribution of migrations. Two points can be drawn as follows. First, more than half of the migrations, to the city population, to the town population or to the county population, and either intra-provincial or inter-provincial, are from the county population. On average, nearly 70% of migrations are from the county population. This proportion is much higher than the proportion of the county population in the total population. As a result, the migration proportions from the city population and the town population are lower than their population proportions respectively, except for those proportions of inter-provincial migration from the city population to the city and town populations. On average, about 18% of migrations are from the city population and only 14% from the town population. Second, migrations from the city population play a greater role in inter-provincial migration than intra-provincial migration, while migrations from the town population and the county population play a less important role in inter-provincial migration than intra-provincial migration. It is clear that migrants from the cities are less sensitive to migration distance moved as they often have better education and skills. With regards to inter-provincial migration, 44.21% of all migrations to the city population, 34.1% of all migrations to the town population, and 18.24% of all migrations to the county population are from the city population. With regards to intra-provincial migration, only 23.14% of migrations to the city population, 8.95% of migrations to the town population and 8.50% of migrations to the county population are from the city population.

Table 7-9 Origin distribution of migrations (%)

	Destination\Origin	City	Town	County
Intra provincial migration	City	23.14	10.73	66.13
	Town	8.95	19.04	72.01
	County	8.50	19.27	72.24
	Total	13.47	16.39	70.15
Inter provincial migration	City	44.21	4.90	50.89
	Town	34.10	6.41	59.49
	County	18.24	3.57	78.20
	Total	35.36	4.89	59.75
Total migration	City	29.38	9.01	61.62
	Town	11.82	17.60	70.58
	County	10.67	15.76	73.57
	Total	17.99	14.01	68.00

Notes:
1: underlined numbers indicate the major origin regions of migration.
2: migrations (transitions) refer to the period 1982-1987.

Table 7-10 presents the destination distribution of migrations. Four points can be drawn as follows. First, less than 34% of migrations of whatever kind are to the county population. On average, 36.70% of migrations are to the city population, 39.66% to the town population, and 23.63% to the county population. Second, over 66% of migrations from the county population are to the city population and the town population. This proportion is much higher in intra-provincial migrations (76%) than in the inter-provincial migrations (67%). On average, some 33.26% of migrations from the county population are to the city population, and a further 41.17% to the town population. The major intra-provincial migration destination of the county population is the town population which absorbs 45.47% of migrations from the county population. The major inter-provincial migration destination of the county population is the city population which absorbs 44.74% of migrations from the county population. Third, over half inter-provincial migrations from the town population are to the city population. With regards to intra-provincial migrations, more than half of the migrations from the town population are to its own population elsewhere while only 21.33% of migrations are to the city populations. Fourth, most migrations from the city population are to other cities. Nearly 56% of intra-provincial migrations from the city population are to its own population while a much higher proportion of inter-provincial migrations from the city population, 65.69%, are to the city population.

In a word, the city population has a tendency to move to its own population. The town population usually moves to its own population at the intra-provincial level but to the city population at the inter-provincial level. The county population on the other hand invariably moves to the town population at the intra-provincial level and to the city population at the inter-provincial level.

Table 7-10 Destination distribution of migrations (%)

Destination\Origin		City	Town	County	Total
Intra provincial migration	City	<u>55.98</u>	21.33	30.71	32.58
	Town	29.42	<u>51.47</u>	<u>45.47</u>	<u>44.29</u>
	County	14.60	27.20	23.82	23.13
Inter provincial migration	City	<u>65.69</u>	<u>52.67</u>	<u>44.74</u>	<u>52.54</u>
	Town	21.13	28.70	21.82	21.91
	County	13.18	18.63	33.44	25.55
Total migration	City	<u>59.93</u>	23.59	33.26	36.70
	Town	26.05	<u>49.83</u>	<u>41.17</u>	<u>39.66</u>
	County	14.02	26.58	25.57	23.63

Notes:
1: underlined numbers indicate the major destination regions of migration.
2: migrations (transitions) refer to the period 1982-1987.

7.4.2 Intra-provincial migration compared to inter-provincial migration

The intra-provincial migration pattern is different from the inter-provincial migration pattern. The two migration streams have different implications in regional and multiregional population analyses and projections. The multiregional population analysis in this research is concerned with the inter-provincial migration pattern. This section is devoted to a detailed comparison of intra-provincial migration with inter-provincial migration although of course some findings have already been made clear in the previous section.

The city population plays a more significant role in inter-provincial migration than in intra-provincial migration. In all intra-provincial migrations, 13.47% are from the city population, 16.39% from the town population and 70.15% from the county population. In all inter-provincial migrations, 35.36% are from the city population, 4.89% from the town population and 59.75% from the county population. In all intra-provincial migrations, 32.58% are to the city population, 44.29% to the town population and

23.13% to the county population. In all inter-provincial migrations, 52.54% are to the city population, 21.91% to the town population and 25.55% to the county population.

Table 7-11 presents the proportions of inter-provincial migrations in total inter- and intra-provincial migrations. On average, inter-provincial migrations account for some 20.7% of total migrations. The migrations to and from the city population have the highest inter-provincial migration proportion while the migration to and from the town population have the lowest. Over 40% of migrations from the city population are inter-provincial migrations. Over 18% of migrations from the county population are inter-provincial migrations. But only 7.2% of migrations from the town population are inter-provincial migrations.

Table 7-11 Proportions of inter-provincial migration in total migrations (%)

Destination\Origin	City	Town	County	Total
City	44.5	16.1	24.4	29.6
Town	33.0	4.2	9.6	11.4
County	38.2	5.1	23.8	22.3
Total	40.6	7.2	18.2	20.7

Note: Migrations (transitions) refer to the period 1982-1987.

Table 7-12 Intra-provincial and inter-provincial migration rates (%)

		Total migration	Intra-provincial	Inter-provincial
In-migration rates	City	5.81	4.09	1.72
	Town	6.03	5.34	0.69
	County	1.07	0.83	0.24
Out-migration rates	City	2.85	1.69	1.16
	Town	2.13	1.98	0.15
	County	3.08	2.52	0.52
Total		2.86	2.27	0.59

Note: Migrations (transitions) refer to the period 1982-1987.

Table 7-12 presents the five-year in-migration rates and out-migration rates for China (1982-1987). For simplicity, these rates are calculated by dividing the total number of migrants by the population at their origin or destination region in 1987. The total in-migration rate is 2.86%. The intra-provincial in-migration rate is 2.27% while the inter-provincial in-migration rate is only 0.59%. The city population and the town population have high in-migration rates which are 5.81% and 6.03% respectively. The inter-provincial in-migration rate of the city population is also relatively high (1.72%). But it is still less than its intra-provincial in-migration rate (4.09%). The overall in-migration rate of the county population is the least (1.07%). The intra-provincial in-migration rate of the county population is 0.83% while the inter-provincial in-migration rate is much lower still (0.24%).

The county population has the highest out-migration rate as expected (3.08%). The out-migration rates of the city population and the town population are 2.85% and 2.13% respectively, and much less than their in-migration rates. The intra-provincial out-migration rates of the county population and the town population are much greater than their inter-provincial out-migration rates respectively. The inter-provincial out-migration rate of the city population is on the whole relatively high (1.16%) and as a matter of fact, over 65% of these migrations are city to city migrations.

In a word, the city population and the town population have high in-migration rates while the county population has a low in-migration rate. The out-migration rates of the city population, the town population and the county population are reasonably close though the county population does have the highest. The intra-provincial migration rates are much higher than the inter-provincial migration rates. The city population has a relatively high inter-provincial migration rate than the town population and the county population.

7.4.3 Inter-provincial migration rates

In this section, spatial patterns of various five-year inter-provincial migration rates in 1982-1987 and their relations will be discussed. Table 7-13 presents the correlation coefficients between the inter-provincial in-migration rates of city, town and county populations and the value added per capita. See section 7.5 for a regression analysis between the inter-provincial migration rate and the value added per capita. The inter-provincial in-migration rates of the town and county populations are significantly correlated at the 0.05 level. However, both of them are not significantly correlated with the inter-provincial in-migration rate of the city population.

The inter-provincial in-migration rates of the town and county populations are significantly correlated with the value added per capita. It is clear that the level of economic development plays a major role in attracting inter-provincial migration, especially in the town and county populations. The inter-provincial migration of the city population is more complex. The difference in the real income of the city population in various provinces is much less than the difference in economic level in terms of value added per capita. As mentioned in chapter two, the government has assumed the responsibility to provide employment and various subsidies to the registered non-agricultural population, mostly city population, in China. On the other hand, most town and county populations have to rely mainly on themselves for a living and the inter-provincial difference in the standard of living is much wider. The inter-provincial migration of the city population however may depend more on the specific national construction programmes and urban developments in various regions than the general economic level. As a result, the spatial pattern of the inter-provincial in-migration rate of the city population is different from those of the town and county populations.

Table 7-13 Correlation coefficients between the inter-provincial in-migration rates of various populations and the value added per capita

	City population	Town population	County population
City population	1		
Town population	0.209	1	
County population	0.235	0.788*	1
Value added per capita	0.111	0.841*	0.897*

Note: * Significant at the 0.05 level

Table 7-14 presents the inter-provincial in-migration rates, out-migration rates and net migration rates of various populations. With regard to total population, the eight regions with high inter-provincial in-migration rates over 0.8% are as follows: Beijing (3.35%), Shanghai (3.04%), Ningxia (2.13%), Tianjin (1.62%), Xinjiang (1.43%), Hebei (1.04%), Liaoning (0.83%) and Inner Mongolia (0.82%). Beijing, Shanghai and Tianjin are three leading municipalities in China. Liaoning has been an important industrial base of China since the beginning of this century and is highly urbanized and industrialized. They are the main destinations of inter-provincial migrations. Hebei benefits from its easy access to Beijing and Tianjin which are surrounded by Hebei. Thus Hebei becomes the second best choice for those organizations and migrants who are not able to move into Beijing. Ningxia, Xinjiang and Inner Mongolia have been the traditional destinations of inter-provincial migrations since the 1950s. The migration flows into these regions are still significant though they may also experience a large amount of out-migrations.

The nine regions with high inter-provincial out-migration rates over 0.8% are as follows: Qinghai (2.40%), Xinjiang (1.70%), Heilongjiang (1.33%), Ningxia (1.17%), Jilin (1.02%), Beijing (1.01%), Inner Mongolia (1.00%), Shaanxi (0.92%), and Gansu (0.90%). Most of these regions except Beijing received a large amount of in-migrations in the pre-reform period. It seems that many migrants are leaving these regions in the current reform period as more relaxed and flexible policies have been introduced. Beijing, as the capital of the country, has a lot of personnel exchanges with the rest of the country. It is not surprising that its out-migration rate is also high.

Net migration rate is the difference between the in-migration rate and the out-migration rate. Figure 7-2 shows the net inter-provincial in-migration rates of various regions. Shanghai (2.38%), Beijing (2.34%), Tianjin (1.05%), Ningxia (0.96%), Hebei (0.39%) have net in-migration rates over 0.30%. All these regions have high in-migration rates over 0.8%. Only Beijing and Ningxia also have high out-migration rates over 0.8%. But their in-migration rates are much greater than their out-migration rates. The case of Ningxia is particularly interesting. Ningxia is one of those regions which received many migrants in the pre-reform period. But it still gains population through migration while most of these regions are losing population through migration in the current reform period. The reason is that Ningxia are experiencing substantial constructions including mineral and industrial development. Qinghai (-1.72%), Heilongjiang (-0.77%), Gansu (-0.45%), Guangxi (-0.38%) and Jilin (-0.30%) have net out-migration rates under -0.30%. All these regions except for Guangxi received many migrants in the pre-reform period and now have high out-migration rates. The high net out-migration rate in Guangxi is due to its low in-migration rate of only 0.15%, the lowest among the 28 provincial regions. In total, ten regions have net in-migrations while eighteen regions have net out-migrations. All those regions with net in-migrations except for Hubei and Ningxia are in the eastern economic zone.

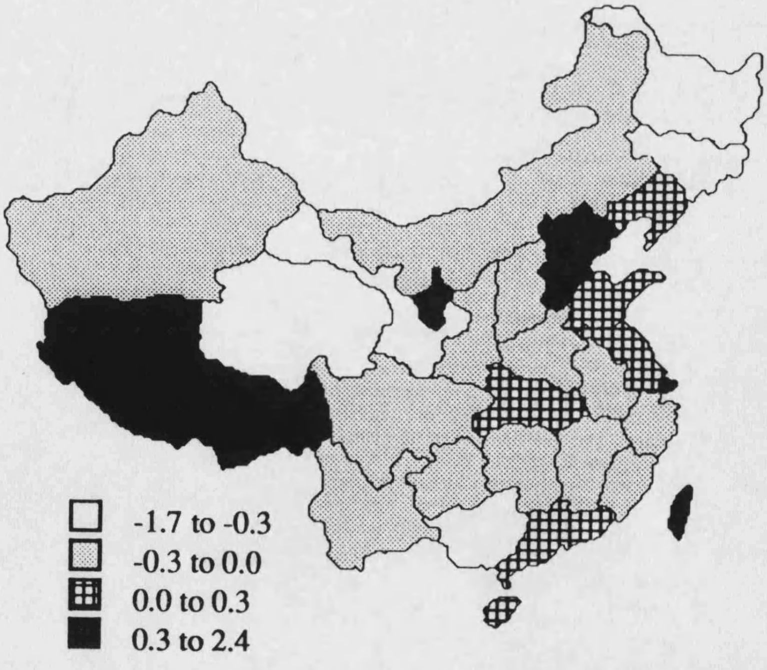

Figure 7-2 Net inter-provincial migration rates in China 1982-1987 (%)

Table 7-14 In-migration rates, out-migration rates and net migration rates of inter-provincial migrations (%)

Region	City			Town		
	IR	OR	NR	IR	OR	NR
Beijing	4.56	1.43	3.13	1.87	0.13	1.74
Tianjin	2.00	0.69	1.31	1.67	0.06	1.61
Hebei	4.20	1.04	3.16	0.47	0.13	0.34
Shanxi	1.74	0.92	0.82	0.26	0.08	0.18
Inner Mongolia	1.63	1.19	0.44	0.71	0.53	0.18
Liaoning	1.12	0.88	0.24	0.79	0.11	0.68
Jilin	0.67	0.94	-0.27	0.90	0.16	0.74
Heilongjiang	1.05	1.04	0.01	0.40	0.33	0.07
Shanghai	3.83	1.07	2.76	3.53	0.13	3.40
Jiangsu	2.42	1.12	1.30	1.10	0.20	0.90
Zhejiang	0.55	0.56	-0.01	0.41	0.17	0.24
Anhui	1.06	0.78	0.28	0.48	0.14	0.34
Fujian	0.68	0.91	-0.23	0.29	0.14	0.15
Jiangxi	0.95	1.03	-0.08	0.35	0.26	0.09
Shandong	0.82	0.31	0.51	1.06	0.09	0.97
Henan	1.42	0.94	0.48	0.37	0.13	0.24
Hubei	1.93	1.61	0.32	0.45	0.04	0.41
Hunan	2.21	4.74	-2.53	0.32	0.09	0.23
Guangdong	1.23	0.75	0.48	2.13	0.14	1.99
Guangxi	1.05	1.79	-0.74	0.17	0.14	0.03
Sichuan	1.53	0.92	0.61	0.62	0.09	0.53
Guizhou	1.24	0.67	0.57	0.70	0.09	0. 61
Yunnan	0.76	0.79	-0.03	0.67	0.18	0.49
Shaanxi	2.60	2.04	0.56	0.79	0.12	0. 67
Gansu	1.74	3.22	-1.48	0.78	0.25	0.53
Qinghai	3.28	5.73	-2.45	0.36	2.08	-1.72
Ningxia	13.98	4.99	8.99	0.92	0.18	0.74
Xinjiang	3.06	3.68	-0.62	1.20	0.61	0.59
Total	1.72	1.16	0.56	0.69	0.50	0.19

Notes:
1: underlined numbers indicate noteworthy rates.
2: IR---in-migration rate.
3: OR---out-migration rate.
4: NR---net migration rate.

Considering next the inter-provincial migrations of the city population, the ten regions with high in-migration rates over 2.0% are as follows: Ningxia (14.0%), Beijing (4.56%), Hebei (4.20%), Shanghai (3.83%), Qinghai (3.28%), Xinjiang (3.06%), Shaanxi (2.60%), Jiangsu (2.42%), Hunan (2.21%) and Tianjin (2.00%). Beijing, Tianjin, Hebei, Shanghai and Jiangsu are the more developed regions in the eastern economic zone. The remaining regions also have high out-migration rates over 2.0%. In addition, Gansu also has a high out-migration rate of 3.22%.

Table 7-14 In-migration rates, out-migration rates and net migration rates of inter-provincial migrations (continued)

Region	County			Total		
	IR	OR	NR	IR	OR	NR
Beijing	1.57	0.44	1.13	3.35	1.01	2.34
Tianjin	0.81	0.41	0.40	1.62	0.57	1.05
Hebei	0.29	0.68	-0.39	1.04	0.65	0.39
Shanxi	0.24	0.83	-0.59	0.61	0.67	-0.06
Inner Mongolia	0.40	1.06	-0.66	0.82	1.00	-0.18
Liaoning	0.56	0.70	-0.14	0.83	0.61	0.22
Jilin	0.54	2.30	-1.76	0.72	1.02	-0.30
Heilongjiang	0.35	2.35	-2.00	0.56	1.33	-0.77
Shanghai	1.83	0.17	1.66	3.04	0.66	2.38
Jiangsu	0.38	0.47	-0.09	0.75	0.51	0.24
Zhejiang	0.16	0.77	-0.61	0.30	0.58	-0.28
Anhui	0.15	0.49	-0.34	0.31	0.48	-0.17
Fujian	0.24	0.34	-0.10	0.32	0.39	-0.07
Jiangxi	0.14	0.31	-0.17	0.28	0.41	-0.13
Shandong	0.41	0.70	-0.29	0.69	0.43	0.26
Henan	0.18	0.36	-0.18	0.33	0.40	-0.07
Hubei	0.24	0.33	-0.09	0.54	0.44	0.10
Hunan	0.18	0.32	-0.14	0.38	0.65	-0.27
Guangdong	0.03	0.17	-0.14	0.47	0.24	0.23
Guangxi	0.06	0.58	-0.52	0.15	0.53	-0.38
Sichuan	0.16	0.47	-0.31	0.37	0.45	-0.08
Guizhou	0.10	0.43	-0.33	0.37	0.40	-0.03
Yunnan	0.13	0.52	-0.39	0.30	0.52	-0.22
Shaanxi	0.21	0.84	-0.63	0.73	0.92	-0.19
Gansu	0.18	0.68	-0.50	0.45	0.90	-0.45
Qinghai	0.10	1.65	-1.55	0.68	2.40	-1.72
Ningxia	0.33	0.74	-0.41	2.13	1.17	0.96
Xinjiang	0.80	1.12	-0.32	1.43	1.70	-0.27
Total	0.24	0.56	-0.32	0.59	0.59	0.0

Notes:
1: underlined numbers indicate noteworthy rates.
2: IR---in-migration rate.
3: OR---out-migration rate.
4: NR---net migration rate.

Ningxia (8.99%), Hebei (3.16%), Beijing (3.13%), Shanghai (2.76%), Tianjin (1.31%) and Jiangsu (1.30%) all have high net in-migration rates over 1.0%. All these regions have high in-migration rates. Only Ningxia also has a high out-migration rate. Hunan (-2.53%), Qinghai (-2.45%) and Gansu (-1.48%) have net out-migration rates under -1.0%. All of these regions have high out-migration rates. Hunan and Qinghai also have high in-migration rates. In total, eighteen regions have net in-migrations while ten regions have net out-migrations.

As for the inter-provincial migrations of the town population, some seven regions have high in-migration rates over 1.0% and these are as follows: Shanghai (3.53%), Guangdong (2.13%), Beijing (1.87%), Tianjin (1.67%), Xinjiang (1.20%), Jiangsu (1.10%) and Shandong (1.06%). All of them except for Xinjiang are more developed regions in the eastern economic zone. Xinjiang is one of the traditional destinations of inter-provincial migrations. The out-migration rates of most regions are less than 1.0% so that most regions have net in-migrations of the town population. Some of these in-migrations are from the city and the county populations. Only Qinghai has a high out-migration rate of 2.08% and net out-migration rate of -1.72%. The eight regions with net in-migration rates over 0.7% are as follows: Shanghai (3.40%), Guangdong (1.99%), Beijing (1.74%), Tianjin (1.61%), Shandong (0.97%), Jiangsu (0.90%), Jilin (0.74%) and Ningxia (0.74%). All of them have high in-migration rates over 0.90%.

Lastly for the inter-provincial migrations of the county population, some ten regions have high in-migration rates over 0.3%. They are as follows: Shanghai (1.83%), Beijing (1.57%), Tianjin (0.81%), Xinjiang (0.80%), Liaoning (0.56%), Jilin (0.54%), Shandong (0.41%), Inner Mongolia (0.40%), Jiangsu (0.38%) and Heilongjiang (0.35%). As pointed out before, Xinjiang, Jilin, Inner Mongolia and Heilongjiang are traditional regions of agricultural in-migrations in China. The remaining regions are in the more developed eastern economic zone. The eleven regions with high out-migration rates over 0.70% are: Heilongjiang (2.35%), Jilin (2.30%), Qinghai (1.65%), Xinjiang (1.12%), Inner Mongolia (1.06%), Shaanxi (0.84%), Shanxi (0.83%), Zhejiang (0.77%), Ningxia (0.74%), Liaoning (0.70%) and Shandong (0.70%). The relatively high out-migration rates in Heilongjiang, Jilin, Qinghai, Xinjiang and Inner Mongolia which are traditional regions of agricultural in-migrations may result from return migrations. All regions except three municipalities have net out-migrations of the county population as there are net migrations to the city and town populations. The nine regions with a net out-migration rate under -0.5% are made up of: Heilongjiang (-2.00%), Jilin (-1.76%), Qinghai (-1.55%), Inner Mongolia (-0.66%), Shaanxi (-0.63%), Zhejiang (-0.61%), Shanxi (-0.59%), Guangxi (-0.52%) and Gansu (-0.50%). All of them except for Zhejiang, Shanxi and Guangxi are among those regions which received many migrants in the pre-reform period. Some migrants may leave these regions in the current period. Zhejiang, Shanxi and Guangxi are also losing their county populations through migration. In the case of Zhejiang, many rural people have moved to other regions to engage in various kinds of small business.

According to the analysis above, some five regions have substantial net in-migrations. The three municipalities Beijing, Tianjin and Shanghai have relatively great net in-migrations of city, town and county populations. Ningxia receives high net inflows of city and town populations. Hebei on the other hand only seems to have high net in-migration of city population. The net in-migrations of city and town populations play the major role in determining the net in-migrations in these regions. Some five regions have substantial net out-migrations. Qinghai has substantial net out-migrations of city, town and county populations. Gansu loses significant amount of population through net out-migrations of city and county populations. Heilongjiang, Jilin and Guangxi on the other hand only seem to lose large amounts of people through net out-migration of county population. The net out-migration of county population plays the major role in determining the net out-migrations in these regions.

7.4.4 Inter-provincial migration direction and flow

Migration directions and flows are different in various regions and can only be analyzed via origin and destination specific migration flows. In this section, an inter-provincial migration matrix is used as a basis for an analysis of inter-provincial migration directions and flows in the period 1982-1987 in China.

The seven regions which have more than 3000 in-migrations (1% sampling population) are Hebei, Liaoning, Shanghai, Jiangsu, Shandong, Guangdong and Sichuan. The seven regions which have more than 3000 out-migrations are Hebei, Heilongjiang, Jiangsu, Shandong, Henan, Hunan and Sichuan. Hebei, Jiangsu, Shandong have net in-migrations and Sichuan has net out-migrations though they both have more than 3000 in-migrations and 3000 out-migrations. Liaoning, Shanghai and Guangdong have net in-migrations dominated by high in-migration flows. Heilongjiang, Henan and Hunan have net out-migrations dominated by high out-migration flows. It can be usefully noted that most of the coastal provinces including Liaoning, Beijing, Tianjin, Hebei, Shandong, Jiangsu, Shanghai, Guangdong have net in-migrations though Zhejiang, Fujian and Guangxi do not confirm to this generalization.

A detailed migration direction analysis will be carried out for each region. The main destination provinces of out-migrations and origin provinces of in-migrations are identified for each province. These main destination or origin provinces are defined as the four major destination or origin provinces and the additional provinces which have more than 200 in-migrations (1% sampling figures) from or out-migrations to the province concerned. It is found that most of the main destination or origin provinces are neighbouring provinces of the province concerned indicating the sensitivity of migration to distance. The results are presented in appendix C. Only four regions will be considered here. Beijing and Shanghai are two developed municipalities in the eastern economic zone. Heilongjiang and Xinjiang are two less developed regions in the middle and western economic zones respectively. They received many migrants in the pre-reform period and now are losing population through migration.

Beijing has a high net in-migration rate 2.34%. The main out-migration destination regions are Jiangsu (87---number of migrations, 1% sampling figure), Hunan (73), Shandong (70) and its neighbour Hebei (206). The main in-migration origin regions are Shanxi (204), Shandong (184), Sichuan (178) and its neighbour Hebei (904). The migration link between Beijing and Hebei is really strong.

Shanghai has a high net in-migration rate 2.38%. The main out-migration destination regions are Beijing (49), Henan (27) and its neighbours Jiangsu (347), Zhejiang (101). The main in-migration origin regions are Jiangxi (190), Anhui (72) and its neighbours Jiangsu (1024), Zhejiang (533). It is not surprising that there are strong migration links among Shanghai, Jiangsu and Zhejiang which form the core regions of Shanghai economic zone.

Heilongjiang has a high net out-migration rate 0.77%. The main out-migration destination regions are Shandong (1380), Liaoning (1044), Hebei (278) and its neighbours Jilin (610), Inner Mongolia (253). The main in-migration origin regions are Shandong (604), Liaoning (342) and its neighbours Jilin (405), Inner Mongolia (187). Note that there has been a traditional migration link between Heilongjiang and Shandong.

Xinjiang has a net out-migration rate 0.27%. The main out-migration destination regions are Jiangsu (450), Sichuan (432), Shaanxi (242), Henan (225). The main in-migration origin regions are Sichuan (609), Shandong (363), Jiangsu (173) and its neighbour Gansu (150). The long distance migrations between Xinjiang and Shandong and Jiangsu are particularly impressive. Shandong and Jiangsu have been sending migrants to Xinjiang since the 1950s.

To identify the main migration directions in China, the main inter-provincial migration flows over 200 among eastern economic zone, middle economic zone and western economic zone of China are summarized in table 7-15. It is clear that the main migration directions are from the less developed middle and western economic zones to the more developed eastern economic zone. There are only two exceptions. One is the migration flow from Hebei in the eastern economic zone to Henan in the middle economic zone. Another is a slight net migration flow from Guangdong in the eastern zone to Hunan in the middle zone. The migration flows in both directions are 479 and 485 persons (1% sampling figure) respectively. There are only a few migration flows over 200 persons between the middle and western economic zones. Three migration flows are from the western zone to the middle zone. Two net migration flows from Henan to Shaanxi and

Table 7-15 Migration directions among eastern, middle and western economic zones of China (migration flow over 200)

Middle Economic zone	Eastern economic zone						
	Beijing	Hebei	Liaoning	Shanghai	Jiangsu	Shandong	Guangdong
Shanxi	--->	::::::>					
Inner Mongolia		::::::>					
Jilin			::::::>			::::::>	
Heilongjiang		--->	::::::>			::::::>	
Anhui				--->	::::::>		
Henan		<---					
Hubei						--->	
Hunan		--->					<::::::

Western Economic zone	Eastern economic zone						
	Beijing	Hebei	Liaoning	Shanghai	Jiangsu	Shandong	Guangdong
Sichuan		--->			--->	--->	--->
Yunnan					--->		
Shaanxi		--->			--->		
Gansu						--->	
Xinjiang					--->		

Western Economic zone	Middle economic zone	
	Henan	Hubei
Sichuan	--->	::::::>
Shaanxi	<::::::	--->
Xinjiang	<::::::	

Notes:
1: ---> direction of migration flow over 200.
2: ::::::> direction of net migration with migration flows of both directions over 200.

Xinjiang are in the opposite direction.

Table 7-16 presents the gross and net migration flows among eastern, middle and western economic zones for the period 1982-1987. The migration flows from the middle and western economic zones to the eastern economic zones are two times greater than the migration flows in the opposite directions. There are large net migration flows from the middle and western zone to the eastern zone, 6596 and 3789 persons respectively. The migration flows between the middle and western economic zones are almost equal. There is only a small net migration flow of 705 persons from the middle economic zone to the western economic zone.

The migration pattern discussed above is completely different from the traditional migration pattern in the pre-reform period 1949-1978. The main migration directions in the traditional migration pattern were from the eastern economic zone to the middle economic zone and western economic zone in China (Hu and Zhang, 1984; Tian and

Table 7-16 Migration flows among eastern, middle and western economic zones of China 1982-1987

Origin \ Destination	Eastern zone	Middle zone	Western zone
	Gross migration flow		
Eastern zone	*	7426	2847
Middle zone	14022	*	3084
Western zone	6636	3789	*
	Net migration flow		
Eastern zone	0	*	*
Middle zone	6596	0	*
Western zone	3789	705	0

* These flows are irrelevant here

Zhang, 1989). This transition of the migration pattern is due to changes of the migration mechanism and the economic reforms in China since the late 1970s. First, a number of migrations from the eastern economic zone to the middle and western economic zones before 1978 are organized migrations for various construction and development programmes in these regions. Some migrants may be reluctant to be relocated to these regions. With the introduction of economic reforms since 1978, more flexible measures have been introduced with regard to migration and some migrants have been allowed to return to their origin or developed regions in the eastern economic zone for various reasons. Second, it seems that the strategies of regional development have been shifted to the coastal areas in the eastern economic zone to make full use of locational, economic and technological advantages in these regions.

For a long time since the foundation of the People's Republic, the government has emphasized the economic development in the inland provincial regions in China which are less developed. There are three main considerations. The first consideration is the regional balance of economic development. Most old industrial bases were located in the coastal areas when the People's Republic was founded in 1949. The second consideration is the national union of China. Most national minorities reside in the less developed areas far from the coastal regions. The last is the strategic consideration of national defence. It was believed that the old industrial bases in the coastal areas may be easily destroyed in case of foreign invasion. Therefore, many transportation and industrial development projects have been carried out in the middle and western economic zones. The share of the state investment in the middle and western economic zones increased from 49% in 1953 to 68% by 1965. This proportion was still over 50% by 1978 (SSB, 1987). However, such large amount of investment in the less developed regions did not produce substantial economic growth. The share of industrial output in the middle and western economic zones increased from 31% in 1952 to 41% by 1965. Then it decreased again to 39% by 1978 (Department of Industry and Transportation Statistics, 1991). The economic performance of the middle and western economic zones is poor. According to the second industry census conducted in 1985 (Office of the Industry Census et al., 1986), the average profit and taxation earned by manufacturing firms per hundred yuan (the unit of Chinese currency) of fixed capital was higher in the eastern zone than in the middle and western zones. For example, the average profit and taxation per hundred yuan of fixed capital was 35 yuan in Jiangsu in the eastern zone while it was only 15 yuan in Guizhou in the western zone in 1985. Thus it was natural to shift the priority of economic development to the eastern economic zone when China attempted to speed up its socio-economic development in the late 1970s. The share of state investment in the eastern economic zone increased to 52% by the year 1985 (SSB, 1987). It is also recognized that the eastern economic zone has well-educated and skilled labour force and has easy access to the outside world which has been a stimulating factor in the recent development in China. Economic reforms and open door policies have been implemented much earlier and fast in the eastern economic zone. Many regions in the eastern economic zone, notably Jiangsu, Zhejiang and Guangdong, have gained rapid economic growth since the late 1970s. The rapid economic growth in these regions has certainly brought about many opportunities for migrants from other regions (Zhang and Shen, 1991).

7.5 Explanatory model of regional in-migration rate

An explanatory analysis of regional (inter-provincial) in-migration and out-migration rates of China will be carried out in this and the next section. These will be estimated using cross-sectional data for the 28 mainland provinces of China excluding Tibet. Hainan is included in Guangdong province. Various socio-economic variables will be used in the step-wise regression analysis in an attempt to establish optimal regression models.

The following regional data have been obtained or calculated from the official sources (SSB, 1989; DPS, 1988a; 1988b). Only the inter-provincial migrations in the one-year period 1986-1987 are included in this analysis. The variables are defined as follows:

m^i = inter-provincial in-migration rate, %, 1986-1987

m^o = inter-provincial out-migration rate, %, 1986-1987

x_1 = value added per capita, Yuan, 1987

x_2 = net income per peasant, Yuan, 1987

x_3 = total production value index in terms of 1986, 1987

x_4 = population density, persons per square km, 1987

x_5 = farmland per peasant, hectare, 1988

x_6 = proportion of agricultural production value in total production value, %, 1987

x_7 = proportion of agricultural employees in total employees, %, 1987

x_8 = proportion of urban population based on 1982 census definition, %, 1987

x_9 = proportion of population aged 15-29 in total population, %, 1987

x_{10} = migration index of education, 1987

x_{11} = migration index in the pre-reform period

Eight variables x_1 - x_8 are potential explanatory variables for inter-provincial in-migration rate. Twelve variables x_1 - x_{11} and m^i are potential explanatory variables for inter-provincial out-migration rate. Table 7-17 presents the correlation coefficients of these variables.

Two variables are used to describe the level of economic development. Value added per capita (x_1) is calculated on the basis of the whole population of each region. It is well known that the registered agricultural population still accounts for significant proportions of the population and employment in China and that a significant number of inter-provincial migrants are peasants (see tables 7-8 and 7-9). Thus another variable, net income per peasant based on the registered agricultural population (x_2), is used to describe the level of economic development. It turns out that these two variables are significantly correlated with a correlation coefficient of 0.937. This is not surprising as the peasants in the developed regions with a high level of value added per capita have more opportunities to engage in non-agricultural activities such as township industries thus earn higher income than those in the less developed regions.

The total production value index (x_3) is used to describe the economic growth rate. According to table 7-17, it is not significantly correlated with the level of economic development. The economic growth rate is more likely to be affected by short-term factors while the level of economic development is the result of long-term development and is more stable.

Two variables, the population density (x_4) and the farmland per peasant (x_5), are used to describe the land-population relations. These two variables are negatively correlated. Peasants in densely populated regions may have less arable land than those in less populated regions. Population density is positive and significantly correlated with the level of economic development. This is due to a basic feature in China that developed regions usually have a high population density (see chapter five). However, farmland per peasant is not significantly correlated with the level of economic development. This means that peasants in developed regions are not necessary have less arable land. Here two opposite forces are in operation. On the one

Table 7-17 Correlation coefficients of the in-migration and out-migration rates with the potential explanatory variables

	m^i	m^o	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}
m^i	1											
m^o	0.297*	1										
x_1	0.828	0.059*	1									
x_2	0.754	0.007*	0.937	1								
x_3	-0.252*	-0.375			1							
x_4	0.629	-0.238*	0.871	0.806		1						
x_5	-0.043*	0.552			-0.439	-0.399	1					
x_6	-0.680	-0.087*	-0.819	-0.758		-0.596		1				
x_7	-0.771	-0.188*	-0.907	-0.900		-0.650		0.850	1			
x_8	0.423	-0.038*	0.580	0.636				-0.662	-0.678	1		
x_9	-0.329*	0.263*	-0.408	-0.396		-0.620	-0.606				1	
x_{10}	0.869	0.143*	0.880	0.833		0.653		-0.812	-0.911	0.641		1
x_{11}	-0.043*	0.694		-0.394	-0.507	-0.479	0.739					

Notes: * Not significant at the 0.05 level
(a) for key to entries see text.
(b) most correlation coefficients which are insignificant at the 0.05 level are omitted.

hand, arable land may be decreasing as it is used for non-agricultural purposes in developed regions. On the other hand, more and more peasants may engage in non-agricultural activities and eventually become urban population. As a result, the remaining peasants may have more arable land.

Three variables, the proportion of agricultural production value (x_6), the proportion of agricultural employees (x_7) and the proportion of urban population (x_8), are used to describe economic and population structures. The urban population data are based on the 1982 census definition as only these data are available for the provincial regions in the year 1987. These three variables are significantly correlated each other. These variables are also significantly correlated with the value added per capita and net income per peasant as expected. In particular, the proportions of agricultural production value and agricultural employees have large correlation coefficients of over 0.8 with the value added per capita. The proportion of urban population has a much smaller coefficient of 0.58 with the value added per capita due to its imprecise nature of definition. This is also the reason why the urban population definition based on the actual urban non-agricultural employment is preferable and is used in chapter two and chapter four.

Now consider the correlation coefficients of the regional in-migration rate with these potential explanatory variables. The in-migration rate is positively and significantly correlated with the value added per capita (x_1), the net income per peasant (x_2), the population density (x_4) and the proportion of urban population (x_8). The in-migration rate is negatively and significantly correlated with the proportion of agricultural production value (x_6) and the proportion of agricultural employees (x_7). The correlation coefficients of the in-migration rate with the total production value index and the farmland per peasant are insignificant at the 0.05 level.

Except for the correlation between the population density and the proportion of urban population, all those explanatory variables which are significantly correlated with the in-migration rate are significantly correlated each other. They are more or less related to the level of economic development. It is not surprising that the value added per capita has the largest correlation coefficient of 0.826 with the inter-provincial in-migration rate. It means that the level of economic development plays a significant role in attracting inter-provincial in-migrations in China. The developed regions do have high in-migration rates.

According to migration theories, the level of economic development, the economic growth rate and the arable land are 'pull' factors while the population density is a 'push' factor to potential migrants. The signs of correlation coefficients with the in-migration rate are correct for all variables related to the level of economic development (x_1, x_2, x_6, x_7, x_8). However, the signs are not correct for three variables including the total production value index (x_3), the population density (x_4) and the farmland per peasant (x_5). Only the population density has a significant correlation with the in-migration rate at the 0.05 level. This is likely due to the significant correlation of the population density with the level of economic development. The expected effects of these three variables on migration are not observable in this cross-sectional data set of China. These three variables are not considered in the following step-wise regression analysis.

The step-wise regression method is used to establish an optimal regression equation for regional in-migration rate using five explanatory variables including x_1, x_2, x_6, x_7, x_8. The estimated optimal linear regression equation is as follows:

$$m^i = -0.05 + \underset{(7.52)}{0.002403}\, x_1 \qquad (7\text{-}2)$$

$R^2 = 0.685 \qquad \text{Adj. } R^2 = 0.673 \qquad F = 56.553$

Only the value added per capita (x_1) appears in the equation. The t statistics of the regression coefficient of the value added per capita is significant at the 0.05 level. The F statistic of the regression equation is also significant at the 0.05 level.

Figure 7-3 presents the scattergram of the in-migration rate model with the 95% confident bands. Table 7-18 presents the fixed values and standardized residuals of the regional in-migration rates. Beijing has a large positive standardized residual of 3.450. Its in-migration rate is underpredicted by the in-migration rate model (7-2). As the capital of China, it is not surprising that Beijing has a high in-migration rate. The

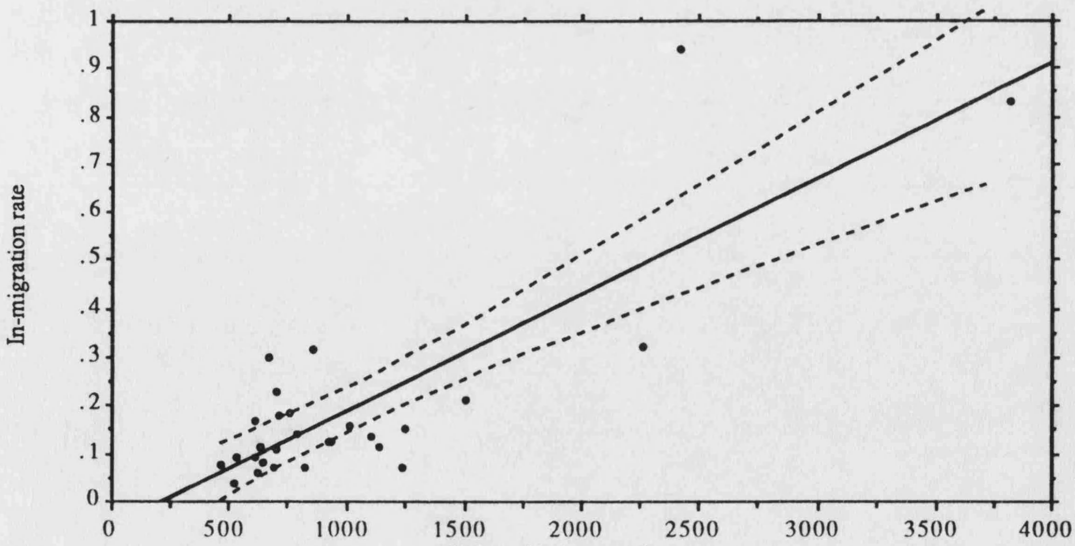

Figure 7-3 Regression scattergram of the in-migration rate model

Table 7-18 Fitted values and standardized residuals of regional in-migration rates

Region	m^i (%)	Fitted m^i (%)	Standardized residual
Beijing	0.9421	0.529	3.450
Tianjin	0.3251	0.494	-1.409
Hebei	0.1442	0.140	0.037
Shanxi	0.1789	0.120	0.496
Inner Mongolia	0.2287	0.118	0.925
Liaoning	0.2104	0.312	-0.853
Jilin	0.1562	0.194	-0.314
Heilongjiang	0.1168	0.223	-0.884
Shanghai	0.8298	0.866	-0.307
Jiangsu	0.1555	0.250	-0.792
Zhejiang	0.0727	0.248	-1.464
Anhui	0.0713	0.113	-0.351
Fujian	0.0694	0.145	-0.636
Jiangxi	0.0605	0.098	-0.317
Shandong	0.1246	0.174	-0.416
Henan	0.0828	0.104	-0.175
Hubei	0.1281	0.172	-0.366
Hunan	0.1077	0.118	-0.083
Guangdong	0.1371	0.213	-0.638
Guangxi	0.0360	0.074	-0.321
Sichuan	0.0932	0.094	-0.009
Guizhou	0.0769	0.061	0.130
Yunnan	0.0950	0.076	0.160
Shaanxi	0.1710	0.096	0.631
Gansu	0.1125	0.101	0.094
Qinghai	0.1859	0.131	0.456
Ningxia	0.3009	0.109	1.602
Xinjiang	0.3165	0.155	1.353

Note: m^i is the regional in-migration rate.

migrations into Beijing involve not only those migrants employed by various firms, but also those employed in the central government and large public organizations which are concentrated in the capital. The in-migration rates in Ningxia, Xinjiang and Inner Mongolia are also underpredicted by the in-migration rate model. These regions were the main destination regions in the pre-reform period before 1978. It seems that they maintained relatively high in-migration rates. However, their in-migration rates are balanced by out-migrations from these regions. Only Ningxia managed to keep a significant net in-migration rate.

The in-migration rates in Tianjin and Zhejiang are overpredicted by the model. Tianjin as one of three municipalities in China does have a high in-migration rate but it is significantly less than two other municipalities, Beijing and Shanghai. Many migrants may be attracted to its neighbor Beijing. Zhejiang has a high level of economic development. This has been achieved mainly by the development of collective and township industries and the utilization of its well-educated and skilled labour force. Thus Zhejiang has a relatively small in-migration rate like many less developed but equally populous regions such as Anhui and Jiangxi.

Overall, the analysis in this section shows that the level of economic development, the value added per capita in particular, plays a decisive role in the inter-provincial in-migrations in China. This is in accord with migration theories that migrants are attracted by economic opportunities in destination regions.

7.6 Explanatory model of regional out-migration rate

The step-wise regression method is again used to establish an optimal regression equation for regional out-migration rate. In addition to eight socio-economic variables considered in the previous section, four more variables are considered. These are the inter-provincial in-migration rate (m^i), the proportion of population aged 15-29 (x_9), the migration index of education (x_{10}) and the migration index in the pre-reform period (x_{11}).

The in-migration rate is considered as a potential explanatory variable for the out-migration rate as a high out-migration rate is often associated with a high in-migration rate. According to table 7-17, the in-migration rate does have positive but insignificant correlation with the out-migration rate. The proportion of population aged 15-29 is used to describe the age composition of population as young people often have a high migration rate. It is also positively but insignificantly correlated with the out-migration rate. It does have significant but negative correlation with the value added per capita and the net income per peasant. This means that some more developed regions have a smaller proportion of population aged 15-29 than less developed regions.

The migration index of education (x_{10}) is used to describe the educational level of the population and its possible effect on the out-migration rate. The migration index of education is calculated by applying different out-migration rates to various population proportions with university education, higher-middle school education, lower-middle school education, primary school education and the proportion of illiterate and semi-illiterate population. The five-year inter-provincial out-migration rates of various populations with different educational levels in 1982-1987 are used as weights in the calculation of the migration index of education. These weights are 0.05824 for the population with university education, 0.01548 for the population with higher-middle school education, 0.00792 for the population with lower-middle school education, 0.00393 for the population with primary school education and 0.000315 for the illiterate and semi-illiterate population.

The migration index of education is significantly correlated with many variables related to the level of economic development. This is not surprising as the people in the more developed regions usually have a higher educational level than those in the less developed regions. The migration index of education is positively but insignificantly correlated with the out-migration rate.

A new pattern of inter-provincial migration has emerged in the reform-period since 1978. Many migrants appear to be moving out of those regions which received many migrants during the pre-reform period before 1978. It is expected that the out-migration rate may be positively correlated with the level of in-migrations in the pre-reform period. Thus a dummy variable called migration index in the pre-reform period is considered as a potential explanatory variable for the out-migration rate. The regional values of the dummy variable are based on Sun (1984). A value of three is assigned to five regions including Inner Mongolia, Heilongjiang, Qinghai, Ningxia and Xinjiang which received large number of net migrants in the pre-reform period. A value of two is assigned to six regions including Jilin, Jiangxi, Guizhou, Yunnan, Shaanxi, Gansu which received small number of net migrants in the same period. A value of one is assigned to all other regions.

According to table 7-17, the migration index in the pre-reform period does have positive and significant correlation with the out-migration rate. It is also negatively and significantly correlated with the net income per peasant, the total production value index and the population density. It is positively and significantly correlated with the farmland per peasant. This is in accord with the fact that the main migration direction in the pre-reform period is toward less developed, less populated regions with more arable land.

Now consider the correlation coefficients of the out-migration rates with eight other potential explanatory variables in table 7-17. It appears that the signs of the correlation coefficients of the out-migration rate with most variables related to the level of economic development (x_1, x_2, x_6 and x_7) and two variables related to the land-population relation (x_4 and x_5) are not correct. The effects of these 'push' or 'pull' factors are not observable in this particular data set. The out-migration rate does have negative and significant correlation with the total production value index. This may reflect the 'push' effect of a slowly growing economy on its population. The out-migration rate is negatively but insignificantly correlated with the proportion of urban population.

In summary, only six out of twelve potential explanatory variables have correct signs of correlation with the out-migration rate. These are the in-migration rate, the total production value index, the proportion of urban population, the proportion of population aged 15-29, the migration index of education and the migration index in the pre-reform period. These six variables are used in the following step-wise regression analysis to establish an optimal explanatory model for the inter-provincial out-migration rate.

The estimated optimal linear regression model is:

$$m^o = 0.028 + \underset{(5.507)}{0.07\, x_{11}} + \underset{(2.546)}{0.123\, m^i} \qquad (7\text{-}3)$$

$R^2 = 0.588 \qquad \text{Adj. } R^2 = 0.555 \qquad F = 17.838$

The migration index in the pre-reform period and the in-migration rate appear in the regression equation (7-3). The t statistics of their regression coefficients are significant at the 0.05 level. The F statistic of the regression equation is also significant at the 0.05 level.

It is not surprising that the migration index in the pre-reform period appears in the optimal regression model (7-3) as it has the largest correlation coefficient of 0.694 with the out-migration rate. A single regression model can be estimated as follows:

$$m^o = 0.054 + \underset{(4.911)}{0.069\, x_{11}} \qquad (7\text{-}4)$$

$R^2 = 0.481 \qquad \text{Adj. } R^2 = 0.461 \qquad F = 24.114$

Figure 7-4 shows the regression scattergram of equation (7-4). It does show a general trend that out-migration rates are higher in those regions with larger migration indexes in the pre-reform period. The total production value index has a significant correlation with the out-migration rate. It does not appear in the optimal regression equation (7-3) probably due to its significant correlation with the migration index in the

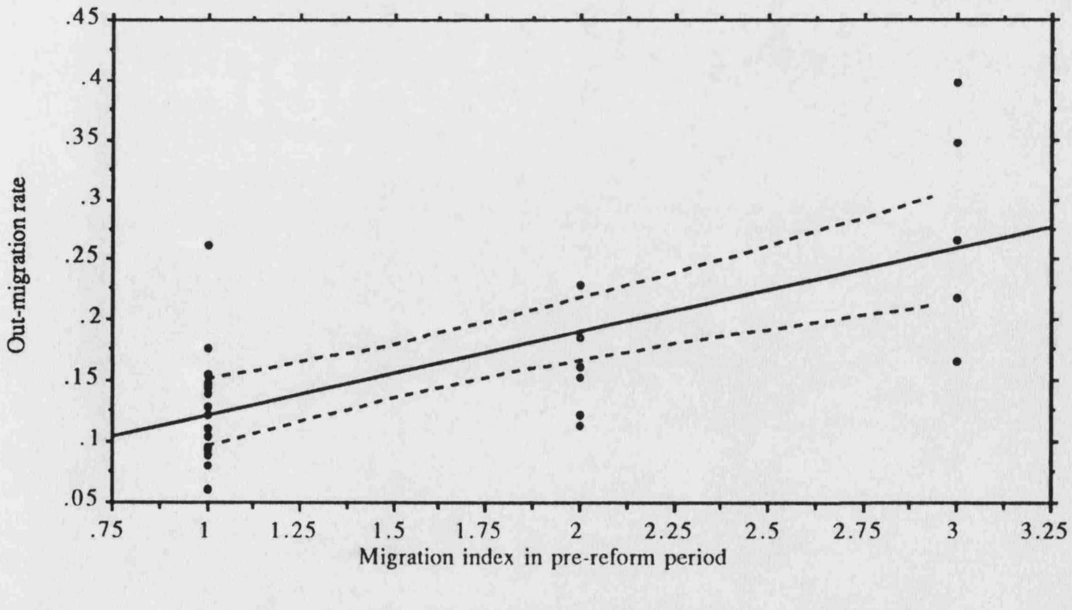

Figure 7-4 Regression scattergram of the out-migration rate model (7-4)

pre-reform period.

The in-migration rate is not significantly correlated with the out-migration rate at the 0.05 level. However, further analysis shows that it has extra power in explaining the standardized residuals of the out-migration rate of the regression equation (7-4). A single regression model is estimated as follows:

$$\text{Standardized residual of out-migration rate} = -0.42 + \underset{(2.593)}{2.127}\ m^i \qquad (7\text{-}5)$$

$R^2 = 0.205$ Adj. $R^2 = 0.175$ $F = 6.724$

The contribution of the in-migration rate is not large as indicated by a small R^2 of 0.205. Nevertheless, the F-statistic of equation (7-5) is significant at the 0.05 level. The reason why the in-migration rate entered in the optimal regression model (7-3) as a second significant explanatory variable for the out-migration rate is that the in-migration rate and the migration index in the pre-reform period represent two contrasting kinds of out-migrations. One kind of out-migration is from those regions which received many migrants in the pre-reform period. This is explained by the migration index in the pre-reform period. Another kind of out-migration is from those regions which currently have high in-migration rates. This, of course, is explained by the in-migration rate. This is in accord with migration theories that a large migration flow from one region to another is often associated with a large flow in the opposite direction. Such phenomenon occurs as solid information and relative networks may have been established which may facilitate migrations between two regions.

Now consider the residuals from the optimal regression model (7-3). Table 7-19 presents the fitted values and the standardized residuals of the inter-provincial out-migration rates. Qinghai and Xinjiang have positive standardized residuals over 1.3. The out-migration flows from these two regions in the north-western China are much stronger than the predictions by the model. Actually, these two regions have the largest out-migration rates in China. Many people in these regions, mostly migrants in the pre-reform period, may like to leave as these two regions are far away from the prosperous regions in the east. The out-migration rate is also significantly underpredicted for Zhejiang. This is due to its low in-migration rate. Its out-migration rate is relatively high as many people in Zhejiang are used to seek economic opportunities in other regions and move out of Zhejiang. In this case, 'pull' rather than 'push' factor is in operation.

The out-migration rates are overpredicted for Jiangxi, Guizhou and Ningxia. These regions received certain number of migrants in the pre-reform period. However, out-migration flows are not as strong as predicted by the model. These regions are much close to the prosperous regions in China than Qinghai and Xinjiang. The out-migration rates in Shanghai and Guangdong are also overpredicted by the model. Shanghai and

Table 7-19 Fitted values and standardized residuals of regional out-migration rates

Region	m^o (%)	Fitted m^o (%)	Standardized residual
Beijing	0.2619	0.214	0.924
Tianjin	0.1213	0.138	-0.315
Hebei	0.1557	0.116	0.766
Shanxi	0.1223	0.120	0.047
Inner Mongolia	0.2185	0.267	-0.917
Liaoning	0.1397	0.124	0.306
Jilin	0.2302	0.187	0.818
Heilongjiang	0.2669	0.253	0.269
Shanghai	0.1464	0.200	-1.018
Jiangsu	0.1494	0.117	0.620
Zhejiang	0.1765	0.107	1.331
Anhui	0.1282	0.107	0.412
Fujian	0.0942	0.106	-0.233
Jiangxi	0.1218	0.176	-1.027
Shandong	0.0893	0.113	-0.456
Henan	0.0955	0.108	-0.239
Hubei	0.0809	0.114	-0.624
Hunan	0.1053	0.111	-0.110
Guangdong	0.0602	0.115	-1.041
Guangxi	0.1443	0.102	0.802
Sichuan	0.1105	0.109	0.023
Guizhou	0.1133	0.178	-1.228
Yunnan	0.1523	0.180	-0.526
Shaanxi	0.1865	0.189	-0.051
Gansu	0.1621	0.182	-0.380
Qinghai	0.3980	0.261	2.611
Ningxia	0.1656	0.275	-2.097
Xinjiang	0.3470	0.277	1.331

Note: m^o is the regional out-migration rate.

Guangdong are among the most prosperous regions in China. Therefore, people are less likely to leave these regions.

7.7 Conclusion

A preliminary analysis of migration causes, migration selectivity and migration structure in China has been carried out using 1982-1987 migration data. It seems that there is clear evidence in China to confirm the common laws of migration found in other countries.

Three major causes of migration in China are employment, marriage and joining family. Migrations for employment and joining family are more important in city and town in-migrations than in county in-migrations where marriage is the first major cause. Migrations for employment and joining family are more important at the inter-provincial level than at the intra-provincial level. Most marriage migrations are intra-provincial and these migrations account for nearly 90% of total marriage migrations in China. Study and training are an important cause of in-migrations in the city population as cities are centers of science, technology and education in China. It is interesting that the proportion of retirement migrations in total in-migrations is higher in the county population than in the city and town populations. This means that there is a trend of retirement migration from the urban areas to the rural areas. According to correlation analysis, employment migration is significantly correlated with study and training migration, retirement migration, marriage migration and migration for joining family. It is also found that migrations for employment, study and training are also significantly correlated with value added per capita.

Age and gender selectivity of migration is also clear. The age-groups 15-29, 20-24, 25-29 have much higher proportions in the migration population than in the total population. Gender selectivity is quite different among the city, town and county populations. The gender ratio of the out-migrations from the city population is higher than the gender ratio of the total population. The gender ratios are much higher still in the city to town and city to county migrations where most migrants are male. The gender ratios of the town and county migration populations are much less than the gender ratio of the total population. An important part of migrations in the town and county populations is marriage migration which is dominated by females.

Labor skill selectivity is analyzed via educational and occupational selectivity of migration. The migration population has a higher educational level than the total population. In towns and counties, the educational levels are close in intra-provincial and inter-provincial migration populations. In cities, the proportion with university education is much higher in the inter-provincial migration population stream than in the intra-provincial. Most occupations except peasants have higher proportions in the migration population than in the total population. It seems that occupational selectivity of migration is less clear in the town and county female populations as a significant part of migration is for marriage.

Several points can be summarized with regard to the migration structure and migration directions in China. First, the city population tends to move to its own population. The town population has a tendency to move to its own population at the intra-provincial level but move to the city population at the inter-provincial level. The county population invariably moves to the town population at the intra-provincial level and to the city population at the inter-provincial level.

Second, the county population has a higher out-migration rate but a lower in-migration rate than the town and city populations. There are net migrations from the county population to the town and city populations. The intra-provincial migration rates of the county, town and city populations are higher than the inter-provincial migration rates respectively though the city population has a relatively high inter-provincial migration rate.

Third, the level of economic development plays a major role in attracting inter-provincial migrations especially in the town and county populations. Shanghai, Beijing, Tianjin, Ningxia, Hebei have high net inter-provincial in-migration rates. Most of these regions except Ningxia are in the more developed eastern economic zone. Furthermore, all those regions with net in-migrations except for Ningxia and Hubei are in the eastern economic zone. Qinghai, Heilongjiang, Gansu, Guangxi and Jilin have high net inter-provincial out-migration rates. Most of these regions except Guangxi are in the less developed middle and western economic zones.

Fourth, most large inter-provincial migration flows occur between neighbouring provinces indicating the sensitivity of migration to distance moved. The main migration directions in China in the period 1982-1987 are from the less developed middle and western economic zones to more developed eastern economic zone in China. This migration pattern is completely different from the traditional migration pattern in the pre-reform period 1949-1978. This change is a result of economic reforms since 1978. More flexible measures with regard to migration have been adopted and the strategies of regional development have been shifted to coastal areas in the eastern part of the country. Both of these have stimulated migrations from the less developed zones to the more developed economic zone.

Finally, an explanatory analysis of regional in-migration and out-migration rates was carried out using cross-sectional data of China. It seems that the level of economic development has the most significant effect on the regional in-migration rate and that the migration index in the pre-reform period and the current in-migration level have significant effects on the regional out-migration rate. It is interesting to note that current and previous in-migration flows have significant contributions to the explanation of the regional out-migration rate. On the other hand, the inter-provincial in-migration rate of a region is much more sensitive to its level of economic development.

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8
Multiregional population projection

8.1 Introduction

The main features of the spatial distribution of China's population and regional trends in population change since the 1950s have been examined in chapter five. Fertility, mortality and migration analyses have been carried out to reveal the major factors affecting regional disparities in chapters six and seven. This chapter attempts to construct a multiregional population projection of China at a provincial level. This may reveal the future multiregional population dynamics of the country and the results may be useful for socio-economic planning (Song et al., 1981; Hobcraft, 1989). A precise and straightforward multiregional population projection model based on forward demographic rates will be developed. The model will be calibrated using the 1982 census data and the 1987 one-percent population sampling data (DPS, 1988a; 1988b). It is probably the first attempt to develop a consistent multiregional (provincial level) population model of China and as a result the findings can only be regarded as preliminary.

The forward demographic rates-based approach to multiregional population modelling needs some introductory discussion. It is true that significant progress has already been made in spatial population analysis. There are two kinds of migration data, transition data and movement data, each of which requires different analytical methods (Rees, 1986). The discussion here is confined to transition data. Multiregional population models were developed to link the populations at the beginning and end of a period by a growth matrix consisting of transition probabilities (Rogers, 1966; 1973; 1975). A major problem here is how to calculate these transition probabilities or growth matrix more precisely. A major innovation was the introduction of multiregional population accounts (Rees and Wilson, 1977). Given successful estimation of the elements in the multiregional population accounts, transition probabilities can be straightforwardly calculated for population projections. It is noted that migration and mortality rates are not represented independently (they are combined into transition probabilities) in such transition probabilities-based population models. Thus it is only possible to use constant migration and mortality rates for population projections. An iterative population model was developed by Rees and Wilson (1977) using occurrence-exposure demographic rates. These rates can be correctly and precisely defined and can also be used to estimate multiregional population accounts. A transition probabilities matrix can be derived by matrix inversion from occurrence-exposure demographic rates (Rees, 1989; Rogers and Willekens, 1986; Willekens and Drewe, 1984). This matrix inversion procedure may need to be repeated for each projection period if changing demographic rates are to be used for population projections.

A forward demographic rates-based approach has been developed recently (Shen, 1994). Forward demographic rates are similar to transition probabilities but mortality and migration rates are defined independently. This is achieved by dividing population into two categories --- migrating population and non-migrating population. A set of extended multiregional population accounts is also used. Forward mortality or fertility rates (they may be termed probabilities) can be defined for migrating population and non-migrating population respectively and they can be linked together. Forward migration rates can also be defined. Transition probabilities are calculated by dividing transitions by the starting population in population accounts. It is difficult to define mortality probability independently in the context of transition probabilities as it is related to migration probability.

It has been demonstrated that forward demographic rates have unique relations with occurrence-exposure rates (Shen, 1994). Different population projection models can be developed on the basis of occurrence-exposure rates and forward rates respectively and both are correct if corresponding demographic rates are used. However, the forward demographic rates-based model does have the advantage that population projections can be simply carried out while an iterative procedure is needed for the occurrence-exposure rates-based population model. In chapter four, an approximate version of a forward demographic rates-based model has been used to make urban-rural population projections of China. An improved version of the model has also been developed recently (Shen, 1994). In this chapter, a more precise forward demographic rates-based model will be further developed by defining the relations between the one-period and half-period demographic rates more realistically. These relations are essential to link the one-period and half-period demographic rates defined for migrating and non-migrating populations respectively. External migration will also be included in the model in line with recent trends in multiregional population modelling (Rees, 1989; 1991, Rogers, 1989; Willekens and Drewe, 1984).

The model will be formally developed in section 8.2. In section 8.3, input data for the projection model will be estimated and prepared from various sources. In section 8.4, multiregional population projection results will be discussed and presented.

8.2 A forward demographic rates-based multiregional population model

8.2.1 Definitions of forward demographic rates

The spatial population system of interest here is an open system consisting of N regions, and is interrelated with the rest of the world via external migration. For simplicity, the rest of the world is called region R and region N+1 alternatively. The same age and time intervals are assumed. All derivations are same for male and female populations except that fertility rates are defined for the female population only. So gender label g is omitted in most cases, but will be added back in the multiregional projection model.

Table 8-1 presents an example of population accounts of period-cohort a for two regions i and j (a = 0, 2, ... A; k = i, j), and the rest of the world (region R). The population account for the rest of the world is not and does not need to be complete. Only those population items of the rest of the world that are related with the population system concerned are included. Period-cohort zero refers to the infants-cohort and A the last period-cohort. The birth account in table 8-2 shows the births produced by the female population of period-cohort a in each region. Similar population accounts for a general case of an open system consisting of N regions can be obtained. Here, an extended multiregional population account is adopted. Population is divided into two categories: non-migrating population and migrating population. Migrating population may die in its origin and destination regions. Non-migrating population may die in one region only. The migrating population includes the potential migrating population who fail to realize migration because of death during the accounting period.

The variables are defined as follows:

Pk^*_a	is the starting population of region k in period t to t+1 in period-cohort a, k=1, 2, ... , N. Period-cohort a refers to the same population group in the period t to t+1 that belongs to age-group a in time t.
P^*k_a	is the ending population of region k in period t to t+ 1 in period-cohort a, k=1, 2, ... , N.
P^*dk_a	is the population in period-cohort a who died in period t to t+1 in region k, k=1, 2, ... , N.
$Peksl_a$	is the population of period-cohort a who exist in region k at time t and survive in region l in period t to t+1, k,l=1, 2, ... , N.
$PeksR_a$	is the population of period-cohort a in region k at time t who emigrated to the rest of the world in period t to t+1, k=1, 2, ... , N.
$PeRsk_a$	is the population of period-cohort a immigrated from the rest of the world who survive in region k in period t to t+1, k=1, 2, ... , N.
$Pekdk_{ak}$	is the population of period-cohort a who died in region k in period t to t+1 corresponding to non-migrating population in region k, k=1, 2, ... , N.

Table 8-1 The population account for period-cohort a

Starting state	Ending state in period t to t+1					
	Survival in region			Death in region		
	i	j	R	i	j	Total
Region i	$Peisi_a$	$Peisj_a$	$PeisR_a$	$Peidi_{ai}$ $Peidi_{aj}$ $Peidi_{aR}$	$Peidj_{aj}$	$Pi*_a$
Region j	$Pejsi_a$	$Pejsj_a$	$PejsR_a$	$Pejdi_{ai}$	$Pejdj_{aj}$ $Pejdj_{ai}$ $Pejdj_{aR}$	$Pj*_a$
Region R	$PeRsi_a$	$PeRsj_a$	*	$PeRdi_{ai}$	$PeRdj_{aj}$	
Total	$P*i_a$	$P*j_a$	*	$P*di_a$	$P*dj_a$	$P**_a$

Note: See text for explanations.

Table 8-2 The birth account

Starting state	Ending state in period t to t+1		
	Birth in region		
	i	j	Total
Region i	$Peibi_{ai}$ $Peibi_{aj}$ $Peibi_{aR}$	$Peibj_{aj}$	$Pib*_a$
Region j	$Pejbi_{ai}$	$Pejbj_{aj}$ $Pejbj_{ai}$ $Pejbj_{aR}$	$Pjb*_a$
Region R	$PeRbi_{ai}$	$PeRbj_{aj}$	*
Total	$P*bi_a$	$P*bj_a$	$P*b*_a$

Note: See text for explanations.

$Pekdk_{al}$ is the population of period-cohort a who died in region k in period t to t+1 corresponding to migrating population from region k to region l, k,l=1, 2, ... , N; k≠l. Here subscript 'l' indicates the destination region of potential migrations if migrants did not die in the origin region before migration.

$Pekdk_{aR}$ is the population of period-cohort a who died in region k in period t to t+1 corresponding to emigrating population from region k to the rest of the world, k=1, 2, ... , N.

$Pekdl_{al}$ is the population of period-cohort a who died in region l in period t to t+1 corresponding to migrating population from region k to region l, k,l=1, 2, ... , N; k≠l.

$PeRdk_{ak}$ is the population of period-cohort a who died in region k in period t to t+1 corresponding to immigrating population from the rest of the world to region k, k=1, 2, ... , N.

$Pekbk_{ak}$ is the births in region k in period t to t+1 produced by non-migrating population of period-cohort a in region k, k=1, 2, ... , N.

$Pekbk_{al}$ is the births in region k in period t to t+1 produced by migrating population of period-cohort a from region k to region l, k, l=1, 2, ... , N; k≠l.

$Pekbk_{aR}$ is the births in region k in period t to t+1 produced by emigrating population of period-cohort a from region k to the rest of the world, k=1, 2, ... , N.

$Pekbl_{al}$ is the births in region l in period t to t+1 produced by migrating population of period-cohort a from region k to region l, k, l=1, 2, ... , N; k≠l.

$PeRbk_{ak}$ is the births in region k in period t to t+1 produced by immigrating population of period-cohort a from the rest of the world to region k, k=1, 2, ... , N.

Pkb^*_a is the number of births in period t to t+1 produced in N regions by population of period-cohort a who are in region k at time t, k=1, 2, ... , N.

P^*bk_a is the number of births in period t to t+1 produced in region k by population of period-cohort a in all regions, k=1, 2, ... , N.

Here the death component $Pekdk_a$ and the birth component $Pekbk_a$ have been further divided into two items corresponding to one non-migrating population and N migrating populations as well as one emigrating population:

$$Pekdk_a = Pekdk_{ak} + \Sigma^{N+1}{}_{l=1;l\neq k}\, Pekdk_{al} \qquad k=1, 2, \ldots , N \qquad (8\text{-}1)$$

$$Pekbk_a = Pekbk_{ak} + \Sigma^{N+1}{}_{l=1;l\neq k}\, Pekbk_{al} \qquad k=1, 2, \ldots , N \qquad (8\text{-}2)$$

Population accounts equations can be obtained from the population accounts. The row sum equation of period-cohort a is as follows:

$$Pk^*_a = \Sigma^{N+1}{}_{l=1}\, Peksl_a + \Sigma^{N+1}{}_{l=1}\, Pekdk_{al} + \Sigma^{N}{}_{l=1;l\neq k}\, Pekdl_{al} \qquad (8\text{-}3)$$

$$k=1, 2, \ldots , N$$

Note that the emigrating population who die in the rest of the world have been counted in the emigrating population, $PeksR_a$.

The column sum equations of period-cohort a are as follows:

$$P^*k_a = \Sigma^{N+1}{}_{l=1}\, Pelsk_a \qquad k=1, 2, \ldots , N \qquad (8\text{-}4)$$

$$P^*dk_a = \Sigma^{N+1}{}_{l=1}\, Pekdk_{al} + \Sigma^{N+1}{}_{l=1;l\neq k}\, Peldk_{ak} \qquad k=1, 2, \ldots , N \qquad (8\text{-}5)$$

The row-sum equation for births is as follows:

$$Pkb^*_a = \Sigma^{N+1}_{l=1} Pekbk_{al} + \Sigma^{N}_{l=1;l\neq k} Pekbl_{al} \qquad k=1, 2, \dots, N \qquad (8\text{-}6)$$

Note that the births produced by the emigration population in the rest of the world are not included.

The column sum equation for births is as follows:

$$P^*bk_a = \Sigma^{N+1}_{l=1} Pekbk_{al} + \Sigma^{N+1}_{l=1;l\neq k} Pelbk_{ak} \qquad k=1, 2, \dots, N \; (8\text{-}7)$$

Now, forward demographic rates can be defined in terms of the time unit of a whole period or a half period. On average, a non-migrating population spends a whole accounting period in one region while a migrating population spends half of the accounting period in the origin and destination regions. One-period and half-period forward mortality rates can be defined for the non-migrating population and migrating population respectively as follows:

$$u^k_a = Pekdk_{ak} / (Peksk_a + Pekdk_{ak}) \qquad (8\text{-}8)$$

$$u^k_{0.5a} = Pekdk_{al} / (Peksl_a + Pekdl_{al} + Pekdk_{al}) \qquad (8\text{-}9)$$

$$u^l_{0.5a} = Pekdl_{al} / (Peksl_a + Pekdl_{al}) \qquad (8\text{-}10)$$

Half-period forward mortality rates can be defined for emigrating and immigrating population respectively as follows:

$$u^k_{0.5a} = Pekdk_{aR} / (PeksR_a + Pekdk_{aR}) \qquad (8\text{-}11)$$

$$u^k_{0.5a} = PeRdk_{ak} / (PeRsk_a + PeRdk_{ak}) \qquad (8\text{-}12)$$

It is assumed that the half-period forward mortality rates $u^k_{0.5a}$ of region k defined in equations (8-9)-(8-12) are equal. It is useful to derive the relation between the one-period and the half-period forward mortality rates.

Assuming equal mortality rates in region k and region l, a one-period forward mortality rate can be defined:

$$u^k_a = (Pekdk_{al} + Pekdl_{al}) / (Peksl_a + Pekdl_{al} + Pekdk_{al}) \qquad (8\text{-}13)$$

It can be derived by using equations (8-9) and (8-10) that:

$$u^k_{0.5a} = 1 - (1 - u^k_a)^{1/2} = u^k_a / (1 + (1 - u^k_a)^{1/2}) \qquad (8\text{-}14)$$

Note that an approximate expression of $0.5u^k_a/(1-0.25u^k_a)$, i.e., $u^k_a/(1+(1-u^k_a+0.25(u^k_a)^2)^{1/2})$, for $u^k_{0.5a}$ has been used in the development of an earlier version of the model (Shen, 1994). There is an extra small item $0.25(u^k_a)^2$ in this expression. This means that the model developed here is more precise, at least theoretically, than the earlier one.

Similarly, one-period and half-period forward fertility rates can be defined for the non-migrating population and migrating population as follows:

$$f^k_a = Pekbk_{ak} / (Peksk_a + Pekdk_{ak}) \qquad (8\text{-}15)$$

$$fk_{0.5a} = Pekbk_{al} / (Peksl_a + Pekdl_{al} + Pekdk_{al}) \quad (8\text{-}16)$$

$$fl_{0.5a} = Pekbl_{al} / (Peksl_a + Pekdl_{al}) \quad (8\text{-}17)$$

$$fk_{0.5a} = Pekbk_{aR} / (PeksR_a + Pekdk_{aR}) \quad (8\text{-}18)$$

$$fk_{0.5a} = PeRbk_{ak} / (PeRsk_a + PeRdk_{ak}) \quad (8\text{-}19)$$

It is assumed that the half-period forward fertility rates $fk_{0.5a}$ of region k defined in equations (8-16)-(8-19) are equal. Similarly, the following relation between the one-period and the half-period forward fertility rates can be derived:

$$fk_{0.5a} = fk_a/(1 +(1 - uk_a)^{1/2}) = fk_a (1 - (1 - uk_a)^{1/2}) / uk_a \quad (8\text{-}20)$$

Three forward internal migration rates mkl_{1a}, mkl_{2a}, mkl_{3a} can be defined as follows:

$$mkl_{1a} = (Peksl_a + Pekdl_{al} + Pekdk_{al}) / Pk^*_a \quad (8\text{-}21)$$

$$mkl_{2a} = (Peksl_a + Pekdl_{al}) / Pk^*_a = mkl_{1a}(1 - uk_{0.5a}) = mkl_{1a} (1 - uk_a)^{1/2} \quad (8\text{-}22)$$

$$mkl_{3a} = Peksl_a /Pk^*_a = mkl_{2a}(1 - ul_{0.5a}) = mkl_{2a} (1 - ul_a)^{1/2}$$
$$= mkl_{1a} (1 - uk_a)^{1/2} \; (1 - ul_a)^{1/2} \quad (8\text{-}23)$$

Here three forward destination-specific migration rates are defined. All migrants, including potential migrants, are accounted in migration rate mkl_{1a}. Only migrants that actually make migrations are accounted in migration rate mkl_{2a}. Only survival migrants are accounted in migration rate mkl_{3a}.

Two forward emigration rates mkR_{1a}, mkR_{2a} can be defined as follows:

$$mkR_{1a} = (PeksR_a + Pekdk_{aR})/Pk^*_a \quad (8\text{-}24)$$

$$mkR_{2a} = PeksR_a/Pk^*_a = mkR_{1a}(1 - uk_{0.5a}) = mkR_{1a} (1 - uk_a)^{1/2} \quad (8\text{-}25)$$

All emigrants, including potential emigrants, are accounted in emigration rate mkR_{1a}. Only emigrants that actually make migrations are accounted in emigration rate mkR_{2a}.

8.2.2 Estimation of population accounts and forward demographic rates

Methods are required to estimate the forward demographic rates on the basis of the multiregional population accounts. It is assumed that the following population data are available: the ending population of period-cohort a P^*k_a; the survival migration population $Peksl_a$; the emigration population $PeksR_a$; the survival immigration population $PeRsk_a$; the death population Dk_a who died at age a in region k in period t to t+1; the birth population Bk_a produced by the female population at age a in region k in period t to t+1; the total births in region k, i.e., the starting population of the infants-cohort (period-cohort zero) Pk^{*}_{0}. Alternative equations to define the forward mortality and fertility rates will be discussed first.

Substitute equation (8-14) into equations (8-9)-(8-12):

$$Pekdk_{al} = (Peksl_a + Pekdl_{al} + Pekdk_{al})(1 - (1 - uk_a)^{1/2}) \quad (8\text{-}26)$$

$$Pekdl_{al} = (Peksl_a + Pekdl_{al})(1 - (1 - ul_a)^{1/2}) \quad (8\text{-}27)$$

$$Pekdk_{aR} = (PeksR_a + Pekdk_{aR})(1 - (1 - uk_a)^{1/2}) \quad (8\text{-}28)$$

$$PeRdk_{ak} = (PeRsk_a + PeRdk_{ak})(1 - (1 - uk_a)^{1/2}) \quad (8\text{-}29)$$

Multiply both sides of equations (8-26), (8-28) and (8-29) by $0.5(1+ (1 - uk_a)^{1/2})$ and both sides of equation (8-27) by $0.5(1+ (1 - ul_a)^{1/2})$, and rearrange:

$$Pekdk_{al} = 0.5(Peksl_a + Pekdl_{al} + (1+1/(1+ (1 - uk_a)^{1/2}))Pekdk_{al})\, uk_a \quad (8\text{-}30)$$

$$Pekdl_{al} = 0.5(Peksl_a + (1+1/(1+ (1 - ul_a)^{1/2}))Pekdl_{al})\, ul_a \quad (8\text{-}31)$$

$$Pekdk_{aR} = 0.5(PeksR_a + (1+1/(1+ (1 - uk_a)^{1/2}))Pekdk_{aR})\, uk_a \quad (8\text{-}32)$$

$$PeRdk_{ak} = 0.5(PeRsk_a + (1+1/(1+ (1 - uk_a)^{1/2}))PeRdk_{ak})\, uk_a \quad (8\text{-}33)$$

The following can be obtained from equations (8-5), (8-8) and (8-30)-(8-33):

$$\begin{aligned} P^{*dk}_a = (&Peksk_a + 0.5\ \Sigma^{N+1}{}_{l=1;l\neq k} (Peksl_a + Pelsk_a) + Pekdk_{ak} \\ &+ 0.5\ \Sigma^{N+1}{}_{l=1;l\neq k} (1+1/(1+ (1 - uk_a)^{1/2}))(Pekdk_{al} + Peldk_{ak}) \\ &+ 0.5\Sigma^{N}{}_{l=1;l\neq k}\, Pekdl_{al})uk_a \end{aligned} \quad (8\text{-}34)$$

Therefore, an alternative equation to define the forward mortality rate is as follows:

$$uk_a = P^{*dk}_a / PST^{*dk}_a \quad (8\text{-}35)$$

Here PST^{*dk}_a is the starting population corresponding to the death population P^{*dk}_a:

$$\begin{aligned} PST^{*dk}_a = &Peksk_a + 0.5\ \Sigma^{N+1}{}_{l=1;l\neq k} (Peksl_a + Pelsk_a) + Pekdk_{ak} \\ &+ 0.5\ \Sigma^{N+1}{}_{l=1;l\neq k} (1+1/(1+ (1 - uk_a)^{1/2}))(Pekdk_{al} + Peldk_{ak}) \\ &+ 0.5\ \Sigma^{N}{}_{l=1;l\neq k}\, Pekdl_{al} \end{aligned} \quad (8\text{-}36)$$

Similarly, an alternative equation to define the forward fertility rate is as follows:

$$fk_a = P^{*bk}_a / PST^{*bk}_a \quad (8\text{-}37)$$

Here PST^{*bk}_a is the starting population corresponding to the birth population P^{*bk}_a:

$$PST^{*bk}_a = PST^{*dk}_a \quad (8\text{-}38)$$

The estimation of the mortality rate of the infants-cohort will be discussed first. The following can be obtained from equations (8-9), (8-10) and (8-14):

$$\begin{aligned} Pekdl_{01} &= Peksl_0\, ul_{0.5,0}/(1 - ul_{0.5,0}) = Peksl_0 (1 - (1 - ul_0)^{1/2})/ (1 - ul_0)^{1/2} \\ &= Peksl_0\, ul_0 /(1 - ul_0 + (1 - ul_0)^{1/2}) \quad k,l = 1, 2, ..., N;\ k\neq l \end{aligned} \quad (8\text{-}39)$$

$$\mathrm{Pekdk}_{0l} = (\,\mathrm{Peksl}_0 + \mathrm{Pekdl}_{0l}\,)\, u^k{}_{0.5,0} / (\,1 - u^k{}_{0.5,0}\,)$$

$$= \mathrm{Peksl}_0\, u^k{}_0 / (\,(1 - u^l{}_0)^{1/2}\,(\,1 - u^k{}_0 + (1 - u^k{}_0)^{1/2}\,))$$

$$k,l = 1, 2, ..., N;\ k \neq l \qquad (8\text{-}40)$$

Similarly, the following can be obtained from equations (8-11), (8-12) and (8-14) for external migrations:

$$\mathrm{PeRdk}_{0k} = \mathrm{PeRsk}_0\, u^k{}_0 / (\,1 - u^k{}_0 + (1 - u^k{}_0)^{1/2}\,) \qquad k = 1, 2, ..., N \quad (8\text{-}41)$$

$$\mathrm{Pekdk}_{0R} = \mathrm{PekSR}_0\, u^k{}_0 / (\,1 - u^k{}_0 + (1 - u^k{}_0)^{1/2}\,) \qquad k = 1, 2, ..., N \quad (8\text{-}42)$$

The following can be obtained from equations (8-3), (8-4) and (8-5) as both the starting and ending populations for the infants-cohort are known:

$$\mathrm{Pekdk}_{0k} = \mathrm{Pk}^*{}_0 - \mathrm{P}^*\mathrm{k}_0 + \Sigma^{N+1}{}_{l=1;l\neq k}\,(\,\mathrm{Pelsk}_0 - \mathrm{Peksl}_0 - \mathrm{Pekdk}_{0l}) - \Sigma^{N}{}_{l=1;l\neq k}\,\mathrm{Pekdl}_{0l}$$

$$k = 1, 2, ..., N \qquad (8\text{-}43)$$

$$\mathrm{Peksk}_0 = \mathrm{P}^*\mathrm{k}_0 - \Sigma^{N+1}{}_{l=1;l\neq k}\,\mathrm{Pelsk}_0 \qquad k = 1, 2, ..., N \qquad (8\text{-}44)$$

$$\mathrm{P}^{*\mathrm{dk}}{}_0 = \mathrm{Pk}^*{}_0 - \Sigma^{N+1}{}_{l=1}\mathrm{Peksl}_0 - \Sigma^{N}{}_{l=1;l\neq k}\mathrm{Pekdl}_{0l} + \Sigma^{N+1}{}_{l=1;l\neq k}\mathrm{Peldk}_{0k}$$

$$= \mathrm{Pk}^*{}_0 - \mathrm{P}^*\mathrm{k}_0 + \Sigma^{N+1}{}_{l=1;l\neq k}(\,\mathrm{Pelsk}_0 - \mathrm{Peksl}_0 + \mathrm{Peldk}_{0k}\,) - \Sigma^{N}{}_{l=1;l\neq k}\,\mathrm{Pekdl}_{0l}$$

$$k = 1, 2, ..., N \qquad (8\text{-}45)$$

The forward mortality rate of the infants-cohort can be calculated using equation (8-35):

$$u^k{}_0 = \mathrm{P}^{*\mathrm{dk}}{}_0 / \mathrm{PST}^{*\mathrm{dk}}{}_0 \qquad k = 1, 2, ..., N \qquad (8\text{-}46)$$

An iterative procedure is necessary to estimate the mortality rate of the infants-cohort as unknown mortality rates appear in the right-hand side of equations (8-39)-(8-43) and (8-45). An initial forward mortality rate can be estimated using the following derived by assuming same mortality rate in all regions and using equations (8-3) and (8-4):

$$u^k{}_0 = (\,\mathrm{Pekdk}_{0k} + \Sigma^{N+1}{}_{l=1;l\neq k}(\,\mathrm{Pekdk}_{0l} + \mathrm{Pekdl}_{0l}\,))/\mathrm{Pk}^*{}_0$$

$$= (\,\mathrm{Pk}^*{}_0 - \mathrm{Peksk}_0 - \Sigma^{N+1}{}_{l=1;l\neq k}\,\mathrm{Peksl}_0 + \mathrm{PeksR}_0 u^k{}_{0.5,0}\,)/\mathrm{Pk}^*{}_0$$

$$= (\,\mathrm{Pk}^*{}_0 - \mathrm{P}^*\mathrm{k}_0 + \Sigma^{N+1}{}_{l=1;l\neq k}(\,\mathrm{Pelsk}_0 - \mathrm{Peksl}_0\,) + 0.5\mathrm{PeksR}_0 u^k{}_0\,)/\mathrm{Pk}^*{}_0$$

$$k = 1, 2, ..., N \qquad (8\text{-}47)$$

Note that PekdR_{0R} is generally not defined. But it is assumed here that:

$$\mathrm{PekdR}_{0R} = \mathrm{PeksR}_0 u^k{}_{0.5,0} = 0.5\mathrm{PeksR}_0 u^k{}_0 \qquad (8\text{-}48)$$

Therefore, an initial forward mortality rate of the infants-cohort can be estimated using the following equation:

$$u^k{}_0 = (\,\mathrm{Pk}^*{}_0 - \mathrm{P}^*\mathrm{k}_0 + \Sigma^{N+1}{}_{l=1;l\neq k}(\,\mathrm{Pelsk}_0 - \mathrm{Peksl}_0\,))/(\,\mathrm{Pk}^*{}_0 - 0.5\mathrm{PeksR}_0)$$

$$k = 1, 2, ..., N \qquad (8\text{-}49)$$

Now, the estimation procedure can be carried out by repeating calculations using equations (8-39)-(8-43) and (8-45)-(8-46). Equations (8-44) and (8-49) will be used in the first step. Then new estimation of the mortality rate of the infants-cohort in equation (8-46) can be used in the next iteration. Unknown items in the population account of the infants-cohort are estimated by equations (8-39)-(8-44).

The death population $P^{*dk}{}_0$ of the infants-cohort in region k was estimated by equation (8-45). The death population $P^{*dk}{}_a$ of the remaining period-cohorts in the region k can be estimated using the following equation:

$$P^{*dk}{}_1 = D^k{}_0 - P^{*dk}{}_0 + 0.5D^k{}_1 \qquad k = 1, 2, ..., N \qquad (8\text{-}50)$$

$$P^{*dk}{}_a = 0.5(D^k{}_{a-1} + D^k{}_a) \qquad a = 2, 3, ..., A\text{-}1;\ k = 1, 2, ..., N \qquad (8\text{-}51)$$

$$P^{*dk}{}_A = 0.5D^k{}_{A-1} \qquad k = 1, 2, ..., N \qquad (8\text{-}52)$$

The estimation of the forward mortality rate of period-cohort a (a=1, 2, ..., A) will be discussed next. The ending population $P^{*k}{}_a$ and death population $P^{*dk}{}_a$ are known.

Similar to the infants-cohort, the following can be obtained from equations (8-9)-(8-12), (8-14), (8-3), (8-4) and (8-5) for period-cohort a:

$$Pekdl_{al} = Peksl_a\, u^l{}_{0.5a}/(1 - u^l{}_{0.5a}) = Peksl_a\, (1 - (1 - u^l{}_a)^{1/2})/ (1 - u^l{}_a)^{1/2}$$

$$= Peksl_a\, u^l{}_a /(1 - u^l{}_a + (1 - u^l{}_a)^{1/2}) \qquad k,l = 1, 2, ..., N;\ k\neq l \quad (8\text{-}53)$$

$$Pekdk_{al} = (Peksl_a + Pekdl_{al})\, u^k{}_{0.5a}/(1 - u^k{}_{0.5a})$$

$$= Peksl_a\, u^k{}_a /((1 - u^l{}_a)^{1/2} (1 - u^k{}_a + (1 - u^k{}_a)^{1/2}))$$

$$k,l = 1, 2, ..., N;\ k\neq l \quad (8\text{-}54)$$

$$PeRdk_{ak} = PeRsk_a\, u^k{}_a /(1 - u^k{}_a + (1 - u^k{}_a)^{1/2}) \quad k = 1, 2, ..., N \qquad (8\text{-}55)$$

$$Pekdk_{aR} = PeksR_a\, u^k{}_a /(1 - u^k{}_a + (1 - u^k{}_a)^{1/2})) \quad k = 1, 2, ..., N \qquad (8\text{-}56)$$

$$Pekdk_{ak} = P^{*dk}{}_a - \Sigma^{N+1}{}_{l=1;l\neq k}(Pekdk_{al} + Peldk_{ak}) \qquad k = 1, 2, ..., N \quad (8\text{-}57)$$

$$Peksk_a \doteq P^{*k}{}_a - \Sigma^{N+1}{}_{l=1;l\neq k}\, Pelsk_a \qquad k = 1, 2, ..., N \qquad (8\text{-}58)$$

$$Pk^*{}_a = \Sigma^{N+1}{}_{l=1}\, Peksl_a + \Sigma^{N+1}{}_{l=1}\, Pekdk_{al} + \Sigma^{N}{}_{l=1;l\neq k}\, Pekdl_{al}$$

$$= P^{*k}{}_a + \Sigma^{N+1}{}_{l=1;l\neq k}\, (Peksl_a - Pelsk_a) + P^{*dk}{}_a$$

$$+ \Sigma^{N}{}_{l=1;l\neq k}\, Pekdl_{al} - \Sigma^{N+1}{}_{l=1;l\neq k}\, Peldk_{ak} \qquad k = 1, 2, ..., N \ (8\text{-}59)$$

The forward mortality rate of the period-cohort a can be calculated using equation (8-35):

$$u^k{}_a = P^{*dk}{}_a / PST^{*dk}{}_a \qquad a = 1, 2, ..., A;\ k = 1, 2, ..., N \qquad (8\text{-}60)$$

An iterative procedure is again necessary to estimate the mortality rate of period-cohort a as unknown mortality rates appear in the right-hand side of equations (8-53)-(8-57) and (8-60). To estimate an initial forward mortality rate of period-cohort a, the following can be obtained from equations (8-3), (8-4) and (8-5) by assuming the same mortality rate in all regions:

$$P^{*dk}_a + \Sigma^{N+1}{}_{l=1;l\neq k}(Pekdl_{al} - Peldk_{ak}) = uk_a(P^{*}k_a + \Sigma^{N+1}{}_{l=1;l\neq k}(Peksl_a - Pelsk_a)$$

$$+ P^{*dk}_a + \Sigma^{N}{}_{l=1;l\neq k} Pekdl_{al} - \Sigma^{N+1}{}_{l=1;l\neq k} Peldk_{ak}) \qquad (8\text{-}61)$$

Substitute equations (8-53) and (8-55) into (8-61) assuming same mortality rate in all regions, and rearrange:

$$P^{*dk}_a = uk_a (P^{*}k_a + P^{*dk}_a) + uk_a \Sigma^{N+1}{}_{l=1;l\neq k}(Peksl_a - Pelsk_a)$$

$$+ (uk_a - 1) (\Sigma^{N}{}_{l=1;l\neq k} Pekdl_{al} - \Sigma^{N+1}{}_{l=1;l\neq k} Peldk_{ak}) - PekdR_{aR}$$

$$= uk_a (P^{*}k_a + P^{*dk}_a) + uk_a \Sigma^{N+1}{}_{l=1;l\neq k}(Peksl_a - Pelsk_a)$$

$$- (\Sigma^{N}{}_{l=1;l\neq k} Peksl_a - \Sigma^{N+1}{}_{l=1;l\neq k} Pelsk_a)(1 - uk_a) uk_a/(1 - uk_a$$

$$+ (1 - uk_a)^{1/2}) - PeksR_a uk_{0.5a}$$

$$= uk_a (P^{*}k_a + P^{*dk}_a) + uk_a \Sigma^{N+1}{}_{l=1;l\neq k}(Peksl_a - Pelsk_a)$$

$$- 0.5 (\Sigma^{N}{}_{l=1;l\neq k} Peksl_a - \Sigma^{N+1}{}_{l=1;l\neq k} Pelsk_a) uk_a (1 - (1 - (1 - uk_a)^{1/2})$$

$$/(1 + (1 - uk_a)^{1/2})) - 0.5 PeksR_a uk_a$$

$$= (P^{*}k_a + P^{*dk}_a + 0.5 \Sigma^{N+1}{}_{l=1;l\neq k}(Peksl_a - Pelsk_a))uk_a$$

$$k = 1, 2, ..., N \qquad (8\text{-}62)$$

A small item in equation (8-62) was disregarded. Here, as was the case with equation (8-45) for the infants-cohort, it is assumed that:

$$PekdR_{aR} = PeksR_a uk_{0.5a} = 0.5 PeksR_a uk_a \qquad (8\text{-}63)$$

The initial mortality rate of the period-cohort a can be estimated as follows:

$$uk_a = P^{*dk}_a/(P^{*}k_a + P^{*dk}_a + 0.5\Sigma^{N+1}{}_{l=1;l\neq k}(Peksl_a - Pelsk_a))$$

$$k = 1, 2, ..., N \qquad (8\text{-}64)$$

Now, the estimation procedure can be carried out by repeating calculations using equations (8-53)-(8-57) and (8-59)-(8-60). Equations (8-58) and (8-64) will be used in the first step. Then a new estimation of the mortality rate of the period-cohort a in equation (8-60) can be used in the next iteration. Unknown items in the population account of the period-cohort a are estimated by equations (8-53)-(8-58).

It is straightforward to estimate the forward fertility rates and migration rates as the multiregional population accounts have been estimated above.

The birth population P^{*bk}_a can be estimated in the similar way as the death population P^{*dk}_a:

$$P^{*bk}_a = 0.5 (Bk_{a-1} + Bk_a) \qquad a = a_1, a_1+1, ..., a_2;\ k = 1, 2, ..., N \quad (8\text{-}65)$$

Here a_1 and a_2 are the first and last period-cohorts of the fertile female population.The forward fertility rate $f^k{}_a$ can be estimated using equation (8-37). Three forward internal migration rates can be estimated using equations (8-21)-(8-23). Two forward emigration rates can be estimated using equations (8-24) and (8-25).

8.2.3 Multiregional population projection model

Given the starting population, and forward mortality rates, fertility rates, internal migration rates, emigration rates, and immigration flows, multiregional population projections can be undertaken using a multiregional population projection model. The gender label g (m for male and f for female) will be added back in this section.

It can be demonstrated that the total fertility rate $TFR^k(t+1)$ based on occurrence-exposure fertility rates can be calculated from forward fertility rates as follows:

$$TFR^k(t+1) = \Sigma^{a2}{}_{a=a1}(f^k{}_a(t+1) / (1- 0.5u^k{}_{af}(t+1))) \qquad k =1, 2, ..., N \quad (8\text{-}66)$$

The normal forward fertility rate is defined thus:

$$fn^k{}_a(t+1) = f^k{}_a(t+1)/TFR^k(t+1) \qquad k =1, 2, ..., N \qquad (8\text{-}67)$$

The following can be obtained from equation (8-21). Here the time label is omitted for simplicity, but will be added back later.

$$Peksl_{ag} + Pekdk_{agl} + Pekdl_{agl} = m^{kl}{}_{1ag}\, P^{k*}{}_{ag} \qquad (8\text{-}68)$$

Substitute equation (8-68) into equation (8-3) and the following can be obtained:

$$Peksk_{ag} + Pekdk_{agk} = (1 - \Sigma^{N+1}{}_{l=1,l\neq k}\, m^{kl}{}_{1ag})\, P^{k*}{}_{ag} \qquad (8\text{-}69)$$

Substitute into equation (8-8) and rearrange:

$$Pekdk_{agk} = (1 - \Sigma^{N+1}{}_{l=1,l\neq k}\, m^{kl}{}_{1ag})\, P^{k*}{}_{ag}u^k{}_{ag} \qquad (8\text{-}70)$$

Substitute into equation (8-69):

$$Peksk_{ag} = (1 - \Sigma^{N+1}{}_{l=1,l\neq k}\, m^{kl}{}_{1ag})\, P^{k*}{}_{ag}\, (1 - u^k{}_{ag}) \qquad (8\text{-}71)$$

Substitute equation (8-68) into equation (8-26):

$$Pekdk_{agl} = P^{k*}{}_{ag}m^{kl}{}_{1ag} /(1 - (1 - u^k{}_{ag})^{1/2}) \qquad (8\text{-}72)$$

The following can be obtained from equations (8-26), (8-27) and (8-68):

$$\begin{aligned} Pekdl_{agl} &= (Peksl_{ag} + Pekdl_{agl} + Pekdk_{agl} - Pekdk_{agl})(1 - (1 - u^l{}_{ag})^{1/2}) \\ &= (Peksl_{ag} + Pekdl_{agl} + Pekdk_{agl})\, (1 - u^k{}_{ag})^{1/2}\, (1 - (1 - u^l{}_{ag})^{1/2}) \\ &= P^{k*}{}_{ag}m^{kl}{}_{1ag}\, (1 - u^k{}_{ag})^{1/2}\, (1 - (1 - u^l{}_{ag})^{1/2}) \end{aligned} \qquad (8\text{-}73)$$

Substitute equation (8-73) into equation (8-27) and rearrange:

$$Peksl_{ag} = P^{k*}{}_{ag}m^{kl}{}_{1ag}\ (1 - u^k{}_{ag})^{1/2}\ (1 - u^l{}_{ag})^{1/2} \qquad (8\text{-}74)$$

Similarly, the following equations can be obtained from equations (8-24) and (8-11):

$$PeksR_{ag} + Pekdk_{agR} = m^{kR}{}_{1ag}\, P^{k*}{}_{ag} \qquad (8\text{-}75)$$

$$Pekdk_{agR} = Pk^*_{ag}\, m^{kR}_{1ag} u^k_{0.5ag} = Pk^*_{ag}\, m^{kR}_{1ag} \left(1 - (1 - u^k_{ag})^{1/2} \right) \quad (8\text{-}76)$$

Substitute into equation (8-75) and rearrange:

$$PeksR_{ag} = Pk^*_{ag}\, m^{kR}_{1ag}\ (1 - u^k_{ag})^{1/2} \quad (8\text{-}77)$$

Substitute equations (8-70)-(8-74), (8-76)-(8-77) and (8-55) into equation (8-36) and use equation (8-38), and rearrange:

$$PST^{*bk}_{ag} = PST^{*dk}_{ag} = Pk^*_{ag}(1 - \Sigma^{N+1}_{l=1,l\neq k}\, m^{kl}_{1ag})$$

$$+ Pk^*_{ag}\Sigma^{N+1}_{l=1,l\neq k}\, m^{kl}_{1ag}/(1 + (1 - u^k_{ag})^{1/2})$$

$$+ \Sigma^{N}_{l=1,l\neq k}\, Pl^*_{ag} m^{lk}_{1ag}\ (1 - u^l_{ag})^{1/2}/(1 + (1 - u^k_{ag})^{1/2})$$

$$+ PeksR_{ag} / (1 - u^k_{ag} + (1 - u^k_{ag})^{1/2}) \quad (8\text{-}78)$$

Now, define the survival rate $s^{kl}_{ag}(t+1)$ and special rate $v^k_{ag}(t+1)$ as follows:

$$s^{kk}_{ag}(t+1) = (1 - \Sigma^{N+1}_{l=1,l\neq k}\, m^{kl}_{1ag}(t+1)) (1 - u^k_{ag}(t+1))$$

$$k = 1, 2, ..., N \quad (8\text{-}79)$$

$$s^{kl}_{ag}(t+1) = m^{kl}_{1ag}(t+1)\ (1 - u^k_{ag}(t+1))^{1/2}\ (1 - u^l_{ag}(t+1))^{1/2}$$

$$k,l = 1, 2, ..., N;\ k\neq l \quad (8\text{-}80)$$

$$s^{kR}_{ag}(t+1) = m^{kR}_{1ag}(t+1)\ (1 - u^k_{ag}(t+1))^{1/2} \quad k = 1, 2, ..., N \quad (8\text{-}81)$$

$$v^k_{ag}(t+1) = 1 - \Sigma^{N+1}_{l=1,l\neq k}\, m^{kl}_{1ag}(t+1)(1 - 1/(1 + (1 - u^k_{ag}(t+1))^{1/2}))$$

$$k = 1, 2, ..., N \quad (8\text{-}82)$$

Finally, the following population projection model can be obtained. Births of gender g in region k can be projected using the following equation. Here $Sexk_g$ is the ratio of gender g in total births in region k.

$$Pk^*_{0g}(t) = P^{*bk}_g(t+1) = Sexk_g\ TFR^k(t+1)\Sigma^{a2}_{a=a1}\, fnk_a(t+1)(Pk^*_{af}(t)v^k_{af}(t+1)$$

$$+ (\Sigma^N_{l=1,l\neq k}\, Pl^*_{af}(t)s^{lk}_{af}(t+1) + PeRsk_{af}(t+1))/(1 - u^k_{af}(t+1)$$

$$+ (1 - u^k_{af}(t+1))^{1/2})) \quad k = 1, 2, ..., N \quad (8\text{-}83)$$

The ending population in period t to t+1 can be projected using the following:

$$P^{*k}_{ag}(t+1) = \Sigma^N_{l=1}\, Pl^*_{ag}(t)s^{lk}_{ag}(t+1) + PeRsk_{ag}(t+1) \quad (8\text{-}84)$$

$$a = 0, 1, ..., A;\ g = m, f;\ k = 1, 2, ..., N$$

The total deaths of gender g in region k can be projected using the following:

$$P^{*dk}{}_{*g}(t+1) = \Sigma^A_{a=0}\, u^k_{ag}(t+1)\ (Pk^*_{ag}(t)v^k_{ag}(t+1) +$$

$$(\Sigma^N_{l=1,l\neq k}\, Pl^*_{ag}(t)s^{lk}_{ag}(t+1) + PeRsk_{ag}(t+1))$$

$$/ (1 - u^k_{ag}(t+1) + (1 - u^k_{ag}(t+1))^{1/2})) \quad g = m, f;\ k = 1, 2, ..., N \quad (8\text{-}85)$$

The emigration population of gender g from region k can be projected using the following:

$$P^{eksR}{}_{*g}(t+1) = \Sigma A_{a=0}\, {}^{skR}{}_{ag}(t+1)\, P^{k*}{}_{ag}(t)$$

$$g = m, f;\ \ k = 1, 2, ..., N \qquad (8\text{-}86)$$

The immigration population of gender g to region k can be calculated using the following:

$$P^{eRsk}{}_{*g}(t+1) = \Sigma A_{a=0}\, P^{eRsk}{}_{ag}(t+1) \qquad g = m, f;\ \ k = 1, 2, ..., N \qquad (8\text{-}87)$$

The starting population for the next projection period is as follows:

$$P^{k*}{}_{ag}(t+1) = P^{*k}{}_{a\text{-}1g}(t+1) \qquad a = 1, ..., A\text{-}1;\ g = m, f;\ k = 1, 2, ..., N \ (8\text{-}88)$$

$$P^{k*}{}_{Ag}(t+1) = P^{*k}{}_{A\text{-}1g}(t+1) + P^{*k}{}_{Ag}(t+1)$$

$$g = m, f;\ k = 1, 2, ..., N \qquad (8\text{-}89)$$

Equations (8-79)-(8-89) constitute a multiregional population projection model of the open population system based on the forward demographic rates.

8.3 Data requirements of the multiregional projection model

A formal multiregional population model has been developed in the previous section. It is a region-, age- and gender-specific population model. It requires the base-year population as well as mortality, fertility and migration rates as input data. The spatial population system consists of some 29 provincial regions of mainland China. Hainan is included in Guangdong province. The age and time intervals used are five years. There are 21 period-cohorts in total. The period 1982-1987 is used to estimate most input data using the 1982 census data and the 1987 one percent population sampling data. The base year for population projection is 1987. The projection period runs from 1987 to 2087. Although a formal procedure to estimate forward demographic rates has been developed in section 8.2.2 this is only partly used as some data are not available. Alternative data sources and estimation procedures will be used instead in some cases.

8.3.1 Age-specific population in 1982

In the calibrating period from 1982 to 1987, the starting population is in 1982 and the ending population in 1987. Both of these population data sets are available in the form of five year age groups (0-4, 5-9, etc.). However, the age-specific population data do not cover all populations in the 1982 census. First, there are age-unknown populations in most provinces. These age-unknown populations are allocated to age-groups in proportion to age-known populations in each province. Second, some 28,601 persons in Tibet were indirectly counted and their ages are also unknown. These people are allocated to age-groups again according to the age-known population in Tibet. Third, there are some 4,238,210 persons in the armed forces whose age distributions were not released. Some 100,000 of them are female. These age-unknown population are allocated to age-groups from age 16 to age 22 assuming the same gender ratios in these age-groups. It is also assumed that females and males in the armed forces have the same age distribution. The adjustment is carried out for China as a whole at first. Then the estimated age-known populations in the armed forces are allocated to provincial populations in proportion to their populations in age-groups 4 and 5 (ages 15-24). Coale (1984) used a slightly different procedure to account for the armed forces in his estimation of the age-specific populations for the whole of China.

8.3.2 Age-specific population in 1987

The available population data for 1987 are the 1% sampling population. These data need to be adjusted by the appropriate sampling ratios and to account for armed forces. It seems that sampling ratios differ between regions. Regional sampling ratios are calculated and are used to adjust the sampling populations. These data are then adjusted again according to the sampling ratios of male and female populations. The total male and female populations in 1987 can be calculated from SSB (1991). Male and female sampling ratios can be calculated from the sampling populations and the total populations excluding the armed forces.

According to SSB (1987) and DPS (1986b), it can be inferred that there were 3.14 million males and 0.10 million females in the armed forces in 1987. The adjustment procedure to account for these armed forces has been discussed and used in section 4.4 for the urban-rural population projections of China.

8.3.3 Total births in the period 1982-1987

In the calibrating period 1982-1987, the population in the period-cohort zero in the beginning of the period is the total number of births in that period. Regional birth rates are applied to regional populations in each year of 1982-1985 to obtain the regional numbers of births in these years. These numbers of regional births are then adjusted to match the total births of China calculated in the same way as the regional numbers (DPS, 1988b SSB, 1991). As the calibrating period runs from mid-1982 to mid-1987, only about half of the births in 1982 need to be included by applying a ratio of 55.19% which is the actual ratio of births in the second half year in 1986 (DPS, 1988a). The numbers of regional births in the period from January 1986 to mid-1987 are available from the one percent population sampling data and are adjusted by the regional sampling ratios as well (DPS, 1988a). The population of period-cohort zero in 1982 is obtained by adding together these two parts of births in 1982-1985 and 1986-1987.

8.3.4 Origin- and destination-specific migrations and migration rates

The origin- and destination-specific inter-provincial migration data are available from the 1987 one percent population sampling data (DPS, 1988a). However, these migration data only record the last place of residence of a migrant in the period 1982-1987 which was different from that in 1987. Therefore, the last place of residence may not be the place of residence in 1982 as a migrant may make more than one migration in a five year period. In the case of urban-rural migrations in chapter four, the problem was avoided by assuming only one migration in one year period and a special estimation procedure was used to derive one-year migration rates from five-year migration data. In the case of inter-provincial migrations in China, the average five year inter-provincial migration rate is known to be 0.59%. It can be roughly estimated that the average one year inter-provincial migration rate was only 0.118%. Assuming one migration in one year, simple calculation shows that over 99.5% migrants will make only one migration in a five year period. The proportion of multiple migrations is then less than 0.5%. Thus the last place of residence migration data can be used as the transitional migration data between 1982 and 1987 without large error.

The patterns of inter-provincial migrations have been discussed in chapter seven. The age distribution is not available for inter-provincial migrations. What is available is the age distribution of migrations among city, town and county populations. It is found that migrants were concentrated in age-groups 20-30. For simplicity, the age-specific inter-provincial migrations are estimated by assuming that normal migration rates were same in all regions.

These normal migration rates are also used to estimate the age-specific emigrations to the rest of the world. The emigration data are not available from the 1987 one percent population sampling data. According to official sources (People's Daily, 1990), there were 94 thousand Chinese, excluding those for public affairs, going abroad in 1986 and 1987. It is noted that most of these international migrations were for study, work or joining family. Going abroad for non-public purpose was a new phenomenon in China in 1980s and a number of these Chinese may return home in two to four years especially those going abroad for language studies. For, simplicity, the total number of emigrants in 1986 and 1987 is used as total emigrants in the five year period 1982-1987. These total emigrations of China are allocated to provincial regions according to the distribution of those Chinese living abroad with non-residence registration status in the 1990 census (SSB, 1990). These amount to some 238 thousand, much less than 355 thousand of those going abroad in the period 1986-1989. This difference may be due to the fact that some people did not cancel their residence registration status when going abroad.

Now, it is straightforward to calculate survival migration rates defined in equation (8-23) in section 8.2.1.

The age distribution of total immigrations from abroad is available from the 1987 one percent population sampling data (DPS, 1988a). According to the population model, survival immigration flows will be directly used for population projections. There is no need to define any immigration rate. The regional immigration flows are allocated to their period-cohorts using the national age distribution of total immigrations.

8.3.5 Age-specific mortality rates

The starting and ending populations, and survival migration data have been prepared in previous sections. Theoretically, it is possible to estimate regional mortality rates from these data available. The estimation procedure for the infants-cohort mortality rate developed in section 8.2.2 can be used for all period-cohorts. However, only the mortality rates of the period-cohorts with large number of deaths and high mortality rates can be reasonably estimated as they are less sensitive to the disturbance of various errors in the data available. Table 8-3 presents the regional mortality rates estimated for the period-cohorts 15-17 of the female population.

The age-specific mortality rates for China as a whole can also be estimated by using the starting and ending populations in the calibration period 1982-1987 while disregarding the international migrations. Table 8-4 presents these results as estimation one. Note that only the mortality rates of period-cohorts 13-20 can be reliably estimated.

The national and regional mortality rates of the period-cohorts 15-17 of the female population and those of the period-cohorts 14-16 of the male population are used to calculate ratios of regional to national mortality rates for the female and male populations respectively. The starting populations in the three period-cohorts involved are used as weights to balance the total number of regional deaths in these period-cohorts. These ratios are also presented in table 8-3.

The regional to national ratios for females and males are generally consistent in the sense that most regions which have a female ratio over one will also have a male ratio over one. However, the relative female mortality rates in Liaoning, Hunan, Sichuan, Guizhou, Yunnan and Xinjiang are greater than the national average while their relative male mortality rates are generally lower. The situation is reversed in Fujian. The regional to national mortality ratio is well over 1.20 in Shaanxi, Inner Mongolia, Heilongjiang, Yunnan, Tibet and Shaanxi for the female population and in Inner Mongolia, Heilongjiang, Jiangxi, Hubei, Tibet and Shaanxi for the male population. The ratio is well below 0.80 in Jiangsu, Zhejiang, Guangdong, Guangxi and Qinghai

Table 8-3 Regional mortality rates (female, period-cohorts 15-17) and the ratio of regional to national mortality rates in China

Region	Mortality rate of period-cohort (‰)			Regional to national mortality ratio	
	15	16	17	Female	Male
Beijing	211	320	494	0.86	0.74
Tianjin	200	328	537	0.87	0.76
Hebei	285	435	605	1.13	1.16
Shanxi	354	527	636	1.36	1.18
Inner Mongolia	345	432	655	1.25	1.38
Liaoning	294	397	543	1.08	0.94
Jilin	290	436	581	1.13	1.16
Heilongjiang	368	451	609	1.29	1.23
Shanghai	236	355	538	0.95	0.90
Jiangsu	162	286	492	0.76	0.82
Zhejiang	139	305	512	0.76	0.81
Anhui	285	411	606	1.11	1.11
Fujian	199	305	464	0.81	1.09
Jiangxi	277	433	623	1.13	1.23
Shandong	219	378	555	0.96	0.97
Henan	269	412	588	1.08	1.07
Hubei	289	462	621	1.17	1.20
Hunan	253	411	576	1.05	0.98
Guangdong	185	281	438	0.76	0.84
Guangxi	164	253	385	0.67	0.67
Sichuan	252	394	542	1.01	0.93
Guizhou	285	461	495	1.12	0.92
Yunnan	314	439	624	1.20	0.93
Tibet	370	752	591	1.56	1.41
Shaanxi	352	467	572	1.28	1.23
Gansu	359	475	644	1.33	1.10
Qinghai	151	352	498	0.78	0.97
Ningxia	272	322	455	0.95	0.83
Xinjiang	385	303	650	1.20	0.87

Notes:
1: period-cohort 15 refers to population aged 70-74 in the beginning of five year period and aged 75-79 in the end of period.
2: period-cohort 16 refers to population aged 75-79 in the beginning of five year period and aged 80-84 in the end of period.
3: period-cohort 17 refers to population aged 80-84 in the beginning of five year period and aged 85-89 in the end of period.

for the female population and in Beijing, Tianjin and Guangxi for the male population. There ratios represent the differential mortality rates in various regions which have important effects on regional population dynamics.

National five year age-specific mortality rates can also be estimated from the one year age-specific mortality rates of urban and rural populations estimated in chapter three. In that case, national one year age-specific mortality rates were calculated first as weighted averages of urban and rural mortality rates. The following procedures are used to

Table 8-4 Age-specific mortality rates for China

Period-cohort	Estimation one		Estimation Two	
	Female	Male	Female	Male
0	91.29	77.04	29.50	28.98
1	0	0	7.70	7.78
2	0	0	2.61	3.40
3	15.43	11.91	3.40	3.70
4	12.33	29.28	5.58	6.26
5	3.39	2.41	6.23	6.95
6	18.56	19.65	6.22	7.59
7	5.19	14.10	7.45	9.03
8	5.47	27.09	9.48	12.51
9	2.23	33.12	14.38	19.24
10	2.30	26.76	21.85	31.10
11	11.04	28.13	36.65	49.13
12	37.97	53.42	56.85	83.79
13	83.86	123.38	87.14	137.71
14	157.61	205.93	144.07	209.54
15	250.12	327.76	224.79	306.76
16	380.70	464.28	342.58	435.08
17	543.46	629.55	489.73	579.50
18	704.30	750.30	662.98	735.12
19	742.97	739.36	844.34	878.08
20	768.77	682.08	958.37	966.32

Notes:
1: estimation one uses starting and ending population in the period 1982-1987.
2: estimation two uses the one-year age-specific mortality rates in 1987.
3: period-cohort zero refers to infants-cohort produced in a five year period and period-cohort one refers to population aged 0-4 and 5-9 in the beginning and end of a five year period respectively, and so on.

calculate the national five year age-specific mortality rates.

First, the stable population by one year period-cohort can be calculated using the national age-specific mortality rates for each gender. A stable population is a hypothetical population which has been subjected to constant mortality and fertility rates for a long time and has a constant age composition (Woods, 1979). Here, the stable population is used to account for the age composition by one year age interval within each period-cohort of five year age interval. Thus the stable population is used to calculate the starting population of five year period-cohorts and the ending population by aging on using the one year age-specific mortality rates for a period of five years. Here, it is assumed that the number of births in period-cohort zero of the stable population is one:

$$P1_{0g} = 1 \qquad (8\text{-}90)$$

The populations in the remaining one year period-cohorts can be calculated using the following equation:

$$P^1_{ag} = P^1_{a-1\,g} (1 - u^1_{a-1\,g}) \qquad a=1, 2, ..., 100 \qquad (8\text{-}91)$$

$$P^1_{101\,g} = P^1_{100\,g} (1 - u^1_{100\,g}) / u^1_{101\,g} \qquad (8\text{-}92)$$

Here P^1_{ag} is the stable population of period-cohort a of gender g by one year age intervals denoted by superscript one and u^1_{ag} is the forward mortality rate of period-cohort a of gender g by one year age intervals also denoted by superscript one.

Second, the starting populations of five year period-cohorts in a five year period can be calculated as follows:

$$PST^5_{0g} = 5 \text{ X } P^1_{0g} = 5 \qquad (8\text{-}93)$$

$$PST^5_{ag} = \Sigma^{5a}{}_{i=5a-4}\, P^1_{ig} \qquad a=1, 2, ..., 19 \qquad (8\text{-}94)$$

$$PST^5_{20g} = \Sigma^{101}{}_{i=96}\, P^1_{ig} \qquad (8\text{-}95)$$

Here PST^5_{ag} is the starting population of period-cohort a of gender g by five year age intervals denoted by superscript five.

Third, the ending populations of five year period-cohorts in a five year period can be calculated by aging on the stable populations of one year age intervals for five years and adding up for the period-cohorts of five year age intervals as follows:

$$PED^5_{0g} = \Sigma^5{}_{i=1}\, P^1_{0g} \Pi^{i-1}{}_{k=0} (1 - u^1_{kg}) \qquad (8\text{-}96)$$

$$PED^5_{ag} = \Sigma^{5a}{}_{i=5a-4}\, P^1_{ig} \Pi^4{}_{k=0} (1 - u^1_{i+k\,g}) \qquad a=1, 2, ..., 19 \qquad (8\text{-}97)$$

$$PED^5_{20g} = \Sigma^{101}{}_{i=96}\, P^1_{ig} (1 - u^1_{101g})^{i-96}\, \Pi^{100-i}{}_{k=0} (1 - u^1_{i+kg}) \qquad (8\text{-}98)$$

Here PED^5_{ag} is the ending population of period-cohort a of gender g by five year age intervals denoted by superscript five.

Fourth, the forward mortality rate u^5_{ag} for period-cohort a of gender g of five year age intervals can be calculated from the starting and ending populations of this period-cohort in a five year period as follows:

$$u^5_{ag} = 1 - PED^5_{ag} / PST^5_{ag} \qquad a = 0, 1, ..., 20 \qquad (8\text{-}99)$$

The national mortality rates of China calculated in this way are also presented in table 8-4 as estimation two. It seems that the mortality rates of period-cohort 13-20 in estimation one and two are comparable. However, the mortality rates of period-cohort 0-12 in estimation one are subject to statistical errors in the age-specific starting and ending populations in the period 1982-1987. These errors may be insignificant for age-specific populations. However, they may be significant for age-specific death populations as they may be in a same scale. Therefore, the national mortality rates in estimation two will be used for population projections. These national mortality rates are used to calculate regional mortality rates using the ratios of regional to national mortality rates presented in table 8-3. To keep consistency, the national mortality rates of period-cohorts 15-17 for the females and period-cohorts 14-16 for males in estimation one have been used in calculating these ratios of regional to national mortality rates.

8.3.6 Age-specific fertility rates

National age-specific fertility rates for five year age and time intervals can also be estimated from the age-specific fertility rates for one year age and time intervals based on 1987 one percent population sampling data. These again can be calculated as weighted averages of the urban and rural fertility rates estimated in chapter three. The following equations can be used to calculate the five year age specific fertility rates from the one year age-specific fertility rates of China. The procedures are similar to those used in the calculation of national five year age specific mortality rates in estimation two above.

The number of births $B5_a$ produced by period-cohort a of five year age and time intervals can be calculated as follows:

$$B5_a = \Sigma^{5a}_{i=5a-4}\Sigma^4_{k=0}P1_{i+k\,f}\, f1_{i+k} \qquad a=3, 4, ..., 10 \qquad (8\text{-}100)$$

Here $P1_{af}$ and $f1_a$ are the female stable population of period-cohort a calculated in the previous section and its fertility rate for one year age and time intervals.

The forward fertility rate $f5_a$ of period-cohort a of five year age and time intervals can be calculated as follows:

$$f5_a = B5_a / PST5_{af} \qquad a=3, 4, ..., 10 \qquad (8\text{-}101)$$

Here $PST5_{af}$ is the starting female population of period-cohort a of five year age and time intervals calculated as previously.

The normal fertility rate $fn5_a$ can be calculated using equation (8-66) and (8-67) as follows:

$$fn5_a = f5_a / (\Sigma^{10}_{a=3} f5_a / (1 - 0.5u5_{af})) \qquad a=3, 4, ..., 10 \qquad (8\text{-}102)$$

It is not possible to derive region-specific fertility rates from the 1987 one percent population sampling data available. The one per thousand fertility sampling survey conducted in 1982 by the State Family Planning Commission of China does however provide a detailed record of fertility in China and her provincial regions since the 1940s (Coale and Chen, 1987). The fertility rates for the 28 provincial regions of mainland China except Tibet in 1982 will be used to construct region-specific normal fertility rates for period-cohorts of five year age and time intervals. The available data on fertility rates in 1982 are for period-cohorts of five year age and one year time intervals.

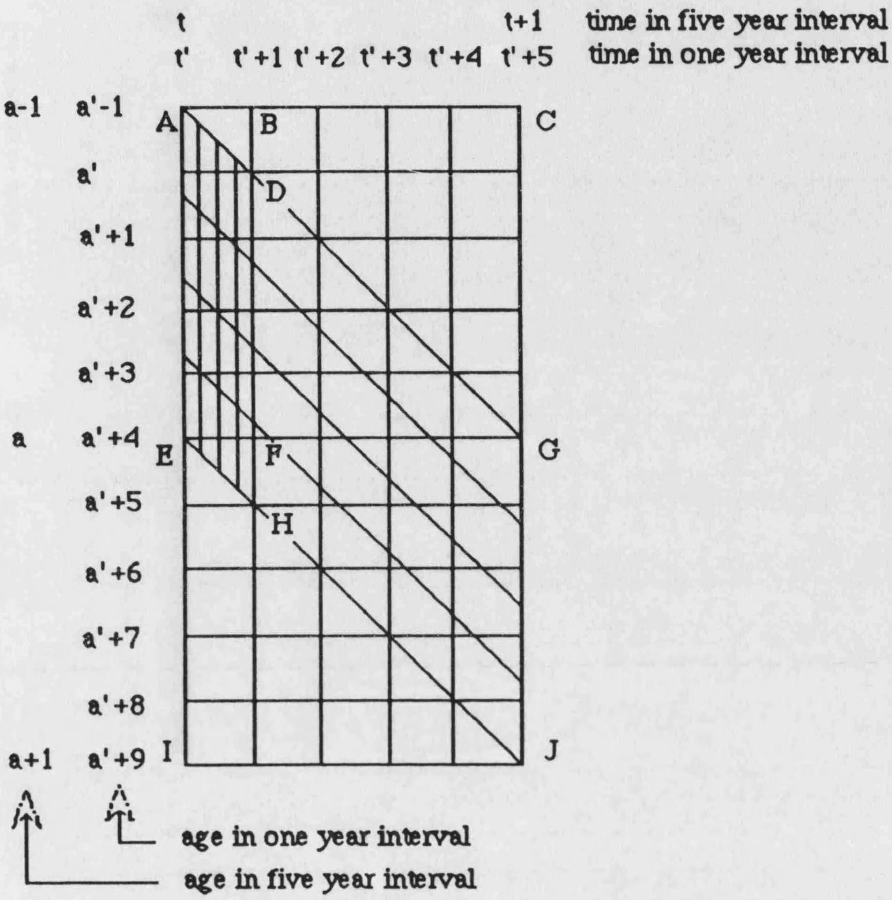
Figure 8-1 shows the meaning of the period-cohort fertility rate of five year age and one year time intervals f^{51}_a (area ADEH) and the period-cohort fertility rate of five year age and time intervals f^5_a (area AGEJ). Here the period fertility rate f^{P51}_a of five year age and one year time intervals (area ABEF) relates to births produced by the population reaching ages between a'-1 and a'+4 in period t' to t'+1. Similarly, the period fertility rate f^{P5}_a of five year age and time intervals (area ACEG) relates to births produced by the population reaching ages between a'-1 and a'+4 (or between a-1 and a in terms of five year age interval) in period t' to t'+5 (or in period t to t+1 in terms of five year time interval). For simplicity, period fertility rate f^{P51}_a (area ABEF) is estimated as the period-cohort fertility rate f^{51}_a (area ADEH). The period fertility rate f^{P5}_a (area ACEG) is estimated as five times the period fertility rate f^{P51}_a (area ABEF). The period fertility rate f^{P5}_{a+1} (area EGIJ) can be similarly estimated. It seems clear that the period-cohort fertility rate f^5_a (area AGEJ) involves two component rates, f^{P5}_a and f^{P5}_{a+1} (areas ACEG and EGIJ respectively), and can be estimated as their average. Thus the following estimation equation is obtained:

$$f^5_a = 0.5 \times 5 \times (f^{51}_a + f^{51}_{a+1}) \qquad a=3, 4, ..., 10 \qquad (8\text{-}103)$$

Here f^5_a is the fertility rate of period-cohort a of five year age and time intervals and f^{51}_a is the fertility rate of a period-cohort of five year age and one year time intervals.

The normal fertility rate of period-cohort a can be calculated again using equation (8-102). The estimation procedure is applied to China as a whole and her 28 provincial regions. Table 8-5 presents the normal fertility rates of China estimated by the two procedures discussed above based on the one percent population sampling data in 1987 and one per thousand fertility sampling data in 1982 respectively.

The normal fertility rates of period-cohorts 4-7 of China estimated using 1982 data are close to those estimated using 1987 data, though the fertility rates of period-cohorts 4 and 5 more or less increased and those of the remaining period-cohorts decreased during the period. The normal fertility rate had a peak of 0.37669 in period-cohort five in 1982, increasing to 0.44239 in 1987. This change reflects a trend of further concentration of childbearing (at ages of 20-30) along with the decline of fertility in China over the period 1982-1987. A ratio of the normal fertility rate of China estimated using 1987 data to that estimated using 1982 data is calculated for each period-cohort and is applied to the regional normal fertility rates estimated using 1982 data to update them. These adjusted fertility rates are re-normalized using equation (8-102) to obtain normal fertility rates for each of the provincial regions. Table 8-6 presents the adjusted normal fertility rates for the 28 regions.



Area ADEH: period-cohort fertility rate of five year age and one year time intervals

Area AGEJ: period-cohort fertility rate of five year age and time intervals

Area ABEF: period fertility rate of five year age and one year time intervals

Area ACEG: period fertility rate of five year age and time intervals

Figure 8-1 Lexis diagram showing the meaning of various fertility rates

The normal fertility rates of all regions had a peak in period-cohort five. However, some regions had a higher peak of normal fertility rate than other regions. Beijing, Tianjin, Liaoning, Jilin, Jiangsu, Zhejiang, Shandong, Sichuan and Shaanxi had a peak of normal fertility rates over 0.47 in period-cohort five which means that over 47% infants were produced in a five year period by the females aged 20-24 at the beginning of that period. Other regions had a more smooth fertility schedule. The peaks of normal fertility rates were below 0.40 in Guangxi, Guizhou, Yunnan, Qinghai and Xinjiang.

Table 8-5 Normal fertility rates of China using 1982 and 1987 data

Period-cohort	Normal fertility rate using data in 1982	1987
3 (10-14 -- 15-19)*	0.01715	0.00803
4 (15-19 -- 20-24)	0.19792	0.21773
5 (20-24 -- 25-29)	0.37669	0.44239
6 (25-29 -- 30-34)	0.25874	0.22201
7 (30-34 -- 35-39)	0.09031	0.07586
8 (35-39 -- 40-44)	0.03894	0.02329
9 (40-44 -- 45-49)	0.01421	0.00667
10 (45-49 -- 50-54)	0.00283	0.00088

Note: * age-groups in the beginning and end of a five year period respectively.

Table 8-6 Regional normal fertility rates for China

Period-cohort	3	4	5	6	7	8	9	10
Beijing	0.00000	0.14807	0.50206	0.29959	0.04718	0.00000	0.00000	0.00000
Tianjin	0.00000	0.10431	0.48019	0.33170	0.06085	0.01110	0.00868	0.00000
Hebei	0.00402	0.16771	0.42061	0.26644	0.10475	0.02616	0.00712	0.00000
Shanxi	0.01060	0.23914	0.44304	0.22301	0.07224	0.00727	0.00162	0.00000
Inner Mongolia	0.00803	0.18766	0.42980	0.26325	0.09413	0.01255	0.00146	0.00000
Liaoning	0.00382	0.22929	0.50990	0.21773	0.02443	0.00904	0.00272	0.00000
Jilin	0.00458	0.26064	0.49895	0.19275	0.02972	0.00802	0.00228	0.00000
Heilongjiang	0.01105	0.26334	0.46945	0.19833	0.04337	0.00758	0.00381	0.00000
Shanghai	0.00434	0.15481	0.46304	0.28749	0.07614	0.01105	0.00000	0.00000
Jiangsu	0.00602	0.23716	0.48812	0.21684	0.03985	0.00536	0.00240	0.00118
Zhejiang	0.00853	0.27911	0.47633	0.17447	0.04133	0.01150	0.00400	0.00164
Anhui	0.01546	0.19663	0.43092	0.25096	0.07410	0.01969	0.00845	0.00065
Fujian	0.01004	0.26630	0.45361	0.17729	0.05626	0.02556	0.00783	0.00000
Jiangxi	0.01887	0.26474	0.41712	0.17790	0.08078	0.03134	0.00531	0.00081
Shandong	0.00219	0.19670	0.47747	0.24861	0.05983	0.01046	0.00164	0.00000
Henan	0.00340	0.18687	0.44627	0.25054	0.08518	0.02040	0.00387	0.00032
Hubei	0.00880	0.25995	0.45761	0.19227	0.05560	0.01648	0.00619	0.00000
Hunan	0.00676	0.23134	0.46615	0.21164	0.05415	0.01903	0.00709	0.00070
Guangdong	0.00974	0.18192	0.41170	0.24520	0.10600	0.03373	0.00699	0.00153
Guangxi	0.00390	0.17140	0.37885	0.24651	0.14354	0.04340	0.00809	0.00106
Sichuan	0.00538	0.25648	0.47675	0.19097	0.04571	0.01597	0.00536	0.00029
Guizhou	0.00778	0.16288	0.35807	0.23418	0.15109	0.06363	0.01632	0.00273
Yunnan	0.00843	0.19941	0.38257	0.21246	0.12599	0.05121	0.01390	0.00276
Shaanxi	0.00711	0.26397	0.47099	0.18792	0.05094	0.01245	0.00266	0.00087
Gansu	0.02264	0.24375	0.43244	0.20305	0.05006	0.02826	0.01548	0.00116
Qinghai	0.01371	0.13707	0.28360	0.24756	0.20112	0.08917	0.02435	0.00000
Ningxia	0.00503	0.21520	0.41056	0.21837	0.09445	0.02879	0.01940	0.00493
Xinjiang	0.01530	0.18018	0.37077	0.24739	0.13033	0.03973	0.01067	0.00240

Note: period-cohort 3 refers to population aged 10-14 and 15-19 in the beginning and end of a five year period, and so on.

8.3.7 Total fertility rates

Normal fertility rates have been estimated for 28 provincial regions of China and are assumed constant in multiregional population projections. Total fertility rates for the twenty five-year projection periods also need to be assumed for population projections. Three sets of urban-rural total fertility rates have been assumed for urban-rural population projections of China in chapter four. In set (A), it is assumed that the total fertility rates of the urban and rural populations will remain unchanged from the base year 1987. In set (B), it is assumed that the total fertility rate of the urban population will gradually decline to 1.5 in 2000, remain unchanged until 2010, gradually increase to 2.2 in 2030, then remain unchanged until 2087. The total fertility rate of the rural population is assumed to decline gradually to 2.2 in 2020 and then remain unchanged until 2087. In set (C), it is assumed that the total fertility rate of the urban population will decline to 1.5 in 2000 and then remain unchanged until 2087. The total fertility rate trend of the rural population is assumed to be the same as in set (B). To make consistent population projections of China, three sets of national total fertility rates are calculated from these urban and rural total fertility rates and the projected proportions of urban and rural populations. It is noted that the national total fertility rate in set (A) shows a declining trend because of the increasing proportion of the urban population though constant total fertility rates are assumed for urban and rural populations respectively. These national total fertility rates refer to periods of one year only. An average national total fertility rate for each five-year projection period can be calculated for each of the three sets of fertility assumptions (A), (B) and (C).

The total fertility rates for the 29 provincial regions of China in 1990 are available from the 1990 census (SSB, 1991). The regional to national ratio of total fertility rates in 1990 can be calculated and are presented in table 8-7. This ratio was well below 0.8 in Beijing, Tianjin, Liaoning, Heilongjiang, Shanghai, Zhejiang and Sichuan, and over 1.20 in Henan, Guangxi, Guizhou, Tibet and Xinjiang. It is difficult to project the regional differentials of total fertility rates for the projection periods. For simplicity, these ratios are applied to three sets of national total fertility rates assumed above to calculate regional total fertility rates for the twenty five-year projection periods (1987-2087). However, the actual national total fertility rates in the projection periods derived from these regional total fertility rates will be different from those assumed originally due to the changing shares of regional populations with different total fertility rates. The following adjustment ratio is calculated and used to re-adjust regional total fertility rates (TFR) to ensure the national total fertility rates used in population projections are equal to those assumed originally.

Table 8-7 Total fertility rates and regional to national ratios of total fertility rates in 1990 for China

Region	TFR	Regional to national TFR ratio
Beijing	1.33	0.591
Tianjin	1.66	0.738
Hebei	2.33	1.036
Shanxi	2.46	1.093
Inner Mongolia	1.97	0.876
Liaoning	1.51	0.671
Jilin	1.81	0.804
Heilongjiang	1.71	0.760
Shanghai	1.34	0.596
Jiangsu	1.94	0.862
Zhejiang	1.40	0.622
Anhui	2.51	1.116
Fujian	2.36	1.049
Jiangxi	2.46	1.093
Shandong	2.12	0.942
Henan	2.90	1.289
Hubei	2.50	1.111
Hunan	2.40	1.067
Guangdong	2.55	1.133
Guangxi	2.73	1.213
Sichuan	1.76	0.782
Guizhou	2.96	1.316
Yunnan	2.59	1.151
Tibet	4.22	1.876
Shaanxi	2.71	1.204
Gansu	2.34	1.040
Qinghai	2.47	1.098
Ningxia	2.61	1.160
Xinjiang	3.16	1.404
China	2.25	1.000

Data source: total fertility rates from SSB (1991)

$$\text{Adjustment ratio} = \frac{\text{National TFR assumed}}{\text{National TFR derived from regional TFRs}} \qquad (8\text{-}104)$$

Here, the national total fertility rates derived from the regional total fertility rates can be calculated using the following equation:

$$\text{National TFR derived from regional TFRs} = \Sigma^{10}_{a=3} (\Sigma^{N}_{k=1} \text{TFR}^{k} f^{nk}_{a} \text{PST}^{k}_{af} / \Sigma^{N}_{k=1} \text{PST}^{k}_{af}) / (1 - 0.5\, u^{5}_{af}) \qquad (8\text{-}105)$$

Here, TFR^k and f^{nk}_a are the regional total fertility rate and normal fertility rate of period-cohort a of the female population in region k respectively, and PST^k_{af} is the starting female population for the calculation of the number of births in region k. Three procedures have been combined in equation (8-105). First, the number of births produced by the female population of period-cohort a in region k is calculated by multiplying the regional total fertility rate, the normal fertility rate and the starting population of period-cohort a. Second, the total number of births of the country as a whole produced by the female population of period-cohort a is calculated by the summation of regional births. Then, a national forward fertility rate of period-cohort a is obtained by dividing the total number of births by the total number of the starting population of the country in period-cohort a. Third, a national total fertility rate can be calculated using equations (8-66) and (8-67).

8.3.8 Summary of input data and assumptions for multiregional population projections

The projection period runs from 1987 to 2087. The time and age intervals are five years in the population projection model. The spatial population system consists of 29 mainland provincial regions of China and is connected with the rest of the world via international migration. The base year is 1987. Age-specific regional populations have been prepared in section 8.3.2.

Constant regional mortality and normal fertility rates prepared in sections 8.3.5 and 8.3.6 are used in the population projections. Note that the normal fertility rates for Tibet are not available. According to the 1990 census (SSB, 1991), Tibet had the highest total fertility rate (4.22) among 30 provincial regions (including the new province of Hainan) in 1990 in China and Xinjiang had the second highest (3.16). It is likely that the fertility schedule of a population is associated with the size of its total fertility rate. For simplicity, the normal fertility rates of Xinjiang are assumed for Tibet.

Constant migration rates prepared in section 8.3.4 will also be assumed for population projections with one exception. It is recognized that the number of Chinese going abroad has been increasing in recent years. According to official sources (People's Daily, 1990), the number was 40 thousand in 1986 and 133 thousand in 1989 excluding those going abroad for public affairs. In the estimation of emigration rates, a total number of emigrants of 94 thousands was assumed for China for the period 1982-1987. At the moment, it is difficult to project the number of emigrants in future as this depends on the situation in China as well as the restrictions of the destination countries. For simplicity, a total number of 665 thousand is assumed for a five year period based on a simple grossing up of the figure in 1989. Comparing this number of emigrants (665 thousand) with the 94 thousand assumed for the period 1982-1987, means that the emigration rates should be increased by a factor of about 7.07. This inflation figure is assumed for population projections.

Three sets of national total fertility rates have been assumed on the basis of three sets of urban and rural fertility rates assumptions in chapter four to make consistent population projections. Table 8-8 presents the three sets of the national fertility rates assumed for the multiregional population projections of China. Note that the total fertility rate is defined as the sum of age-specific forward fertility rates in chapter four. In the multiregional population model developed in section 8.2, a total fertility rate is defined as the sum of age-specific occurrence-exposure fertility rates which is about 0.316% greater than the former. The total fertility rates presented in table 8-8 have been adjusted according to this figure. All these rates are based on occurrence-exposure fertility rates and are the averages for each five year period. In projection (A), it is assumed that the national total fertility rate of China will decline from 2.356 in the first five-year period 1987-1992 to 1.850 in the last five-year period 1982-1987. Projection (B) assumes lower national total fertility rates for the period 1987-2027 and higher for the period 2027-2087 than projection (A). Projection (C) assumes lower total fertility rates than projections (A) and (B). Regional total fertility rates are calculated from national total fertility rates using constant regional to national ratios of total fertility rates prepared in section 8.3.7 and adjustment ratios in equation (8-104).

Table 8-8 Assumptions of national total fertility rates (A, B and C) for China

Period	A	B	C
1987-1992	2.356	2.310	2.310
1992-1997	2.317	2.195	2.195
1997-2002	2.283	2.090	2.090
2002-2007	2.245	2.003	2.003
2007-2012	2.204	1.949	1.928
2012-2017	2.166	1.956	1.860
2017-2022	2.132	2.012	1.808
2022-2027	2.101	2.100	1.776
2027-2932	2.073	2.180	1.753
2032-2037	2.045	2.206	1.731
2037-2042	2.017	2.205	1.709
2042-2047	1.990	2.205	1.688
2047-2052	1.966	2.204	1.670
2052-2057	1.945	2.204	1.654
2057-2062	1.926	2.204	1.639
2062-2067	1.908	2.204	1.625
2067-2072	1.891	2.203	1.612
2072-2077	1.876	2.203	1.600
2077-2082	1.863	2.203	1.589
2082-2087	1.850	2.203	1.580

Note: These national total fertility rates assumptions are based on the urban and rural fertility rates assumptions in Chapter four. The total fertility rate of set (B) is not exactly constant after 2032 due to the rounding errors.

8.4 Multiregional population projections for China

This section will discuss the results of multiregional population projections using the population model developed in section 8.2. Three sets of projections (A), (B) and (C) were made using the three sets of national total fertility rate assumptions in section 8.3.8. Many results were generated with regard to the numbers of births, deaths, internal migrations, external migrations for the projection period 1987-2087. Here, the emphasis will be placed on population change, population ageing and labour population in the 29 provincial regions of China in the period 1987-2087. Three main variables will be used, namely, a population index, the proportion of the elderly population and the proportion of the labour population. A population index is defined as the total population of a region in year t divided by its total population in the base year 1987. The elderly population includes males aged 65 and over and females aged 60 and over. The labour population includes males aged 18-64 and females 18-59 (Song et al., 1981).

8.4.1 National population projections: the multiregional model versus an urban-rural model

The same base year population and fertility assumptions have been used for population projections of China using the multiregional (provincial level) model described in this chapter and the urban-rural model discussed in chapter four. Two sets of population figures for China as a whole can be aggregated from the regional projections and urban-rural projections respectively. It would be interesting to compare these two sets of population projections for China. Table 8-9 presents the population projection results using the two population models. Each model was used to make three sets of population projections (A), (B) and (C) using three sets of fertility assumptions mentioned before.

The two types of projections for China's total population are close for the period 1987-2052. For each set of projections (A), (B) and (C), the difference between the total populations projected by two models is less than 5 millions or 0.5% of the total population of China for that period. But the difference does increase in the period 2052-2087. In 2072, the differences between the total populations projected by two models are 6, 12 and 5 millions for projections (A), (B) and (C) respectively. In 2087, the differences are much greater and are 40, 54 and 33 millions for projections (A), (B) and (C) respectively. Nevertheless, even in 2087, these differences account for less than 4% of the total population in that year.

The projections of the proportion of elderly population of China by two models are close for each set of projections (A), (B) and (C) in the whole projection periods. For example, the proportion of elderly population will be 18.1% and 18.2% respectively in 2042 according to projection (A) by the multiregional and urban-rural models respectively. In 2087, the proportion of elderly population will be 20.5% and 21.0% respectively according to projection (A) by two models.

Table 8-9 Comparison of population projections for China by multiregional and urban-rural models

Year	Multiregional model A	Multiregional model B	Multiregional model C	Urban-rural model A	Urban-rural model B	Urban-rural model C
	Total population (Million)					
1992	1173	1171	1171	1173	1170	1170
2002	1337	1318	1318	1339	1320	1320
2012	1444	1401	1400	1448	1403	1403
2022	1542	1475	1458	1548	1480	1463
2032	1594	1514	1463	1599	1518	1467
2042	1599	1513	1414	1602	1514	1418
2052	1578	1497	1333	1579	1495	1335
2062	1534	1472	1232	1530	1463	1229
2072	1482	1453	1125	1476	1441	1120
2087	1410	1469	985	1370	1415	952
	Proportion of elderly population (%)					
1992	7.6	7.6	7.6	7.6	7.7	7.7
2002	8.6	8.8	8.8	8.6	8.7	8.7
2012	9.8	10.1	10.1	9.8	10.1	10.1
2022	12.3	12.8	13.0	12.2	12.7	12.9
2032	16.3	17.2	17.8	16.3	17.2	17.8
2042	18.1	19.1	20.4	18.2	19.2	20.5
2052	17.9	18.8	21.1	17.9	18.9	21.1
2062	19.6	19.7	23.6	19.7	19.9	23.6
2072	19.7	18.6	24.0	19.8	18.7	24.0
2087	20.5	17.6	24.6	21.0	18.2	25.2

Note: See text for assumptions in three sets of projections (A), (B) and (C).

8.4.2 Regional population change in China

This section will discuss regional population projections using the population index defined earlier. Tables 8-10, 8-11 and 8-12 present three projections (A), (B) and (C) of regional population indexes respectively for the period 1987-2087.

According to projection (A) in table 8-10, the total population of China will increase by about 50% in the period 1987-2042 and then decline slowly until 2087. By the year 2087, the total population will be about 30% more than that in 1987. For the China as a whole, a growing stage and a stable or slowly declining stage can be identified with a division around 2040 as found already in chapter four. However, this national trend is just a combination of various regional trends. Some regions will reach their population

Table 8-10 Projections of regional population index for fertility rate assumption (A) in China

Region\Year	1987	1992	2002	2012	2022	2032	2042	2052	2062	2072	2082	2087
Beijing	1	1.07	1.16	1.20	1.22	1.20	1.14	1.06	0.97	0.90	0.82	0.80
Tianjin	1	1.07	1.18	1.23	1.27	1.26	1.21	1.14	1.06	0.98	0.90	0.87
Hebei	1	1.08	1.23	1.34	1.44	1.50	1.50	1.49	1.45	1.40	1.34	1.32
Shanxi	1	1.08	1.23	1.33	1.42	1.47	1.48	1.46	1.43	1.38	1.32	1.30
Inner Mongolia	1	1.07	1.19	1.25	1.28	1.26	1.19	1.09	0.99	0.89	0.80	0.76
Liaoning	1	1.06	1.13	1.15	1.13	1.06	0.94	0.82	0.69	0.58	0.49	0.45
Jilin	1	1.07	1.16	1.20	1.20	1.15	1.05	0.93	0.82	0.71	0.61	0.57
Heilongjiang	1	1.05	1.13	1.14	1.12	1.05	0.93	0.81	0.69	0.58	0.49	0.46
Shanghai	1	1.05	1.08	1.09	1.07	1.01	0.92	0.83	0.75	0.67	0.61	0.58
Jiangsu	1	1.08	1.19	1.24	1.29	1.28	1.23	1.16	1.08	1.00	0.92	0.88
Zhejiang	1	1.04	1.09	1.08	1.05	0.97	0.85	0.72	0.60	0.49	0.40	0.37
Anhui	1	1.09	1.28	1.39	1.51	1.59	1.62	1.62	1.60	1.56	1.52	1.50
Fujian	1	1.09	1.26	1.39	1.51	1.58	1.61	1.60	1.55	1.49	1.42	1.40
Jiangxi	1	1.09	1.27	1.41	1.54	1.63	1.66	1.66	1.62	1.57	1.51	1.49
Shandong	1	1.08	1.22	1.30	1.38	1.40	1.37	1.32	1.25	1.17	1.08	1.05
Henan	1	1.11	1.33	1.49	1.69	1.86	1.98	2.09	2.17	2.23	2.28	2.31
Hubei	1	1.10	1.27	1.39	1.52	1.59	1.63	1.64	1.62	1.59	1.54	1.53
Hunan	1	1.09	1.25	1.35	1.45	1.50	1.51	1.49	1.44	1.38	1.32	1.29
Guangdong	1	1.10	1.29	1.46	1.62	1.75	1.84	1.90	1.93	1.93	1.92	1.92
Guangxi	1	1.09	1.29	1.46	1.62	1.77	1.87	1.93	1.97	1.97	1.97	1.98
Sichuan	1	1.06	1.17	1.20	1.21	1.18	1.09	0.99	0.87	0.76	0.67	0.63
Guizhou	1	1.10	1.34	1.55	1.74	1.93	2.07	2.18	2.26	2.32	2.36	2.39
Yunnan	1	1.09	1.27	1.42	1.55	1.65	1.70	1.70	1.68	1.64	1.60	1.58
Tibet	1	1.12	1.40	1.67	2.01	2.39	2.78	3.22	3.67	4.14	4.64	4.92
Shaanxi	1	1.10	1.27	1.39	1.53	1.60	1.66	1.69	1.69	1.68	1.65	1.65
Gansu	1	1.09	1.25	1.35	1.44	1.48	1.47	1.43	1.37	1.30	1.23	1.20
Qinghai	1	1.06	1.20	1.32	1.39	1.43	1.44	1.41	1.35	1.29	1.23	1.21
Ningxia	1	1.13	1.40	1.64	1.87	2.06	2.20	2.29	2.33	2.34	2.33	2.34
Xinjiang	1	1.12	1.37	1.59	1.81	2.02	2.17	2.31	2.41	2.49	2.55	2.59
China	1	1.08	1.23	1.33	1.42	1.47	1.48	1.46	1.41	1.37	1.32	1.30

Table 8-11 Projections of regional population index for fertility rate assumption (B) in China

Region \ Year	1987	1992	2002	2012	2022	2032	2042	2052	2062	2072	2082	2087
Beijing	1	1.07	1.15	1.18	1.19	1.16	1.09	1.00	0.92	0.86	0.81	0.80
Tianjin	1	1.07	1.16	1.21	1.23	1.21	1.15	1.08	1.01	0.94	0.89	0.88
Hebei	1	1.08	1.21	1.30	1.38	1.42	1.42	1.41	1.39	1.37	1.36	1.37
Shanxi	1	1.08	1.21	1.28	1.36	1.39	1.39	1.38	1.37	1.35	1.34	1.36
Inner Mongolia	1	1.06	1.17	1.22	1.23	1.20	1.13	1.04	0.95	0.86	0.8	0.79
Liaoning	1	1.05	1.12	1.12	1.09	1.02	0.90	0.77	0.66	0.56	0.48	0.45
Jilin	1	1.06	1.15	1.17	1.16	1.10	1.00	0.88	0.77	0.68	0.60	0. 58
Heilongjiang	1	1.05	1.11	1.11	1.08	1.00	0.89	0.76	0.65	0.56	0.48	0.46
Shanghai	1	1.04	1.07	1.07	1.04	0.97	0.88	0.79	0.71	0.64	0.59	0.58
Jiangsu	1	1.08	1.18	1.21	1.24	1.22	1.17	1.10	1.03	0.96	0.91	0.90
Zhejiang	1	1.04	1.08	1.06	1.02	0.94	0.82	0.69	0.57	0.47	0.39	0.37
Anhui	1	1.09	1.26	1.34	1.44	1.50	1.53	1.54	1.54	1.54	1.55	1.57
Fujian	1	1.09	1.24	1.35	1.44	1.50	1.52	1.51	1.49	1.46	1.44	1.45
Jiangxi	1	1.08	1.25	1.37	1.47	1.54	1.57	1.57	1.55	1.54	1.54	1.55
Shandong	1	1.08	1.20	1.27	1.32	1.33	1.30	1.25	1.19	1.13	1.09	1.08
Henan	1	1.11	1.31	1.44	1.60	1.75	1.86	1.99	2.10	2.21	2.35	2.44
Hubei	1	1.10	1.25	1.34	1.45	1.50	1.54	1.55	1.56	1.56	1.57	1.60
Hunan	1	1.09	1.23	1.30	1.38	1.42	1.43	1.41	1.38	1.36	1.34	1.34
Guangdong	1	1.10	1.27	1.41	1.55	1.66	1.75	1.81	1.85	1.90	1.95	2.00
Guangxi	1	1.09	1.27	1.41	1.55	1.68	1.77	1.84	1.90	1.95	2.02	2.07
Sichuan	1	1.06	1.16	1.17	1.17	1.13	1.04	0.94	0.83	0.73	0.66	0.64
Guizhou	1	1.09	1.31	1.49	1.65	1.82	1.96	2.07	2.19	2.30	2.44	2.54
Yunnan	1	1.08	1.25	1.37	1.48	1.56	1.61	1.62	1.62	1.62	1.63	1.66
Tibet	1	1.12	1.37	1.59	1.88	2.23	2.61	3.08	3.61	4.22	4.98	5.44
Shaanxi	1	1.10	1.25	1.34	1.45	1.51	1.56	1.59	1.62	1.66	1.69	1.74
Gansu	1	1.09	1.23	1.31	1.37	1.40	1.39	1.35	1.31	1.28	1.25	1.26
Qinghai	1	1.06	1.18	1.28	1.32	1.36	1.37	1.35	1.31	1.28	1.26	1.27
Ningxia	1	1.12	1.38	1.59	1.78	1.95	2.08	2.17	2.24	2.31	2.38	2.44
Xinjiang	1	1.11	1.35	1.53	1.71	1.90	2.05	2.20	2.34	2.48	2.65	2.77
China	1	1.08	1.22	1.29	1.36	1.40	1.40	1.38	1.36	1.34	1.34	1.36

Table 8-12 Projections of regional population index for fertility rate assumption (C) in China

Region \ Year	1987	1992	2002	2012	2022	2032	2042	2052	2062	2072	2082	2087
Beijing	1	1.07	1.15	1.18	1.18	1.14	1.05	0.94	0.83	0.72	0.63	0.59
Tianjin	1	1.07	1.16	1.21	1.22	1.18	1.10	1.00	0.89	0.78	0.68	0.64
Hebei	1	1.08	1.21	1.30	1.37	1.37	1.33	1.26	1.17	1.06	0.96	0. 93
Shanxi	1	1.08	1.21	1.28	1.34	1.34	1.29	1.22	1.13	1.03	0.93	0.89
Inner Mongolia	1	1.06	1.17	1.22	1.22	1.17	1.06	0.94	0.81	0.69	0.58	0.54
Liaoning	1	1.05	1.12	1.12	1.09	1.00	0.87	0.72	0.58	0.47	0.37	0.33
Jilin	1	1.06	1.15	1.17	1.15	1.07	0.95	0.81	0.67	0.55	0.45	0. 41
Heilongjiang	1	1.05	1.11	1.11	1.07	0.98	0.84	0.70	0.57	0.45	0.36	0.33
Shanghai	1	1.04	1.07	1.07	1.04	0.96	0.85	0.74	0.63	0.54	0.46	0.43
Jiangsu	1	1.08	1.18	1.21	1.23	1.19	1.11	1.01	0.89	0.78	0.68	0.64
Zhejiang	1	1.04	1.08	1.06	1.01	0.92	0.79	0.65	0.51	0.40	0.31	0.28
Anhui	1	1.09	1.26	1.34	1.42	1.45	1.42	1.36	1.27	1.17	1.08	1.04
Fujian	1	1.09	1.24	1.35	1.42	1.45	1.42	1.35	1.24	1.13	1.02	0.98
Jiangxi	1	1.08	1.25	1.36	1.45	1.48	1.46	1.38	1.28	1.17	1.06	1.02
Shandong	1	1.08	1.20	1.27	1.31	1.29	1.23	1.13	1.02	0.90	0.79	0.75
Henan	1	1.11	1.31	1.44	1.58	1.68	1.71	1.73	1.70	1.65	1.59	1.57
Hubei	1	1.10	1.25	1.34	1.43	1.45	1.42	1.37	1.28	1.19	1.09	1.05
Hunan	1	1.09	1.23	1.30	1.37	1.37	1.33	1.25	1.15	1.05	0.94	0.90
Guangdong	1	1.10	1.27	1.41	1.53	1.60	1.62	1.60	1.55	1.47	1.38	1.35
Guangxi	1	1.09	1.27	1.41	1.53	1.61	1.64	1.63	1.58	1.51	1.43	1.40
Sichuan	1	1.06	1.16	1.17	1.16	1.10	0.99	0.86	0.72	0.60	0.49	0.46
Guizhou	1	1.09	1.31	1.49	1.63	1.74	1.80	1.81	1.79	1.74	1.68	1.66
Yunnan	1	1.08	1.25	1.37	1.46	1.50	1.49	1.43	1.34	1.25	1.15	1.11
Tibet	1	1.12	1.37	1.58	1.84	2.09	2.32	2.54	2.74	2.92	3.10	3.20
Shaanxi	1	1.10	1.25	1.34	1.43	1.45	1.44	1.39	1.32	1.24	1.15	1.11
Gansu	1	1.09	1.23	1.31	1.36	1.35	1.29	1.20	1.09	0.98	0.87	0.83
Qinghai	1	1.06	1.18	1.27	1.31	1.31	1.28	1.20	1.10	0.99	0.90	0.87
Ningxia	1	1.12	1.38	1.59	1.76	1.88	1.93	1.92	1.86	1.77	1.67	1.63
Xinjiang	1	1.11	1.35	1.53	1.69	1.81	1.88	1.90	1.88	1.84	1.78	1.77
China	1	1.08	1.22	1.29	1.35	1.35	1.30	1.23	1.14	1.04	0.94	0.91

peaks much earlier. Zhejiang will reach its population peak as early as in the year 2002; Liaoning, Jilin, Heilongjiang and Shanghai in 2012; Beijing, Tianjin, Inner Mongolia, Jiangsu and Sichuan in 2022; Hebei, Shandong and Gansu in 2032. Some regions will reach their population peaks much later. Shanxi, Anhui, Fujian, Jiangxi, Hunan, Yunnan and Qinghai will reach their population peaks in 2042 along with the whole country. Other important peaks are Hubei and Shaanxi in 2052, Guangdong in 2062, and Ningxia in 2072. Henan, Guangxi, Guizhou, Tibet and Xinjiang will show continuous growth of population over the whole projection period 1987-2087. It seems that those regions which reach their population peaks earlier will have a lower rate of population growth in their growing period compared to other regions and have smaller population indexes in subsequent years. Figures 8-2(a) and 8-2(b) present the regional population indexes of projection (A) in 2042 and 2087 respectively. Liaoning, Heilongjiang, Shanghai and Zhejiang will have less population in 2042 than in 1987. On the other hand, Henan, Guangdong, Guangxi, Guizhou, Tibet, Ningxia, and Xinjiang will have more than 80% population increase in the period 1987-2042. By the year 2087, Liaoning, Heilongjiang, and Zhejiang will have 50% less population than in 1987. Another seven regions including Beijing, Tianjin, Inner Mongolia, Jilin, Shanghai, Jiangsu and Sichuan will have less population in 2087 than in 1987. On the other hand, Hubei, Guangdong, Guangxi, Yunnan, Shaanxi will have more than 50%, but less than 100%, population increase in period 1987-2087. Henan, Guizhou, Tibet, Ningxia and Xinjiang will have their population more than doubled in the period 1987-2087.

Figure 8-3 presents the trends in the regional population indexes for each region. For example, the population of Beijing will increase by 22% in the period 1987-2022, then begin to decline. By the year 2060, Beijing will have the same size of population as in 1987. By the year 2087, the population in Beijing will be further reduced to a size of 80% as in 1987. The population in Shandong will increase by 40% in the period 1987-2032, then begin to decline. However, it will still have 5% more population in 2087 than in 1987. According to figure 8-3, the ranks of regional population indexes change little during the projection period. By the year 2087, Zhejiang will have the smallest population index of 0.37 resulting from its low total fertility rate and high net out-migration in the early years of the projection period. Due to net in-migration, Beijing, Tianjin and Shanghai will have greater population indexes of 0.8, 0.87 and 0.58 respectively in 2087 than Zhejiang though their total fertility rates are also low and the population as a whole will decline. Due to its high total fertility rate, the population in Tibet will increase rapidly during the period 1987-2087. Its population will be doubled by the year 2022 and doubled again by 2072 under these assumptions.

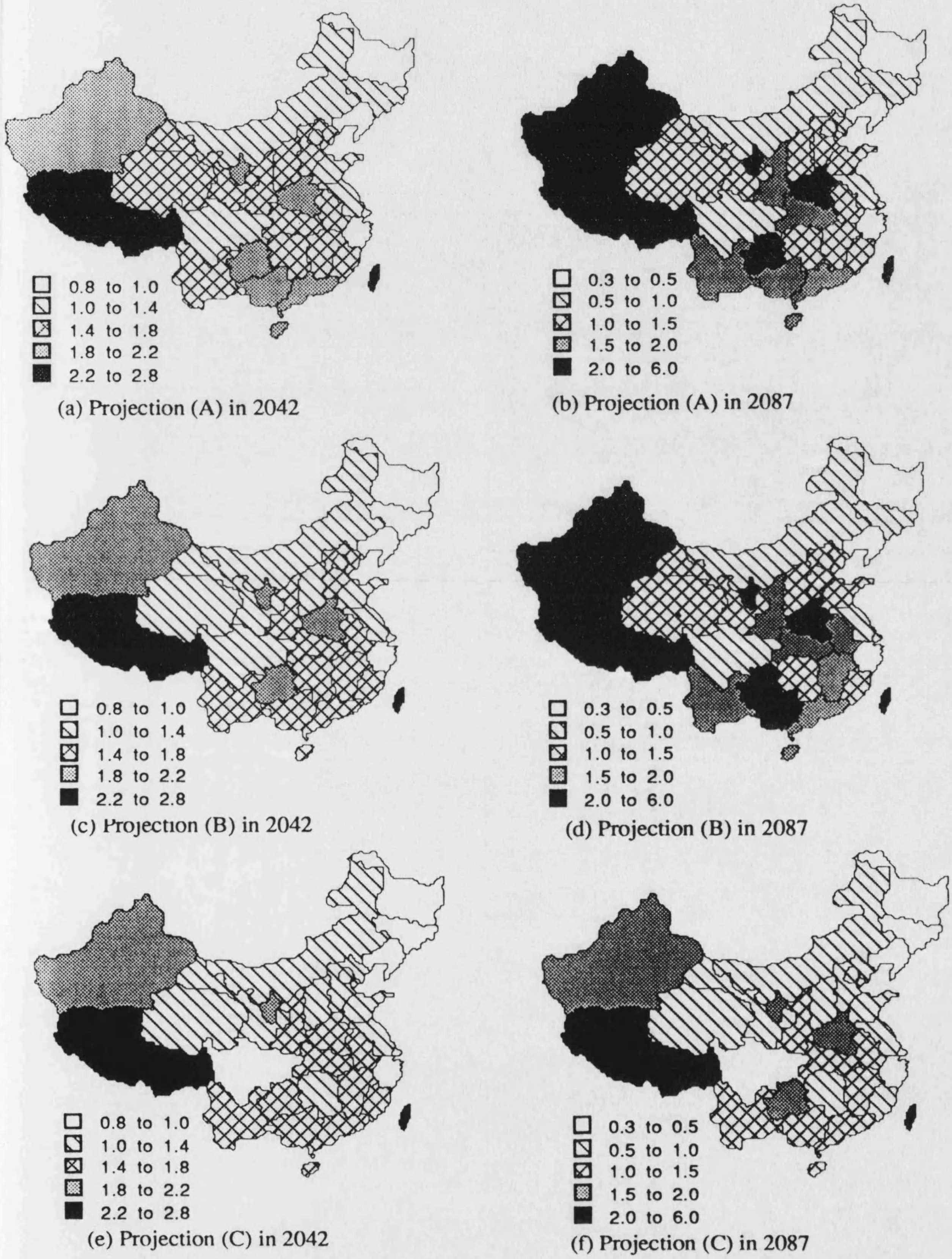


Figure 8-2 Projections of regional population index (A, B, and C) in China

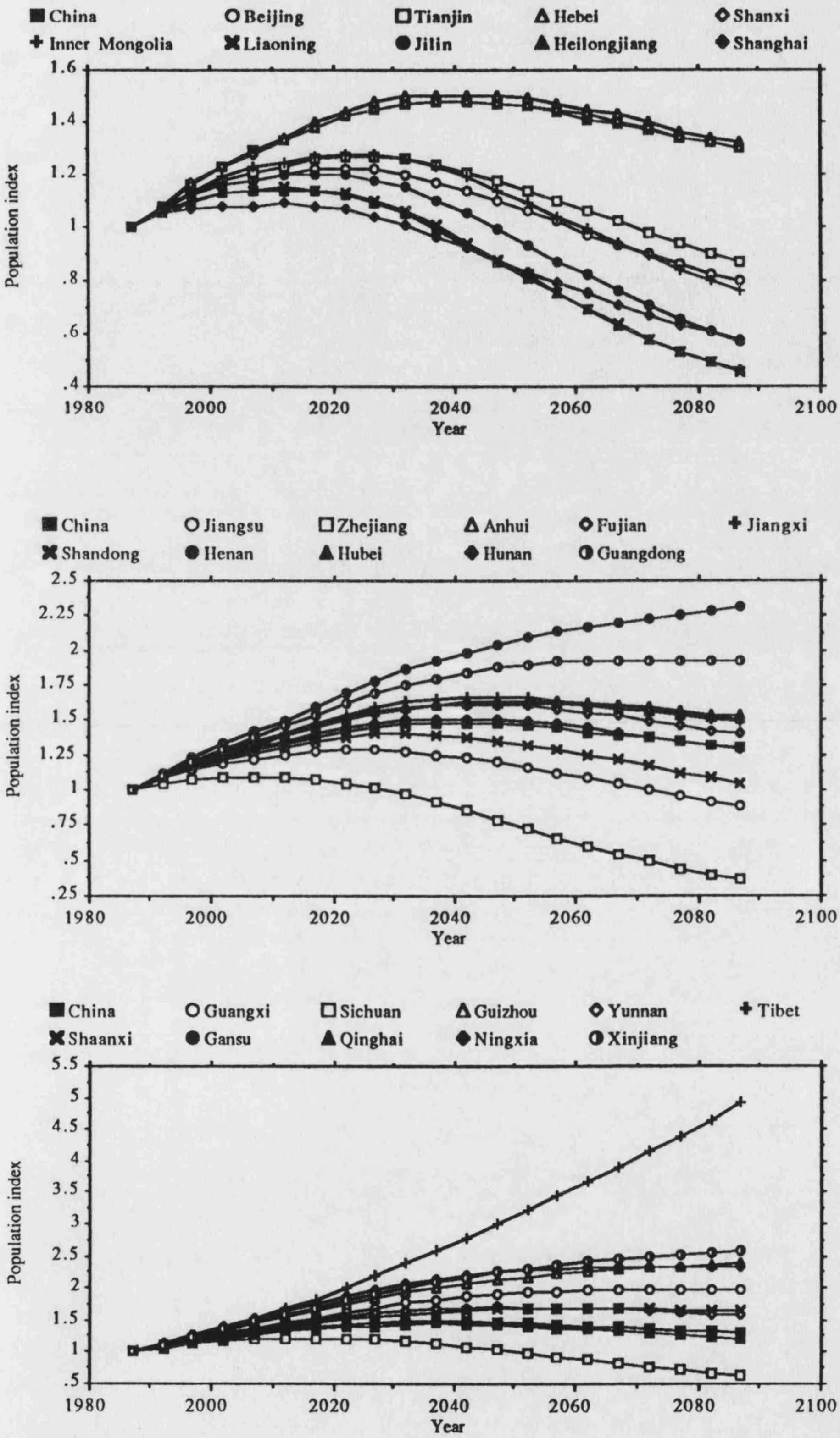


Figure 8-3 Regional population index of projection (A) in China

In summary, the following regions will have less population in 2087 than in 1987: Beijing, Tianjin, Inner Mongolia, Liaoning, Jilin, Heilongjiang, Shanghai, Jiangsu, Zhejiang and Sichuan. Among these regions, Beijing, Tianjin, Liaoning, Shanghai, Jiangsu, Zhejiang are in the more developed eastern economic zone of China. Sichuan is the most populous province in China. The remaining provincial regions will have more population in 2087 than in 1987. The second most populous province --- Shandong will increase by some 8% over this period. Table 8-13 reports the absolute numbers of projected regional populations.

Using the fertility rate assumption (B), the trend of the national population is similar to that in projection (A). The total population of China will increase by 40% in the period

Table 8-13 Projections of regional populations for fertility rate assumption (A) in China (millions)

Region \Year	1987	2042	2087
Beijing	10.0	11.4	8.0
Tianjin	8.4	10.2	7.4
Hebei	57.8	86.9	76.2
Shanxi	27.3	40.3	35.5
Inner Mongolia	20.8	24.8	15.9
Liaoning	38.3	36.2	17.4
Jilin	23.8	24.9	13.6
Heilongjiang	34.2	31.9	15.6
Shanghai	12.7	11.6	7.4
Jiangsu	64.4	79.2	57.0
Zhejiang	41.8	35.7	15.5
Anhui	53.6	86.7	80.6
Fujian	28.3	45.6	39.7
Jiangxi	36.1	60.0	53.6
Shandong	80.0	109.9	83.9
Henan	80.4	158.8	185.3
Hubei	51.3	83.6	78.5
Hunan	58.6	88.5	75.8
Guangdong	65.3	120.5	125.3
Guangxi	40.7	76.0	80.6
Sichuan	106.1	116.0	67.0
Guizhou	30.9	64.1	74.0
Yunnan	35.6	60.4	56.3
Tibet	2.1	5.8	10.3
Shaanxi	31.3	51.9	51.5
Gansu	21.3	31.3	25.7
Qinghai	4.2	6.1	5.1
Ningxia	4.4	9.6	10.2
Xinjiang	14.2	31.0	36.9
China	1084.0	1599.1	1409.8

Note: the figures for 1987 are base year populations.

1987-2032 and then decline slowly. By the year 2087, the total population will be about 36% more than in 1987.

Projection (B) assumes a lower national total fertility rate than projection (A) in the period 1987-2027 but a higher national total fertility rate at a replacement level than projection (A) in the period 2027-2087. Due to the effect of this assumption, some regions now reach their population peaks earlier in projection (B) than in projection (A). According to table 8-11, Liaoning, Heilongjiang and Shanghai now reach their population peak by the year 2002 along with Zhejiang. The year 2012 will see Sichuan reaching its population peak which is much the same date as in Jilin. Shanxi will reach its population peak by the year 2032 along with Hebei, Shandong and Gansu. Some regions will reach their population peaks in the same year in projection (B) as in projection (A). These regions include Zhejiang, Jilin, Hebei, Shandong and Gansu mentioned above. Other regions include Beijing, Tianjin, Inner Mongolia and Jiangsu reaching their maximum in the year 2022, Fujian, Jiangxi, Hunan and Qinghai in 2042. Other regions will show more continuous population growth, though slowly, until 2087 in addition to Henan, Guangxi, Guizhou, Tibet and Xinjiang in projection (A). These regions include Anhui, Hubei, Guangdong, Yunnan, Shaanxi and Ningxia. Figures 8-2(c) and 8-2(d) present the regional population indexes of projection (B) in 2042 and 2087 respectively. In the year 2042, all regions will have less population in projection (B) than in projection (A). Jilin in addition to Liaoning, Heilongjiang, Shanghai and Zhejiang in projection (A) will have no more population in 2042 than in 1987. On the other hand, only five regions instead of seven in projection (A) including Henan, Guizhou, Tibet, Ningxia and Xinjiang will have more than 80% population increase in the period 1987-2042. Generally, most regions will have more population by the year 2087 in projection (B) than in projection (A). However, Beijing, Liaoning, Heilongjiang, Shanghai and Zhejiang will have almost same population by the year 2087 in projection (B) as in projection (A). The spatial pattern of regional population indexes of projection (B) in 2087 shown in figure 8-2(d) is close to that of projection (A) in figure 8-2(b). Broadly speaking, the patterns of regional population trends in the period 1987-2087 of projection (B) shown in figure 8-4 are similar to those in projection (A) in figure 8-3.

Projection (C) assumes lower national total fertility rates than projections (A) and (B) in the period 1987-2087. According to table 8-12, the total population of China will increase by 35% in the period 1987-2022, and then decline slowly until 2087. By the year 2087, the total population of China will be only 90% of that in 1987. Due to the assumption of lower total fertility rates, most regions will reach population peaks much earlier in projection (C) than in either of the other projections. Figure 8-5 presents the

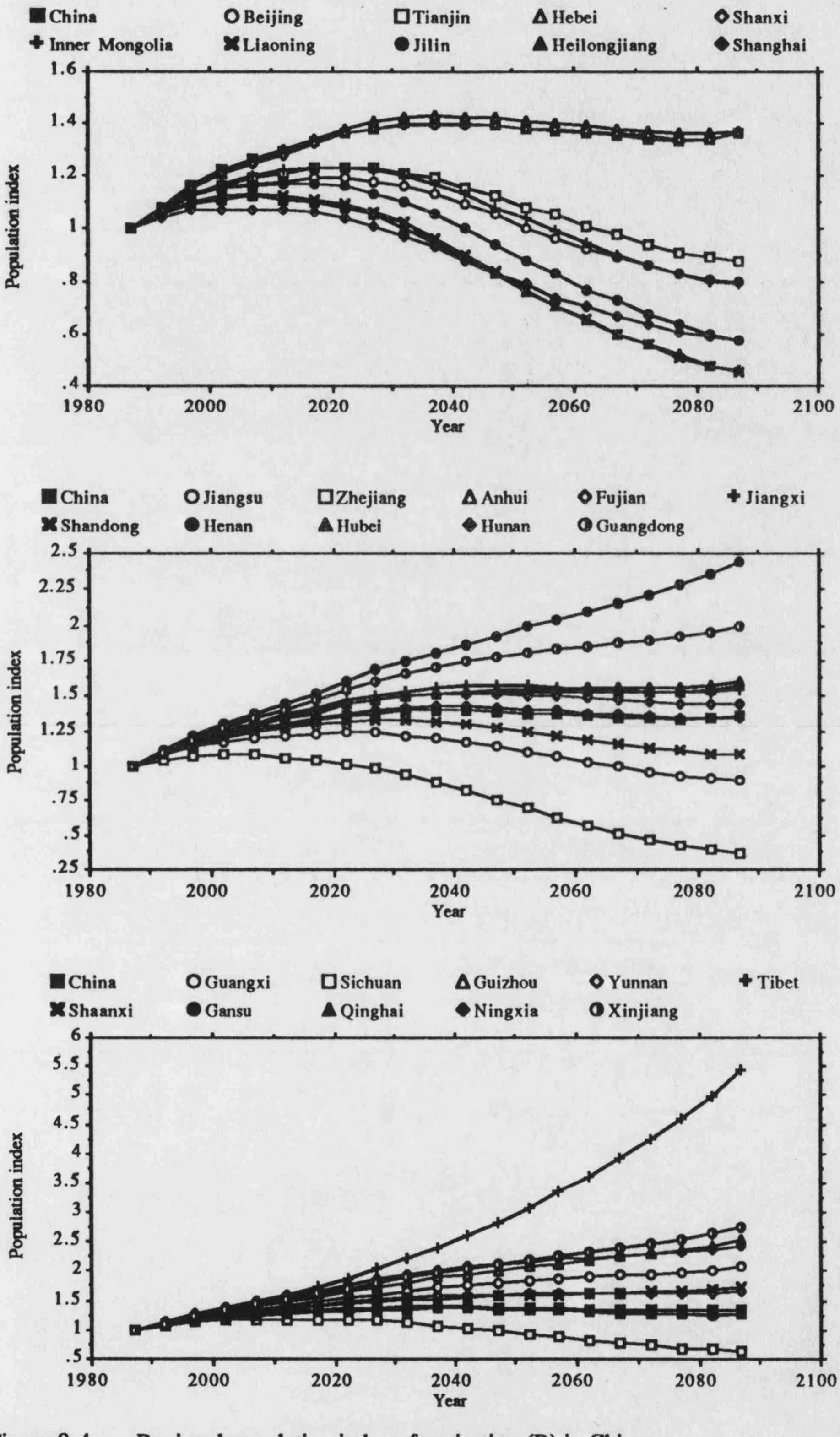


Figure 8-4 Regional population index of projection (B) in China

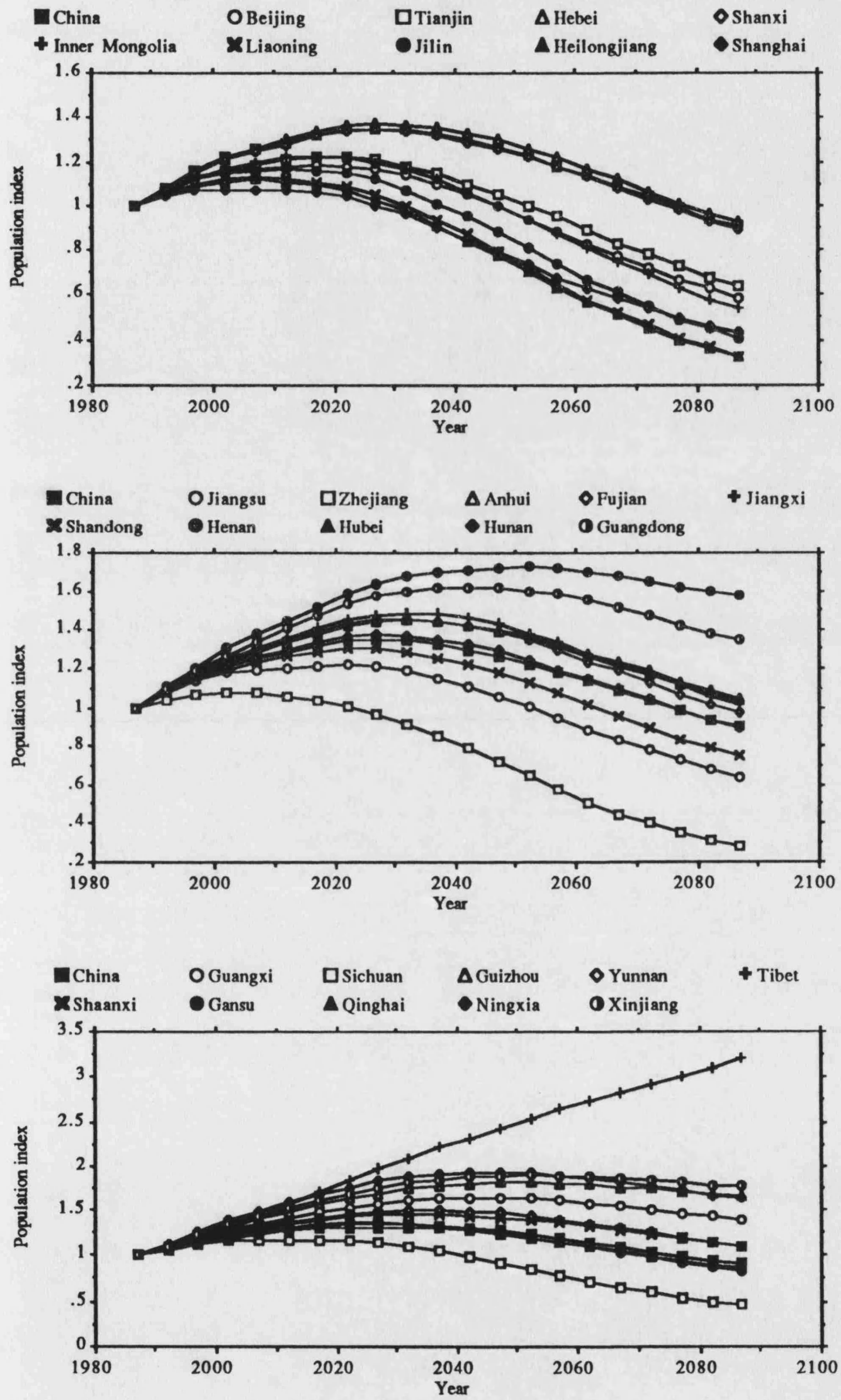


Figure 8-5 Regional population index of projection (C) in China

trends of regional population indexes based on projection (C). All regions except Tibet will show a trend of population decline before 2087. Liaoning, Heilongjiang, Shanghai and Zhejiang will reach their population peaks by the year 2002. Beijing, Inner Mongolia, Jilin and Sichuan in 2012. Tianjin, Hebei, Shanxi, Jiangsu, Shandong, Hunan, Gansu and Qinghai in 2022. Anhui, Fujian, Jiangxi, Yunnan and Shaanxi in 2032. Guangdong, Guangxi, Ningxia in 2042. Henan, Guizhou and Xinjiang in 2052. The population in Tibet will continue to grow until 2087. Its population will be more than tripled in the period 1987-2087. Figures 8-2(e) and 8-2(f) present the regional population indexes of projection (C) in 2042 and 2087 respectively. In the year 2042, all regions will have less population in projection (C) than in projections (A) and (B). Sichuan in addition to Liaoning, Jilin, Heilongjiang, Shanghai and Zhejiang in projections (A) and (B) will have less population in 2042 than in 1987. On the other hand, only Tibet, Ningxia and Xinjiang will have more than 80% population increase in the period 1987-2042. By the year 2087, all regions will have less population in projection (C) than in projections (A) and (B). Liaoning, Jilin, Heilongjiang, Shanghai, Zhejiang and Sichuan will have less than 50% population in 2087 than in 1987. Another eleven regions including Beijing, Tianjin, Hebei, Shanxi, Inner Mongolia, Jiangsu, Fujian, Shandong, Hunan, Gansu and Qinghai will also have less population in 2087 than in 1987. Anhui, Jiangxi, Henan, Hubei, Guangdong, Guangxi, Guizhou,Yunnan, Tibet, Shaanxi, Ningxia and Xinjiang will have more population in 2087 than in 1987. However, only five regions including Henan, Guizhou, Tibet, Ningxia and Xinjiang will have 50% more population in 2087 than in 1987.

8.4.3 Proportion of labour population

The regional trends of total populations have been discussed in section 8.4.2. According to projections (A), (B) and (C) using different fertility rate assumptions, many provincial regions of China will experience a decline of population in the future. It is of concern that there may be severe problems of labour shortage and population ageing in China as a whole and in particular regions in the future. Any consideration of population control should always take into account the maintaining of a suitable age composition of the population. This section and the next section will discuss the regional trends of the proportions of labour and elderly populations respectively.

Tables 8-14, 8-15 and 8-16 present three projections (A), (B) and (C) of the proportions of labour population respectively for 29 provincial regions and the whole China in the period 1987-2087.

In 1987, the proportions of the labour population range from 50.8% in Tibet to 67.2% in Shanghai. This is due to the fact that the proportion of population under

Table 8-14 Projections of labour population proportions for fertility rate assumption (A) in China

Region \ Year	1987	1992	2002	2012	2022	2032	2042	2052	2062	2072	2082	2087
Beijing	65.9	65.9	65.6	68.6	64.6	60.0	60.4	59.6	58.6	59.3	58.4	57.4
Tianjin	64.4	63.8	63.5	66.2	62.1	58.7	59.9	59.1	58.0	58.6	57.2	56.1
Hebei	58.3	59.1	59.8	62.8	61.8	59.7	60.9	60.8	60.1	60.7	59.8	58.7
Shanxi	57.7	59.3	59.0	62.2	61.8	59.4	60.4	61.2	60.3	61.2	60.4	59.2
Inner Mongolia	57.4	60.9	62.9	65.5	65.2	61.9	61.3	62.1	61.1	61.3	60.7	59.1
Liaoning	62.9	64.6	66.4	68.8	65.4	59.9	59.2	59.1	57.7	57.8	56.6	54.9
Jilin	60.4	62.8	64.3	67.1	64.9	60.3	60.3	60.7	59.3	59.8	58.6	56.9
Heilongjiang	59.1	62.6	64.9	67.5	66.2	61.8	60.6	61.3	60.1	60.2	59.4	57.3
Shanghai	67.2	65.4	66.9	69.4	62.2	59.7	61.7	61.2	60.2	61.0	60.0	58.7
Jiangsu	62.4	63.2	61.3	63.7	61.5	57.0	58.0	58.4	56.7	57.6	56.2	54.8
Zhejiang	61.7	63.9	65.8	67.6	63.9	57.5	54.8	54.2	52.7	52.8	51.7	49.9
Anhui	56.5	59.0	57.3	60.4	62.4	58.5	59.2	60.4	58.8	60.0	59.2	57.9
Fujian	54.0	56.3	58.0	61.4	61.6	59.2	58.7	58.8	58.2	58.4	57.8	56.8
Jiangxi	51.5	55.4	58.1	61.1	62.7	60.5	59.5	60.4	59.9	60.2	59.8	58.8
Shandong	57.9	59.9	60.3	63.2	62.5	59.4	59.9	59.9	58.6	59.3	58.2	56.9
Henan	55.1	56.5	55.2	58.5	59.2	56.5	58.1	59.1	57.9	59.1	58.4	57.5
Hubei	57.4	58.6	57.7	61.8	61.1	58.8	60.3	60.6	59.9	60.8	59.8	59.0
Hunan	56.6	58.7	57.8	61.4	61.8	58.7	59.3	59.7	58.7	59.5	58.5	57.4
Guangdong	54.4	55.8	57.0	59.8	60.1	58.0	58.0	58.0	57.4	57.6	57.1	56.2
Guangxi	51.6	54.1	55.7	57.7	59.4	57.1	56.0	56.3	55.8	55.7	55.4	54.6
Sichuan	58.6	63.3	62.9	65.2	66.0	60.9	58.6	60.0	57.8	58.5	57.7	55.8
Guizhou	51.2	55.5	55.9	56.7	60.1	58.3	56.9	58.9	58.2	58.1	58.3	57.5
Yunnan	52.4	55.7	57.2	59.6	61.8	59.5	58.4	59.7	59.0	59.0	58.8	57.8
Tibet	50.8	50.5	47.8	49.7	51.6	50.2	52.0	53.1	52.9	54.0	53.9	53.4
Shaanxi	57.3	58.6	56.9	60.6	59.8	58.0	59.7	59.9	59.6	60.4	59.6	58.8
Gansu	56.6	60.1	58.7	61.8	63.2	59.8	60.1	61.0	59.9	60.8	60.0	58.8
Qinghai	51.8	56.3	58.1	57.5	60.7	58.0	55.3	56.7	56.6	55.8	55.5	54.5
Ningxia	51.6	55.5	57.6	59.5	61.3	59.3	58.5	59.2	58.4	58.6	58.1	57.3
Xinjiang	52.5	55.1	54.1	55.6	57.7	56.0	56.2	57.4	56.6	57.2	56.9	56.1
China	57.2	59.4	59.5	62.1	62.0	58.8	58.8	59.4	58.3	58.9	58.2	57.1

Table 8-15 Projections of labour population proportions for fertility rate assumption (B) in China

Region \ Year	1987	1992	2002	2012	2022	2032	2042	2052	2062	2072	2082	2087
Beijing	65.9	66.0	66.2	69.6	65.2	59.7	59.1	57.7	56.7	58.5	58.8	58.0
Tianjin	64.4	63.9	64.1	67.4	62.9	58.4	58.7	57.2	56.1	57.6	57.2	56.3
Hebei	58.3	59.3	60.7	64.4	63.1	59.6	59.8	58.9	57.9	59.1	58.7	57.7
Shanxi	57.7	59.4	59.9	63.8	63.2	59.5	59.3	59.3	58.1	59.3	59.0	57.8
Inner Mongolia	57.4	61.0	63.7	67.1	66.4	61.9	60.2	60.2	59.1	60.0	59.9	58.4
Liaoning	62.9	64.7	67.0	69.9	66.3	59.7	57.9	57.1	55.7	56.9	56.8	55.3
Jilin	60.4	63.0	65.1	68.5	65.9	60.2	59.1	58.8	57.3	58.5	58.2	56.6
Heilongjiang	59.1	62.7	65.7	68.8	67.2	61.7	59.4	59.3	58.1	59.1	59.0	57.0
Shanghai	67.2	65.4	67.4	70.3	62.8	59.3	60.5	59.3	58.3	60.2	60.4	59.3
Jiangsu	62.4	63.3	62.0	64.9	62.5	56.9	56.7	56.4	54.6	56.3	55.8	54.7
Zhejiang	61.7	63.9	66.4	68.6	64.6	57.2	53.5	52.1	50.7	52.0	52.2	50.6
Anhui	56.5	59.2	58.2	62.1	63.8	58.5	58.0	58.5	56.6	58.1	57.8	56.6
Fujian	54.0	56.4	58.9	63.1	63.0	59.3	57.5	56.7	56.0	56.7	56.7	55.9
Jiangxi	51.5	55.5	59.0	62.9	64.2	60.7	58.3	58.5	57.6	58.3	58.4	57.4
Shandong	57.9	60.0	61.1	64.7	63.6	59.4	58.7	57.9	56.5	57.8	57.5	56.3
Henan	55.1	56.6	56.2	60.2	60.7	56.6	56.9	57.1	55.5	57.0	56.6	55.7
Hubei	57.4	58.7	58.6	63.5	62.6	58.9	59.2	58.6	57.6	58.8	58.4	57.6
Hunan	56.6	58.8	58.6	63.0	63.2	58.7	58.1	57.7	56.5	57.7	57.4	56.4
Guangdong	54.4	56.0	57.8	61.5	61.4	57.9	56.7	56.0	55.2	55.9	56.0	55.2
Guangxi	51.6	54.2	56.6	59.4	60.7	57.0	54.8	54.3	53.6	54.1	54.3	53.5
Sichuan	58.6	63.4	63.7	66.4	67.0	60.8	57.3	58.0	55.8	57.4	57.5	55.8
Guizhou	51.2	55.6	56.9	58.5	61.5	58.3	55.6	56.9	55.9	56.2	56.6	55.8
Yunnan	52.4	55.9	58.2	61.3	63.2	59.5	57.2	57.7	56.8	57.3	57.5	56.5
Tibet	50.8	50.6	48.9	51.7	53.4	50.3	50.7	51.1	50.2	51.2	51.0	50.5
Shaanxi	57.3	58.7	57.8	62.3	61.3	58.2	58.6	58.0	57.2	58.3	57.9	57.1
Gansu	56.6	60.3	59.6	63.4	64.6	59.9	58.9	59.1	57.7	59.0	58.7	57.6
Qinghai	51.8	56.4	59.1	59.3	62.0	57.8	54.0	54.7	54.5	54.3	54.5	53.6
Ningxia	51.6	55.6	58.5	61.3	62.7	59.3	57.3	57.2	56.1	56.8	56.8	56.1
Xinjiang	52.5	55.2	55.1	57.5	59.2	56.0	55.0	55.4	54.2	55.0	55.0	54.2
China	57.2	59.5	60.3	63.7	63.2	58.8	57.6	57.4	56.1	57.2	57.0	56.0

Table 8-16 Projections of labour population proportions for fertility rate assumption (C) in China

Region \ Year	1987	1992	2002	2012	2022	2032	2042	2052	2062	2072	2082	2087
Beijing	65.9	66.0	66.2	69.6	65.5	60.6	60.2	58.3	56.4	56.7	55.6	54.5
Tianjin	64.4	63.9	64.1	67.4	63.4	59.5	60.1	58.3	56.3	56.5	54.9	53.6
Hebei	58.3	59.3	60.7	64.4	63.8	61.5	62.3	61.5	60.2	60.5	59.4	58.0
Shanxi	57.7	59.4	59.9	63.9	63.9	61.6	62.1	62.4	60.8	61.3	60.4	58.9
Inner Mongolia	57.4	61.0	63.7	67.1	67.1	63.6	62.3	62.3	60.8	60.6	59.7	57.9
Liaoning	62.9	64.7	67.0	70.0	66.7	60.7	59.1	58.0	55.8	55.4	54.0	52.1
Jilin	60.4	63.0	65.1	68.5	66.5	61.6	60.8	60.5	58.2	58.3	56.9	54.8
Heilongjiang	59.1	62.7	65.7	68.9	67.8	63.1	61.1	60.9	58.9	58.7	57.6	55.2
Shanghai	67.2	65.4	67.4	70.4	63.1	60.1	61.5	59.9	58.0	58.5	57.3	55.9
Jiangsu	62.4	63.3	62.0	64.9	63.0	58.2	58.4	58.1	55.3	55.8	54.1	52.5
Zhejiang	61.7	63.9	66.4	68.6	65.0	58.0	54.4	52.6	50.1	49.7	48.3	46.4
Anhui	56.5	59.2	58.2	62.1	64.6	60.6	60.6	61.5	59.1	60.0	59.1	57.5
Fujian	54.0	56.4	58.9	63.2	63.8	61.3	60.0	59.3	58.1	57.9	56.9	55.7
Jiangxi	51.5	55.5	59.0	62.9	65.0	62.9	61.1	61.5	60.3	60.2	59.7	58.3
Shandong	57.9	60.0	61.1	64.7	64.3	61.1	60.8	60.1	58.0	58.2	56.9	55.4
Henan	55.1	56.6	56.2	60.2	61.6	59.0	60.0	60.7	58.8	59.7	58.9	57.7
Hubei	57.4	58.7	58.6	63.5	63.4	61.0	62.1	61.8	60.4	61.0	59.7	58.6
Hunan	56.6	58.8	58.6	63.1	64.0	60.7	60.6	60.5	58.7	59.2	57.9	56.5
Guangdong	54.4	56.0	57.8	61.5	62.2	60.0	59.4	58.6	57.4	57.2	56.4	55.4
Guangxi	51.6	54.2	56.6	59.5	61.5	59.2	57.4	56.9	55.8	55.2	54.7	53.6
Sichuan	58.6	63.4	63.7	66.5	67.5	62.2	58.8	59.5	56.3	56.6	55.6	53.5
Guizhou	51.2	55.6	56.9	58.5	62.4	60.7	58.7	60.2	59.0	58.6	58.6	57.6
Yunnan	52.4	55.9	58.2	61.4	64.0	61.7	60.0	60.6	59.4	59.0	58.6	57.4
Tibet	50.8	50.6	48.9	51.8	54.5	53.4	55.0	56.1	55.5	56.4	56.2	55.5
Shaanxi	57.3	58.7	57.8	62.4	62.2	60.4	61.7	61.6	60.4	61.1	60.0	58.9
Gansu	56.6	60.3	59.6	63.5	65.4	61.9	61.5	62.0	60.1	60.7	59.6	58.1
Qinghai	51.8	56.4	59.1	59.3	62.8	59.8	56.5	57.1	56.5	55.4	54.7	53.6
Ningxia	51.6	55.6	58.5	61.3	63.5	61.5	60.1	60.1	58.6	58.4	57.7	56.7
Xinjiang	52.5	55.2	55.1	57.5	60.1	58.6	58.3	59.1	57.8	58.0	57.6	56.5
China	57.2	59.5	60.3	63.7	64.0	60.6	60.0	60.0	58.3	58.5	57.7	56.3

working age is high in Tibet, with high fertility rate, and low in Shanghai, with low fertility rate. According to projection (A) in table 8-14, the proportions of labour population will range from 52% in Tibet to 61.7% in Shanghai in 2042 and from 49.9% in Zhejiang to 59.2% in Shanxi in 2087. Zhejiang will have the lowest proportion of labour population due to its high proportion of elderly population, as will be discussed in the next section.

According to projection (B) in table 8-15, the proportions of labour population will range from 50.7% in Tibet to 60.5% in Shanghai in 2042. These proportions of labour population are slightly smaller than those in projection (A) due to lower total fertility rates in the period 1987-2027 in projection (B). In 2087, the proportions of labour population will range from 50.5% in Tibet to 59.3% in Shanghai. In this year, a few regions including Zhejiang will have higher proportions of labour population in projection (B) than those in projection (A) due to higher total fertility rates in the period 2027-2087 in projection (B), while most of other regions will have lower proportions of labour population than those in projection (A) due to the same factor. It seems that higher fertility rates may mean a higher proportion of labour population in some regions and a lower proportion of labour population in other regions in a particular year in the future depending on their particular age compositions.

According to projection (C) in table 8-16, the proportions of the labour population will range from 54.4% in Zhejiang to 62.3% in Hebei and Inner Mongolia in 2042 and from 46.4% in Zhejiang to 58.9% in Shanxi and Shaanxi in 2087. Most regions excluding Henan, Guizhou, Tibet, Shaanxi and Xinjiang will have lower proportions of labour population in projection (C) than in projection (A) in 2087 due to lower total fertility rates in the projection period. Zhejiang will have the lowest proportion of labour population of only 46.4% in 2087. It seems that a U-shaped fertility trend in projection (B) helps to raise the proportion of labour population in Zhejiang to 50.6% in 2087.

In summary, the proportions of labour population in most regions will be in the range of 50-65% in the projection period. It seems that there will be no severe problems of labour shortage in any particular region in China in the future in the sense that there will always be a suitable proportion of labour population in any regional population. However, the total labour supply in a region is determined by the regional population and its proportion of the labour population. Assuming a constant proportion of the labour population, the trend in the labour supply will be close to the trend in the regional population. At the moment, China does not have a problem of labour shortage. However, some regions may face this problem in the future as their populations begin to decline. Encouraging in-migration to these regions is a possible solution. Strategic adjustment of their economic structures by reducing the share of labour-intensive sectors may also relieve the high demand for labour. These choices may need to be carefully assessed in the national and regional development planning.

8.4.4 Proportion of elderly population

Three sets of projections (A), (B) and (C) on the proportions of elderly population in China and her 29 provincial regions are presented in tables 8-17, 8-18 and 8-19 respectively. According to projection (A), the proportion of elderly population in China will increase from 6.9% in 1987 to 9.8% in 2012, 18.1% in 2042, then increase slowly to 20.5% by 2087. Again, the national trend of population ageing is just a combination of various trends of population ageing in the various regions. Some regions with low total fertility rates will experience fast and severe population ageing in the projection period. According to table 8-16 and figure 8-6(a), the proportions of elderly population will be well over 20% in nine regions including Beijing (28.1%), Tianjin (25.0%), Liaoning (27.5%), Jilin (22.5%), Heilongjiang (22.9%), Shanghai (27.2%), Jiangsu (24.4%), Zhejiang (33.7%) and Sichuan (25.5%) by the year 2042. The process of population ageing in these regions will continue until 2087. As shown in figure 8-6(b), by the year 2087, Beijing (31.3%), Liaoning (31.6%) and Zhejiang (37.7%) will have a proportion of elderly population over 30%. Tianjin (29.4%), Jilin (26.4%), Heilongjiang (26.0%), Shanghai (29.9%), Jiangsu (28.6%) and Sichuan (28.6%) will have a population of elderly population over 25% in 2087. Inner Mongolia (21.6%), Heilongjiang (26%), Fujian (21.9%), Shandong (24.1%), Hunan (20.8%), Guangdong (21.2%), Guangxi (21.7%) and Qinghai (21.5%) will also have a proportion of elderly population over 20% by the year 2087. Tibet will have the lowest proportion of elderly population of only 7.9% in 2087 due to its high fertility rate in the projection period. The remaining twelve regions, made up of Hebei, Shanxi, Anhui, Jiangxi, Henan, Hubei, Guizhou, Yunnan, Shaanxi, Gansu, Ningxia and Xinjiang, will also have a proportion of elderly population below 20% in 2087. Figure 8-7 presents the regional trends of the proportions of elderly population for the period 1987-2087. It is noted again that the ranks of the proportions of elderly population in various regions have little change in the projection period.

According to projection (B) in table 8-18 and figure 8-8, the proportion of the elderly population in China will increase from 6.9% in 1987 to 19.1% in 2042, decrease a little to 18.8% in 2052, increase again to 19.7% in 2062 and then decline to 17.6% in 2087. The decline of the proportion of elderly population in the period 2062-2087 is due to the effect of higher national total fertility rates at a replacement level in the period 2032-2087 in projection (B) than in projection (A). This effect is also clear in the regional

Table 8-17 Projections of elderly population proportions for fertility rate assumption (A) in China

Region \ Year	1987	1992	2002	2012	2022	2032	2042	2052	2062	2072	2082	2087
Beijing	8.5	10.1	13.6	15.3	21.0	27.1	28.1	29.2	30.9	30.7	31.2	31.3
Tianjin	8.3	9.9	12.4	14.1	19.6	24.6	25.0	26.1	28.1	28.3	29.2	29.4
Hebei	7.1	7.5	8.2	9.2	11.9	15.3	15.8	16.5	18.2	18.5	19.2	19.5
Shanxi	6.7	7.1	7.7	8.3	10.7	13.9	14.8	14.5	16.5	16.7	17.4	17.8
Inner Mongolia	4.7	5.2	6.9	8.0	11.7	16.5	18.6	18.9	20.5	21.2	21.5	21.6
Liaoning	6.7	7.7	9.9	12.0	17.9	25.2	27.5	28.2	30.4	31.0	31.8	31.6
Jilin	5.6	6.3	7.7	9.7	14.6	20.6	22.5	22.5	25.0	25.3	26.2	26.4
Heilongjiang	4.7	5.5	7.5	9.3	14.0	19.9	22.9	22.9	24.9	25.6	26.0	26.0
Shanghai	10.9	12.4	14.2	15.8	24.0	28.1	27.2	28.1	29.8	29.5	29.9	29.9
Jiangsu	8.6	9.7	11.5	14.0	17.8	23.2	24.4	24.1	27.0	26.9	28.2	28.6
Zhejiang	8.5	10.0	12.1	14.8	21.3	29.5	33.7	35.1	37.2	37.6	38.2	37.7
Anhui	6.5	7.2	8.0	9.0	9.8	13.9	15.8	15.0	17.4	17.6	18.0	18.7
Fujian	6.3	7.1	8.0	8.5	11.0	15.1	17.6	18.4	20.0	20.7	21.6	21.9
Jiangxi	6.3	6.6	6.7	7.1	8.9	12.4	15.4	15.4	16.8	17.6	18.1	18.4
Shandong	7.9	8.5	9.2	10.7	13.8	18.0	19.7	20.2	22.4	22.8	23.7	24.1
Henan	7.3	7.6	7.5	8.0	9.5	12.1	13.2	12.6	14.7	14.9	15.3	15.9
Hubei	7.0	7.2	7.7	8.3	10.3	14.1	14.5	14.6	16.7	16.6	17.7	18.1
Hunan	6.9	7.4	8.4	9.4	11.0	15.4	17.1	17.1	19.3	19.4	20.4	20.8
Guangdong	7.5	8.3	9.2	9.6	11.7	15.2	17.0	18.0	19.4	20.2	20.9	21.2
Guangxi	7.1	7.9	9.1	9.7	11.2	14.8	17.6	18.6	19.9	20.9	21.5	21.7
Sichuan	6.8	7.8	9.3	12.0	14.7	20.7	25.5	24.5	27.5	27.7	28.2	28.6
Guizhou	5.8	6.1	7.0	7.8	8.5	11.0	13.9	13.4	14.6	15.7	15.8	16.1
Yunnan	6.2	6.7	7.5	7.9	9.2	12.9	15.7	15.7	17.0	18.0	18.4	18.6
Tibet	5.7	5.7	5.5	5.4	5.0	6.2	6.5	6.1	7.2	7.4	7.6	7.9
Shaanxi	6.3	6.4	7.2	8.1	9.8	12.8	13.0	13.0	14.9	14.8	15.9	16.2
Gansu	5.1	5.5	7.0	8.7	9.7	14.3	16.2	15.7	18.0	18.0	18.8	19.2
Qinghai	4.5	5.8	7.9	9.6	10.5	15.2	18.8	18.9	19.9	21.3	21.5	21.5
Ningxia	4.6	5.1	6.3	7.7	9.5	12.9	15.7	16.1	17.9	18.7	19.3	19.7
Xinjiang	4.8	5.2	6.5	7.7	8.5	10.8	12.4	12.3	13.8	14.4	14.7	15.1
China	6.9	7.6	8.6	9.8	12.3	16.3	18.1	17.9	19.6	19.7	20.2	20.5

Table 8-18 Projections of elderly population proportions for fertility rate assumption (B) in China

Region \ Year	1987	1992	2002	2012	2022	2032	2042	2052	2062	2072	2082	2087
Beijing	8.5	10.2	13.8	15.6	21.6	28.1	29.4	30.7	31.7	30.0	28.8	28.3
Tianjin	8.3	9.9	12.5	14.4	20.3	25.6	26.2	27.4	28.7	27.4	26.6	26.3
Hebei	7.1	7.5	8.3	9.4	12.5	16.1	16.7	17.4	18.3	17.4	16.9	16.9
Shanxi	6.7	7.1	7.8	8.5	11.2	14.7	15.7	15.3	16.6	15.6	15.2	15.2
Inner Mongolia	4.7	5.2	7.0	8.3	12.2	17.3	19.7	19.8	20.7	20.0	19.1	18.9
Liaoning	6.7	7.7	10.0	12.2	18.5	26.2	28.9	29.7	31.1	30.1	29.1	28.4
Jilin	5.6	6.3	7.8	9.9	15.2	21.6	23.8	23.7	25.4	24.2	23.6	23.3
Heilongjiang	4.7	5.5	7.6	9.5	14.5	20.9	24.1	24.1	25.3	24.5	23.4	22.9
Shanghai	10.9	12.5	14.3	16.0	24.7	29.1	28.5	29.5	30.6	28.8	27.5	26.9
Jiangsu	8.6	9.7	11.7	14.3	18.4	24.2	25.7	25.3	27.5	25.9	25.5	25.3
Zhejiang	8.5	10.0	12.3	15.1	21.9	30.5	35.2	36.7	38.1	36.9	35.5	34.2
Anhui	6.5	7.2	8.2	9.3	10.3	14.7	16.8	15.8	17.4	16.4	15.8	16.0
Fujian	6.3	7.1	8.2	8.8	11.5	16.0	18.6	19.4	20.2	19.5	19.1	18.9
Jiangxi	6.3	6.6	6.8	7.3	9.4	13.1	16.3	16.2	16.9	16.4	15.8	15.7
Shandong	7.9	8.5	9.3	11.0	14.4	19.0	20.8	21.3	22.7	21.7	21.1	21.0
Henan	7.3	7.6	7.6	8.3	10.0	12.8	14.0	13.2	14.6	13.8	13.3	13.5
Hubei	7.0	7.2	7.8	8.6	10.8	14.9	15.4	15.4	16.7	15.5	15.5	15.4
Hunan	6.9	7.4	8.5	9.7	11.5	16.3	18.1	17.9	19.4	18.3	18.0	18.0
Guangdong	7.5	8.3	9.4	9.9	12.3	16.1	17.9	18.8	19.5	19.0	18.4	18.3
Guangxi	7.1	7.9	9.3	10.1	11.8	15.7	18.5	19.5	20.0	19.7	18.9	18.8
Sichuan	6.8	7.8	9.5	12.3	15.2	21.6	26.8	25.8	28.0	26.7	25.6	25.3
Guizhou	5.8	6.1	7.2	8.1	8.9	11.7	14.7	14.0	14.6	14.5	13.7	13.7
Yunnan	6.2	6.8	7.6	8.2	9.7	13.6	16.6	16.4	17.0	16.8	16.1	16.0
Tibet	5.7	5.7	5.7	5.6	5.3	6.7	6.9	6.4	7.0	6.50	6.3	6.5
Shaanxi	6.3	6.5	7.3	8.4	10.3	13.6	13.8	13.7	14.9	13.7	13.7	13.7
Gansu	5.1	5.5	7.1	9.0	10.2	15.1	17.2	16.5	18.0	16.9	16.5	16.5
Qinghai	4.5	5.8	8.1	9.9	11.0	16.0	19.8	19.8	19.9	19.9	19.0	18.6
Ningxia	4.6	5.1	6.4	7.9	10.0	13.7	16.7	17.0	17.9	17.5	17.0	17.0
Xinjiang	4.8	5.2	6.6	8.0	9.0	11.5	13.2	12.9	13.7	13.2	12.7	12.7
China	6.9	7.6	8.8	10.1	12.8	17.2	19.1	18.8	19.7	18.6	17.8	17.6

Table 8-19 Projections of elderly population proportions for fertility rate assumption (C) in China

Region \ Year	1987	1992	2002	2012	2022	2032	2042	2052	2062	2072	2082	2087
Beijing	8.5	10.2	13.8	15.6	21.7	28.5	30.5	32.8	35.4	35.5	36.1	36.1
Tianjin	8.3	9.9	12.5	14.4	20.4	26.2	27.4	29.7	32.6	33.1	34.0	34.1
Hebei	7.1	7.5	8.3	9.5	12.6	16.7	17.9	19.5	21.8	22.3	23.1	23.3
Shanxi	6.7	7.1	7.8	8.5	11.4	15.2	16.9	17.3	20.0	20.4	21.1	21.4
Inner Mongolia	4.7	5.2	7.0	8.3	12.4	17.8	20.9	21.9	24.2	25.2	25.5	25.4
Liaoning	6.7	7.7	10.0	12.2	18.6	26.8	30.0	31.9	35.0	35.9	36.7	36.3
Jilin	5.6	6.3	7.8	9.9	15.3	22.1	25.0	26.0	29.3	29.9	30.9	30.8
Heilongjiang	4.7	5.5	7.6	9.5	14.6	21.4	25.3	26.3	29.1	30.1	30.5	30.1
Shanghai	10.9	12.5	14.3	16.0	24.8	29.6	29.5	31.5	34.2	34.1	34.5	34.2
Jiangsu	8.6	9.7	11.7	14.3	18.6	24.9	27.1	27.8	31.7	32.0	33.4	33.6
Zhejiang	8.5	10.0	12.3	15.1	22.0	31.0	36.4	39.0	42.2	43.1	43.7	42.8
Anhui	6.5	7.2	8.2	9.3	10.4	15.3	18.0	17.9	21.1	21.5	21.9	22.4
Fujian	6.3	7.1	8.2	8.8	11.7	16.5	19.9	21.8	24.1	25.2	26.2	26.3
Jiangxi	6.3	6.6	6.8	7.3	9.5	13.7	17.6	18.4	20.4	21.5	22.0	22.2
Shandong	7.9	8.5	9.3	11.0	14.5	19.5	22.1	23.6	26.7	27.3	28.2	28.5
Henan	7.3	7.6	7.6	8.3	10.2	13.4	15.2	15.2	18.0	18.4	18.9	19.5
Hubei	7	7.2	7.8	8.6	11.0	15.4	16.6	17.4	20.3	20.4	21.6	21.9
Hunan	6.9	7.4	8.5	9.7	11.7	16.9	19.4	20.2	23.2	23.7	24.7	25.0
Guangdong	7.5	8.3	9.4	9.9	12.4	16.7	19.3	21.3	23.4	24.5	25.3	25.5
Guangxi	7.1	7.9	9.3	10.1	11.9	16.3	20.0	22.1	24.0	25.4	26.1	26.2
Sichuan	6.8	7.8	9.5	12.3	15.4	22.2	28.1	28.1	32.1	32.6	33.1	33.2
Guizhou	5.8	6.1	7.2	8.2	9.1	12.2	16.0	16.0	17.9	19.2	19.3	19.5
Yunnan	6.2	6.8	7.6	8.2	9.8	14.2	17.9	18.6	20.6	21.9	22.2	22.3
Tibet	5.7	5.7	5.7	5.7	5.5	7.1	7.8	7.7	9.2	9.4	9.7	10.0
Shaanxi	6.3	6.5	7.3	8.4	10.5	14.1	15.0	15.7	18.3	18.3	19.5	19.8
Gansu	5.1	5.5	7.1	9.0	10.3	15.7	18.4	18.6	21.7	21.9	22.8	23.0
Qinghai	4.5	5.8	8.1	9.9	11.1	16.6	21.3	22.2	23.7	25.5	25.7	25.5
Ningxia	4.6	5.1	6.4	7.9	10.1	14.2	18.0	19.2	21.6	22.8	23.5	23.9
Xinjiang	4.8	5.2	6.6	8.0	9.1	12.1	14.4	14.9	17.0	17.8	18.2	18.5
China	6.9	7.6	8.8	10.1	13.0	17.8	20.4	21.1	23.6	24.0	24.4	24.6

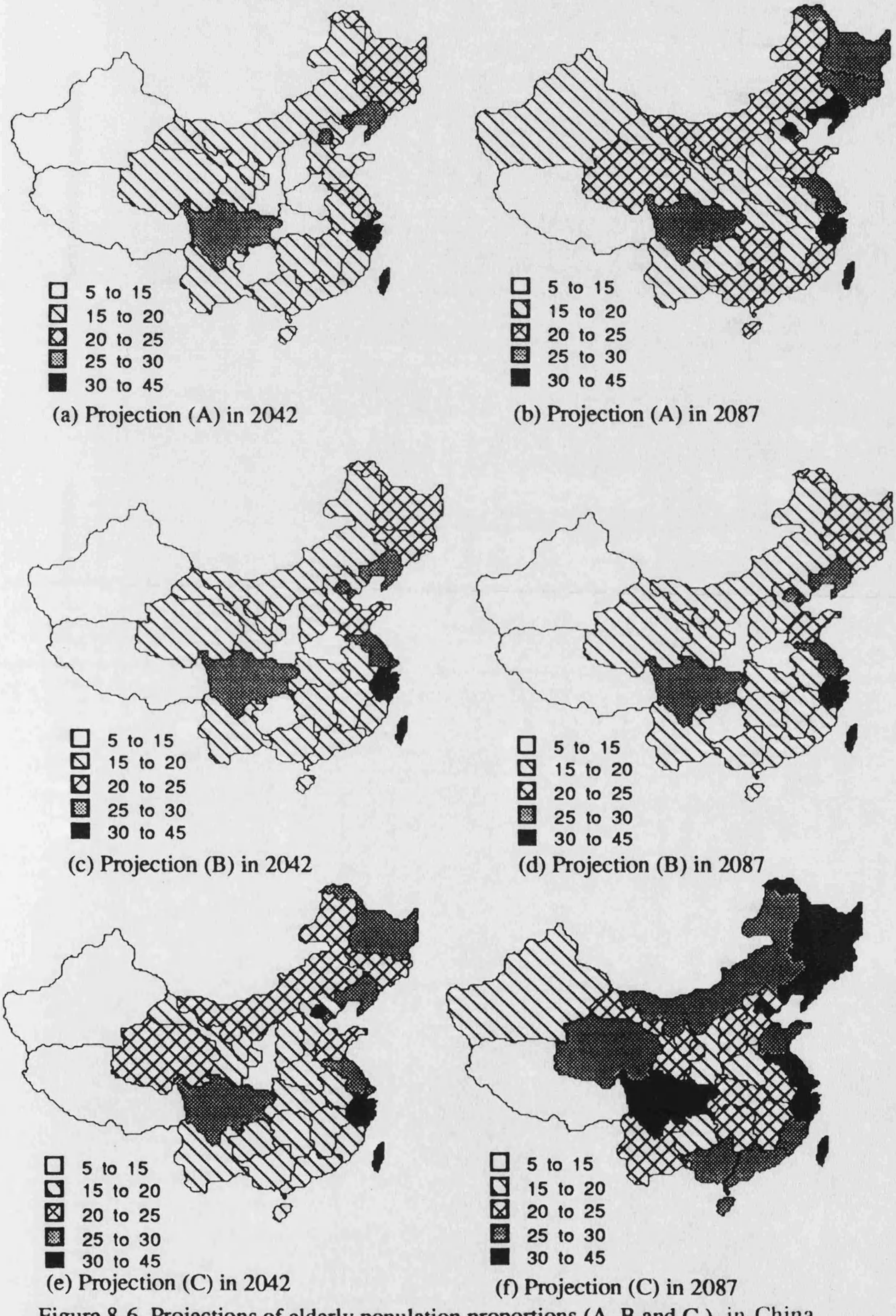


Figure 8-6 Projections of elderly population proportions (A, B and C) in China

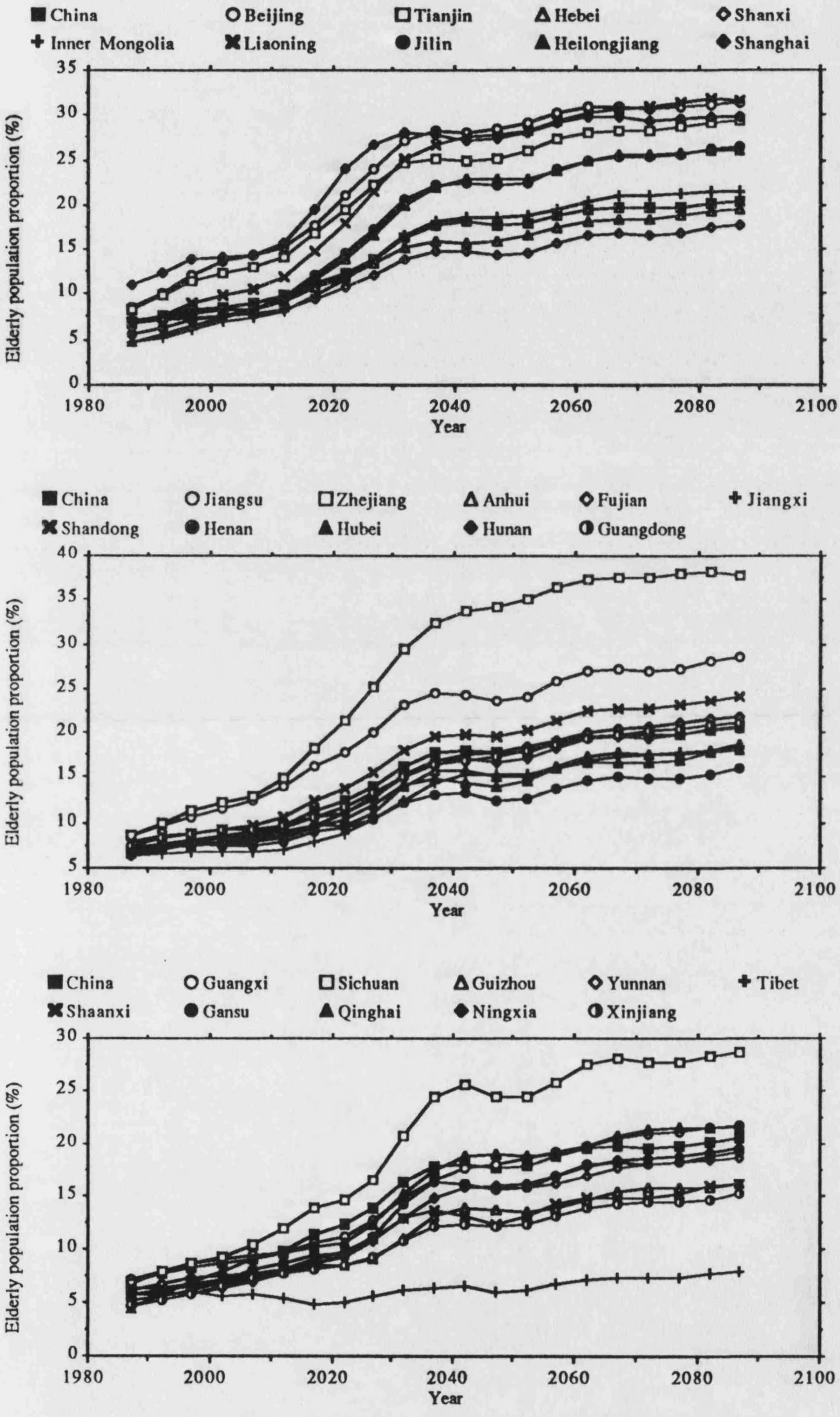
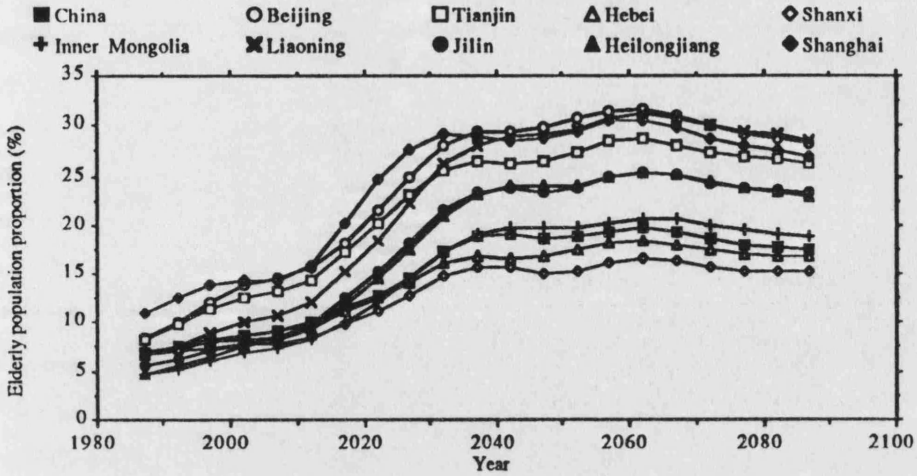
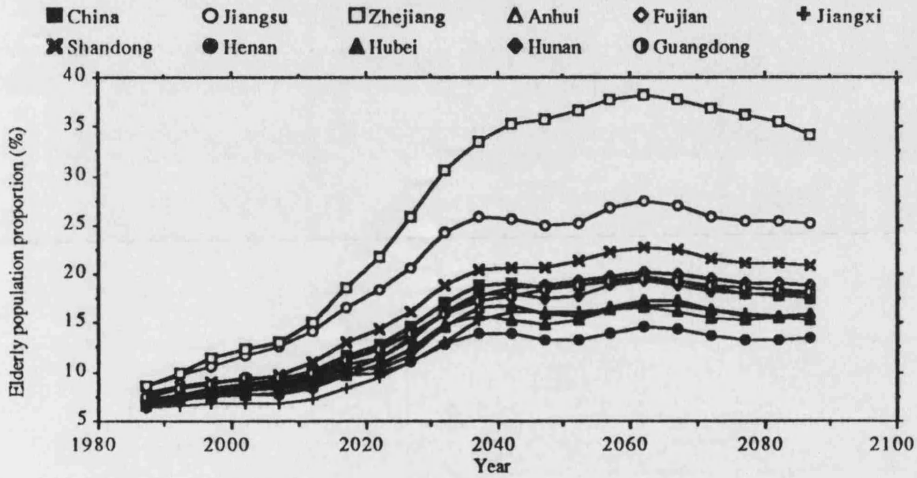


Figure 8-7 Elderly population proportions of projection (A) in China





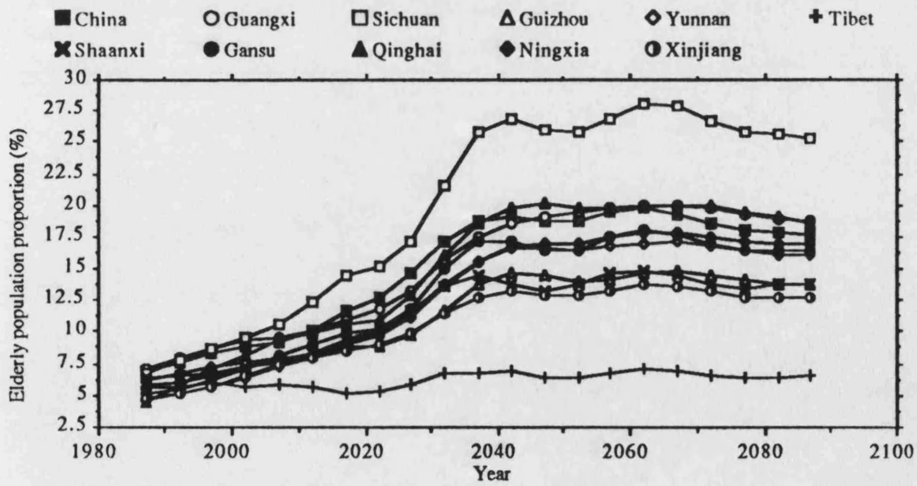


Figure 8-8 Elderly population proportions of projection (B) in China

trends of population ageing. All regions will have a peak of the proportion of elderly population in the year 2062 and their proportions of elderly population will then decline in the period 2062-2087. However, by the year 2042, all regions will have higher proportions of elderly population in projection (B) than in projection (A) due to lower fertility rates in the period 1987-2027. As shown in figure 8-6(C), Shandong (20.8%) in addition to nine regions in projection (A) will have a proportion of elderly population over 20% in 2042. Jiangsu (25.7%) in addition to Beijing, Tianjin, Liaoning, Shanghai, Zhejiang and Sichuan in projection (A) will have a proportion of elderly population over 25% in 2042. By the year 2062, Beijing (31.7%), Tianjin (28.7%), Liaoning (31.1%), Jilin (25.4%), Heilongjiang (25.3%), Shanghai (30.6%), Jiangsu (27.5%), Zhejiang (38.1%) and Sichuan (28.0%) will have a proportion of elderly population over 25% and Inner Mongolia (20.7%), Fujian (20.2%), Shandong (22.7%) and Guangxi (20%) will have a proportion of elderly population in the range of 20-25%. By the year 2087, all regions will have lower proportions of elderly population in projection (B) than in projection (A). The spatial pattern of the proportions of elderly population in 2087 shown in figure 8-6(d) is identical to that in 2042 in figure 8-6(c). Only Zhejiang (34.2%) will have a proportion of elderly population over 30% in 2087. Beijing (28.3%), Tianjin (26.3%), Liaoning (28.4%), Shanghai (26.9%), Jiangsu (25.3%) and Sichuan (25.3%) will have a proportion of elderly population in the range of 25-30% in 2087. Jilin (23.3%), Heilongjiang (22.9%) and Shandong (21.0%) will have a proportion of elderly population over 20% in that year. The remaining nineteen regions will have a proportion of elderly population below 20% in the year 2087. It seems that the proportions of elderly population will be relatively stable after 2042 in projection (B) as shown in figure 8-8.

Projection (C) assumes lower total fertility rates than projections (A) and (B). It can be expected that the problems of population ageing will become much severer in some regions. According to projection (C) in table 8-19 and figure 8-9, the proportion of elderly population of China will increase from 6.9% in 1987 to 20.4% in 2042 and reach 24.6% in 2087. The proportions of elderly population in various regions will also be higher in projection (C) than in projections (A) and (B). As shown in figure 8-6(e), by the year 2042, some eight regions including Beijing (30.5%), Tianjin (27.4%), Liaoning (30.0%), Heilongjiang (25.3%), Shanghai (29.5%), Jiangsu (27.1%), Zhejiang (36.4%) and Sichuan (28.1%) will have a proportion of elderly population over 25%. All these regions will have a proportion of elderly population over 30% by the year 2087 as shown in figure 8-6(f). In addition, Jilin will also have a proportion of elderly population over 30% in 2087. Zhejiang will have a proportion of elderly population as high as 42.8% in 2087. Only five regions including Henan (19.5%),

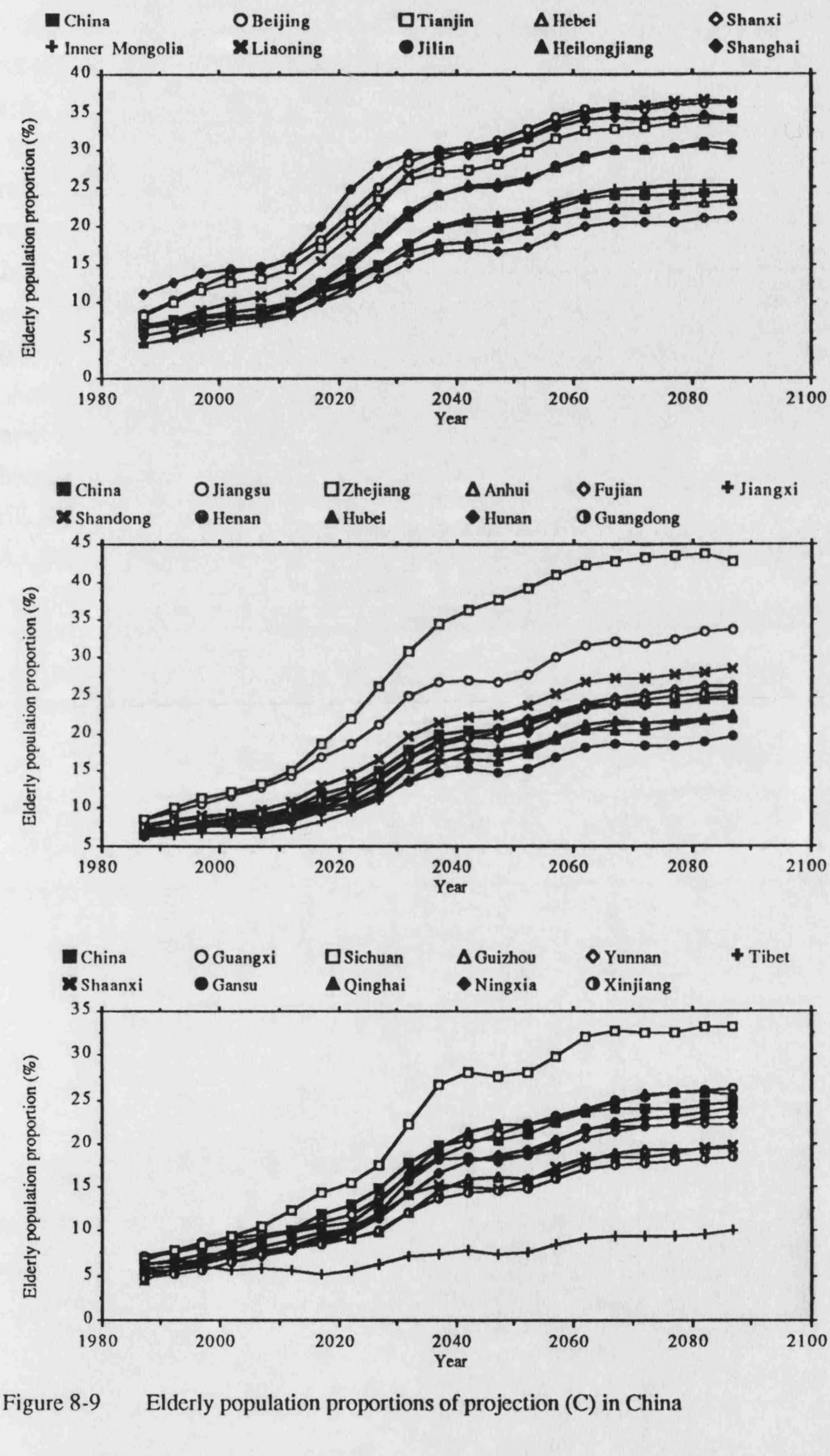


Figure 8-9 Elderly population proportions of projection (C) in China

Guizhou (19.5%), Tibet (10%), Shaanxi (19.8%) and Xinjiang (18.5%) will have a proportion of elderly population below 20% in 2087. The remaining 15 regions will have a proportion of elderly population in the range of 20-30% in the year 2087.

In summary, different regions will face different paces of population ageing in the projection period. According to projection (A), some nine regions will have a proportion of elderly population over 20% by the year 2042. Beijing, Liaoning and Zhejiang will have a proportion of elderly population over 30% by the year 2087. On the other hand, some 12 regions will have a proportion of elderly population under 20% in 2087. The proportion of elderly population in Tibet will be only 7.9% in 2087.

According to projection (B) which assumes a U-shaped fertility trend, all regions will have a peak of the proportion of elderly population in 2062 and their proportions of elderly population will decline in the period 2062-2087. By the year 2087, all regions will have a lower proportion of elderly population in projection (B) than in projection (A). It seems that there may still be some problems of population ageing in some regions such as Zhejiang.

The problems of population ageing will be much more severe according to projection (C). Eight regions will have a proportion of elderly population over 25% by the year 2042 and nine regions over 30% by the year 2087. It is clear that there may be more room for the decline of fertility in some regions than others while the problem of population ageing does not reach the severe stage.

Most regions facing rapid population ageing are more developed regions in China. Hopefully, these regions may be better prepared to solve the ageing problem than other less developed regions. However, population ageing is one of a few important socio-economic problems facing the world today. Even the developed countries have difficulties to solve it. Thus great efforts are needed to tackle the problem of future population ageing in China.

8.5 Conclusion

An attempt has been made in this chapter to make consistent multiregional population projections of China at a provincial level. A forward demographic rates-based multiregional population model is developed on the basis of a set of multiregional population accounts. In the model, forward emigration rates and immigration flows are adopted to describe the external migrations between the spatial population system concerned and the rest of the world. The model is calibrated using the 1982 census data and 1987 one-percent population survey data. Other data sources have also been used to estimate and prepare necessary input data for the multiregional population model.

Three sets of multiregional population projections of China at provincial level have been made. The projections of national figures are comparable to those national figures projected by the urban-rural population model in chapter four. The national population trend is a combination of various regional population trends. Some regions, such as Zhejiang, will reach their population peak as early as the beginning of the next century while other regions, such as Tibet, will face continuous population growth in the whole projection period.

Labour supply and population ageing are two important issues related to the national and regional population trends. The paces of population change and ageing are quite uneven among various regions in China. Currently, China has a problem of labour surplus rather than labour shortage (Taylor and Banister, 1991). All regions will face continuous population growth in the next decade. A low rate of population growth in some regions, such as Zhejiang, may be helpful to their regional economic growth. However, a high rate of population growth in some less developed regions, such as Tibet, Xinjiang and Guizhou, will undoubtedly exacerbate the economic problem there. These regions usually have high fertility rates well over the replacement level. A lot of efforts on family planning should be directed to these less developed regions.

It is likely that some regions may face the problem of labour shortage in the future. For example, Zhejiang has been experiencing rapid economic growth since the late 1970s. But its population will begin to decline at the turn of the next century. Encouraging population in-migration and economic restructuring may be two possible choices to solve the problem.

Most regions will face rapid population ageing in the future, particularly during the period 2012-2032. The national average of the proportion of the elderly population may be close to those in the developed countries at that time. However, some regions, such as Zhejiang, may have a severe ageing problem. Hopefully, most of them are more developed regions in China and may be better prepared to face this problem. Sichuan, as a less developed region, will also have a severe ageing problem. This province has been successful in reducing its fertility which, of course, is helpful to its current economic development. National coordination is needed to tackle the ageing problem in China.

Population process is subject to the effects of various factors. Some of these effects are unforeseeable at the moment. Thus population projections should be carried out regularly to taking into account the changing situation. Nevertheless, the regional population projections produced in this research do provide much important information which will be useful in the understanding of population dynamics and the planning of socio-economic development in China for the future.

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9
Conclusion

This research focuses on an analysis and projection of multiregional population dynamics at urban-rural and provincial levels in China. There are substantial urban-rural and provincial variations in population dynamics. A detailed analysis of regional population changes has been undertaken and this is most useful to assess the population problems (including population growth, population control, population ageing and labour supply) facing various regions of China and their implications on socio-economic and regional development. This concluding chapter attempts to summarize the main findings of this research and the implications of these findings. Some broad policy suggestions about the implementation of the family planning programme, urbanization strategies, employment, population ageing and socio-economic planning will also be proposed and discussed. The forward demographic rates-based approach used in this research for multiregional population analysis and projection will be discussed first in the following.

A forward demographic rates-based approach

Significant progress has already been made in spatial population analysis. There are two kinds of migration data, transition data and movement data, each of which requires different analytical methods. The discussion here is confined to transition data. A major innovation in spatial population analysis was the introduction of multiregional population accounts and occurrence-exposure demographic rates (Rees and Wilson, 1977). Occurrence-exposure demographic rates can be correctly and precisely defined and can also be used to estimate multiregional population accounts. An iterative procedure is needed to make population projections using these occurrence-exposure rates. Given successful estimation of the elements in the multiregional population accounts, transition probabilities can be straightforwardly calculated for population projections. It is noted that migration and mortality rates are not represented independently (they are combined into transition probabilities) in such transition probabilities-based population models. Thus it is only possible to use constant migration and mortality rates for population projections. A transition probabilities matrix can also be derived by matrix inversion from occurrence-exposure demographic rates. This matrix inversion procedure may need to be repeated for each projection period if changing demographic rates are to be used for population projections.

A forward demographic rates-based approach has been used in this research. Forward demographic rates are similar to transition probabilities but mortality and migration rates are defined independently. This is achieved by dividing population into two categories --- migrating population and non-migrating population. A set of extended multiregional population accounts is also used. Forward mortality or fertility rates (they may be termed probabilities) can be defined for migrating population and non-migrating population respectively and they can be linked together. Forward migration rates can also be defined. Transition probabilities are calculated by dividing transitions by the starting population in population accounts. It is difficult to define mortality probability independently in the context of transition probabilities as it is related to migration probability.

It can been demonstrated that forward demographic rates have unique relations with occurrence-exposure rates. Different population projection models can be developed on the basis of occurrence-exposure rates and forward rates respectively and both are correct if corresponding demographic rates are used. However, the forward demographic rates-based model does have the advantage that population projections can be simply carried out while an iterative procedure may be needed for the occurrence-exposure rates-based population model. An approximate version of a forward demographic rates-based model has been used to make urban-rural population projections of China. An improved and more precise version of the model has been further developed for multiregional population projections at the provincial levels by defining the relations between the one-period and half-period demographic rates more realistically. These relations are essential to link the one-period and half-period demographic rates defined for migrating and non-migrating populations respectively.

The population model developed in this research requires a great deal of age- and region-specific population data. The population data available in this research only allow a limited use of the model. Several improvements may be considered in the further research. First, age- and region-specific birth and death data will allow more precise estimation of mortality and fertility rates. Second, age-, origin- and destination-specific migration data will produce more realistic estimation of migration rates. Third, constant mortality rates have been assumed for population projections in this research. A set of declining mortality rates may be used to assess their effects on population ageing.

Population dynamics in urban and rural areas

The first part of the research concerns urban-rural population change which is a natural result of the urbanization process. The change of labour productivity and the change of consumption structure are major forces driving the urbanization process. With the improvement in labour productivity and the increasing level of income, the share of non-agricultural products and services will increase. Hence, the proportion of urban population will also increase. Other factors including population growth, urban-rural differences and government policy may also condition the level and pace of the urbanization process in a particular country or region.

As a vast country with a large population, China had reached a relatively high proportion of urban population in ancient times. However, the proportion of urban population in China has been well below 20% for several decades since the foundation of the People's Republic in 1949 due to rapid population growth and the strict government control over the rural to urban migration aiming to achieve maximum capital accumulation and industrial growth. As a well-organized society lead by the communist party, the government has had and still has a number of measures including resident registration and restrictions on employment opportunities to restrain rural to urban migration effectively. However, rapid urban population growth has occurred since 1977 due to the favourable policy of the government towards urbanization and stable economic growth. The proportion of urban population rose from 14.4% in 1976 to 30.1% by 1987 and the urban population was more than doubled in eleven years. The figure for 1987 has been estimated using an urban population definition based on urban actual non-agricultural population used in this research. There has been increasing confusion about urban population data recently. Two different definitions of urban population were used in the 1982 and 1990 censuses in China respectively. The 1982 census definition includes all the population in urban areas while the 1990 census definition excludes the many registered agricultural population. The problem of the urban population definition lies in the fact that many of the registered agricultural population actually engage in non-agricultural activities. The urban population definition used in this research has effectively solved this problem and may describe the urbanization process in China more realistically.

The urban-rural differentials in population dynamics are analyzed here using an accounts-based approach. The procedures to estimate urban-rural population accounts and urban-rural life tables are developed on the basis of the multiregional population accounts concept. The urban and rural demographic rates of fertility, mortality and migration are estimated and urban-rural population life tables of China are constructed using the 1987 one percent population sample data.

Generally speaking, the urban population enjoys a better living-standard and better health service than the rural population in China. In this analysis, it is found that the urban population does have a slightly higher life expectation at birth than the rural population. This is probably due to a lower mortality rate of children aged below 10 in the urban region. Better health service and nutrition for children in urban areas may be the main causes of their low mortality rate. For those aged over 60, the mortality rate is slightly higher in the urban region than in the rural region probably because of the important social and environmental differences. For elderly people, a clean environment and light physical labour in the rural areas may help to keep them in good physical health. The lower mortality rate for age groups over 60 will also affect the life expectation of age groups aged below 60. Thus, the rural population will have a higher life expectation than the urban population for males aged over 20 and females aged over 60.

The out-migration rates of the rural population are generally much higher than those of the urban population indicating a net migration flow from the rural to urban region. The out-migration rates are the highest among the young population. The urban male population has a small peak of migration rate in age group 55-60 probably due to retirement migrations from urban to rural areas. Because of the higher out-migration rate of the rural population, an average rural female will spend over 16 years in the urban region and an average male 12 years in their life which are much longer periods than an average urban female or male is likely to spend in the rural region.

The total fertility rate of the urban population is significantly less than that of the rural population. The population reproduction is below the replacement level in the urban region while it is well over the replacement level in the rural region. Indeed, the fertility decline in China began much earlier and faster in the urban areas than in the rural areas. This is the combined result of several factors. Most of all, the people in urban areas enjoy a higher income than those in rural areas. Most people in urban areas are covered by some kind of pension scheme. Thus urban people are willing to have only one or two children as is the case in some developed countries. Second, the urban population in China is formally organized by working units which are responsible for the implementation of the government's family planning policy. Local residents committees play this role for those people not covered by working units, including self-employed, unemployed and housewives. These organizations, especially working units, ensure the effective implementation of family planning policy in urban areas. Those people who are keen to have more than one or two children are also restrained from doing so by the community pressure from their colleagues and managers. Here, the community pressure refers to the phenomenon that some people are afraid to do something because other people in the community do not do it and may criticize them for doing so. This factor can be of considerable importance in Chinese society, but is discussed little in the literature. On the other hand, working units together with well-developed medical systems in urban areas deliver effective consultation, contraception and abortion services. These services will keep the production of extra or unexpected children to a minimum. In rural areas, people are less willing to have less than two children. Some people strongly want to have at least one boy. The main reasons are that rural people usually have to depend on their sons for support during their elderly life. The implementation of the government's family planning policy is less effective in rural areas than it is in urban areas as the rural economy and society are not so well organized as in urban areas. The independence and freedom of the rural families have been increasing since the introduction of the family production responsibility system in the late 1970s. Due to these realities, rural couples now usually allowed to have two children. In some of the least developed areas, some couples still produce three, four or more children due to their traditional attitude to childbearing, the lack of the awareness of family planning, and the lack of effective medical services. In these areas, medical services and the education of family planning and the knowledge about population may need to be improved. In some developed rural areas, township enterprises play the role in the implementation of family planing policy similar to working units in urban areas. Thus the expansion of township industries may help to reduce the fertility rate in China. Indeed, rural industrialization is being followed by urbanization. Both of these forces may lead to the decline of fertility in China. In summary, more efforts may be needed to reduce the total fertility rate in the rural region. These efforts include the dissemination of family planing and the knowledge about population, improvement of mass education and medical services, rural industrialization and urbanization. Urbanization processes have a tendency to slow down population growth by simply raising the proportion of the urban population.

The gender differentials in mortality and migration are also clear. The age-specific mortality rates of the female population are less than those of the male population in both regions especially over age 60. Their expectation of life at birth is higher than that of the males. Furthermore, the female population has a higher out-migration rate than the male population in the age group 15-30 which may reflect marriage migrations. As a whole, the rural female population has a higher propensity to make out-migrations than the rural male population. This phenomenon is peculiar to China. In rural society, males usually will not leave the villages of their parents. If they move, they usually move to towns and cities for education or employment. But these rural to urban migrations are relatively small, constrained by the government's policy and the range of employment opportunities in urban areas. However, most young females will move to another place when they got married. Most of these migrations will be rural to rural. However, a number of females will move to urban areas in the course of marriage. Migrations for economic activities are much more important than for marriage in urban to rural migrations. These urban to rural migrations are usually dominated by males. As a result, the urban male population has a slightly greater propensity to make out-migrations than the urban female population.

Urban and rural population changes in the future

To model urban-rural population growth in future, a demo-economic model of urban-rural sectors and an accounts-based urban-rural population model are developed in this thesis. It is noted that the rural to urban population shift in China consists of pure rural to urban migration and a rural to urban transition due to the expansion of urban areas. These two components of rural to urban population shift are covered by the demo-economic model. It seems that administrative procedures related to the designation of cities and towns may affect the rural to urban population transition. However, their effects have been reduced to a minimum by defining the urban population on the basis of urban actual non-agricultural population in this research. The demo-economic model is tested against agricultural and non-agricultural employment data in period 1979-1988 and urban and rural employment data in period 1979-1987. The general trend of urban-rural migration and transition is captured by the demo-economic model. Except for 1980 and 1983 when the urban-rural net labour migration and transition is relatively small and the relative projection error is large, the RMSE (Root of the Mean of the Square of relative Errors) of the projected urban-rural net labour migration and transition is 38%. The total number of projected rural to urban labour shift in the period 1979-1987 is close to the real number in that period. Relative errors of the projected employment levels, however, are much smaller as the employment levels are significantly greater than the number of migration and transition. The RMSE of urban and rural employment are only 4.24% and 1.83% respectively for the period 1979-1987.

The demo-economic model is used to drive urban-rural population migration and transition in the urban-rural population model to make urban-rural population projections for the period 1987-2087. Four main parameters in the demo-economic model are the average increase rates of labour productivity and the income elasticity of consumption for the products of both the urban and rural sectors. They describe the supply and demand sides of the urban and rural economies. The averages of the four parameters for agricultural and non-agricultural sectors in the period 1979-1988 are assumed for population projections. The natural increase rates of urban and rural labour populations needed in the demo-economic model are projected by the urban-rural population model.

To project future urban and rural populations, it is necessary to make some assumptions about fertility and mortality in the future. It is noted that the life expectations of the urban and rural populations are around 70 years. They are close to the life expectations in some developed countries. It is possible that the life expectation in China may be further increased with the improvement of living-standard and medical services. However, such increase is likely to be marginal and quite unpredictable. For simplicity, constant mortality rates are assumed for urban-rural population projections in this research.

The future population trend is much more sensitive to future fertility trends. The total fertility rate in China has declined significantly in the past two decades due to overall socio-economic development and a series of government birth control campaigns. Based on an old urban population definition which includes only urban registered non-agricultural population, the total fertility rate of urban population began to decline in the late 1950s from 6.165 in 1957 to 1.499 in 1982, except for an abnormal fluctuation in the period 1961-1964. Fertility decline in the rural population was much later. The total fertility rate of the rural population began to decline in the early 1970s from 6.313 in 1970 to 2.857 in 1982. According to the estimation of urban population based on actual non-agricultural employment in this research, the total fertility rates of the urban and rural populations were 1.741 and 2.638 respectively in 1987. The rigorous birth control policy has been somewhat relaxed since 1984 in that most rural couples are now allowed to have two children. The recent economic reform and the introduction of the family production responsibility system in rural areas may decrease the effect of government birth control efforts. The overall implication is that socio-economic development and modernization seems likely to play a much greater role in the future trend of the fertility rate, while government birth control efforts will still have some effects and they need to be maintained to slow down the population growth feasibly and quickly. In fact, the total fertility rate of China has been further decreased from 2.618 in 1982 to 2.374 in 1987.

Three sets of urban and rural fertility rates are assumed while constant mortality rates and normal fertility rates are used for the urban-rural population projections. In set (A), it is assumed that the total fertility rates of urban and rural populations will remain unchanged from the base year 1987. The population projection (A) based on this assumption can be used to show the consequence of continuous population growth if fertility rates are not reduced in future. A realistic long-term target of the population control policy may be a zero population growth rate. A U-shaped total fertility trend is probably desirable and feasible to slow down population growth in China while the level of population ageing is kept not too high. A U-shaped trend of the urban total fertility rate is assumed in set (B). It is taken as given that the total fertility rate of the urban population will gradually decline to 1.5 in 2000, remain unchanged until 2010, gradually increase to 2.2 in 2030, then remain unchanged until 2087. A total fertility rate of 1.5 is used as the lower limit of fertility for the urban population. The population of China is about to enter a stable or declining stage in the 2030s and it is desirable that the total fertility rate will be returned to a replacement level of 2.2. The low urban fertility rate below the replacement level before 2030 may be useful to level out the fertility peaks of large fertile cohorts born in the 1960s and 1970s. The total fertility rate of rural population is assumed to decline more slowly to 2.2 in 2020, then remain unchanged until 2087. There may be concern that once the total fertility rate of urban population has declined to such a low level, it may be difficult to reverse the trend unless the earlier decline is a forced one. In set (C), it is assumed that the total fertility rate of urban population will decline to 1.5 in 2000, then remain unchanged until 2087. The total fertility rate of the rural population is assumed to be the same as in set (B).

Three urban-rural population projections (A), (B) and (C) are made assuming three sets of urban and rural total fertility rates respectively. The projection error of the total population for the period 1988-1990 is small. The maximum error was 0.145% in 1990 for projection (A). The projections of the total population and the proportion of urban population are also reasonably comparable and consistent with the United Nations' medium variant projections for the period 1990-2025. The total population of China will be 1513 million in 2025 according to the United Nations' projections. According to three projections (A), (B) and (C) in this research, it will be 1574, 1499 and 1473 million in 2025 respectively. The proportion of urban population will rise from 33.4% in 1990 to 65.8% in 2025 according to the United Nations' projections. It will rise from 32.8% in 1990 to 62.1% in 2025 according to projections (B) in this research. It is noted that some population problems such as population ageing may only emerge in a long term. The urban-rural population projections in this research cover the period 1987-2087 to reveal these trends.

Some major features of the anticipated urban-rural population growth in period 1988-2087 are revealed by these projections. According to projection (A), the total population of China will increase to 1604 million in 2040, then decline to 1370 million in 2087. The proportion of elderly population will increase from 7% in 1988 to 18% in 2040 and 21% in 2087. According to projection (B), the total population of China will increase to 1519 million in 2035, then decline to 1415 million in 2087. The peak population in projection (B) is much smaller than in projection (A) though China's total population in 2087 will be greater in projection (B) than in projection (A). The proportion of the elderly population in 2087 will be smaller in projection (B) than in projection (A). It will increase from 7% in 1988 to 19% in 2040 and then decline to 18% in 2087. According to projection (C), the total population of China will increase to 1472 million in 2025, then decline rapidly to 952 million by 2087. The proportion of the elderly population will be much higher in projection (C) than in projections (A) and (B), though China's total population will decline much faster in projection (C). The proportion of elderly population will increase from 7% in 1988 to 20% in 2040 and 25% in 2087.

Two major phases of future population growth of China can be identified with a division seemingly in the late 2030s. In the first phase before the late 2030s, the total population will continue to grow in most years. The urban population will increase rapidly from 334 million in 1988 to over 1000 million by 2040. The urban population proportion will increase from 30% in 1988 to about 70% in 2040. The labour population will increase rapidly especially before 2020. The proportion of elderly population will increase at first slowly before 2010, then rapidly after 2010.

During this period, China will face three main challenges. The first is the rapid increase of its urban population. Its urban population will triple in about 50 years, increasing from 334 million in 1988 to over 1000 million in 2040. The second is the rapid expansion of its labour force. The total labour force will increase rapidly before 2020. The labour population of China will increase from 632 million in 1988 to over 930 million in 2020. This represents a 50% increase in just three decades. All of these increase will occur in the urban labour market. The urban labour force will be more than doubled in the period 1988-2020. The labour population in the urban region will increase rapidly from 207 million in 1988 to over 560 million in 2020, while the labour population in the rural region seems set to decline from 426 million in 1988 to less than 385 million by 2020. The third challenge is the rapid ageing of the population during the period 2010-2040. The proportion of elderly population will increase rapidly from 7% in 1988 to over 18% in 2040. It is clear that great efforts are needed to coordinate urbanization and socio-economic developments to face these challenges.

In the second phase after late 2030s, the total population of China will probably begin to decline. The proportion of elderly population will be relatively stable or increase only slowly.

Due to significant differences in urban and rural fertility rates, urbanization will have a significant effect on the future population growth of China. The urban-rural population model is used to simulate this effect. It is found that the extent of the effect of urbanization on future population growth is cumulative and depends in large measure on the extent of future urban-rural differentials in fertility. The relative effect of urbanization on total population is 0.84% in 2000, 10.93% in 2040 and 55.16% in 2087 based on set (A) of the urban and rural fertility assumptions. According to set (A), the relative effect of urbanization on births is 6.29% in 2000, 39.39% in 2040 and

135.45% in 2087. The relative effects based on set (C) are close to those based on set (A). There will be no urban-rural differential in total fertility rate after 2030 in set (B). The effect of urbanization on population growth based on set (B) is much smaller. According to set (B), the relative effect of urbanization on total population is 0.91% in 2000, 5.70% in 2040 and 9.05% in 2087. The relative effect of urbanization on births is 7.68% in 2000, 10.87% in 2040 and 9.21% in 2087.

In conclusion, it is most likely that China's population will continue to grow in the period before late 2030s, adding about 300-400 million more people to the already huge population base. To control population growth, further decrease in the fertility rate is needed to level out the fertility peaks of huge fertile population base born in the 1960s and 1970s. Continuing urbanization in China can be regarded as a positive and effective option to slow down population growth especially before 2040. The rural to urban shift will gradually change people's life style and their view of childbearing. People may respond more positively to the government's call for family planning. This is especially important when China becomes more committed to a market economy which may further decrease the effect of the government's birth control efforts. A stable society and steady economic growth are necessary to propel the process of urbanization and modernization which in turn will help to slow down the population growth of China.

Urbanization, employment and ageing problems in China

The urban population will triple in the next fifty years. An immediate question is the kind of urbanization strategy that China should choose, i.e., where and how to accommodate these huge urban population increases? There have been many debates with opposite views in China (e.g., Hu and Zhang, 1984; Li, 1986; Li, 1988; Liu, 1984; Wu, 1985; Wu, 1988; Zhou, 1984; 1986). Two kinds of views have been proposed. The first one is a small-town-based urbanization model. The second one favours large-city-based urbanization.

The small-town-based urbanization model is the popular view in China. This model suggests that the over 200 million surplus labour force in the agricultural sector that will be released before the end of this century will leave the land but not the home area and will be absorbed by developing a large number of towns. It is suggested that the number of these towns may be increased to 20,000 by the year 2000 and that the average population scale of the towns will be of the order of about 16-17 thousand (Wu, 1985). It seems that this model has been adopted by the government of China to absorb the surplus rural population. As an indication the number of towns increased from 2374 in 1980 to 10,609 in 1988.

The large-city-based urbanization model was proposed by Li (1988). His main argument is that there are great agglomeration economies in large cities and that large-city-based urbanization should be adopted in China to facilitate future economic development.

It is argued here that several factors need to be considered in choosing a suitable urbanization model for China. First, urbanization is itself an agglomeration process of population, production and social-economic elements in space to gain scale and agglomeration economies. Its objective is to greatly raise the living standards of residents. It should be emphasized that China is still at the stage of expanding industrialization and urbanization. The development of small towns in China is quite different from the counterurbanization trends seen in the developed countries. These towns are based on a number of small, mostly manufacturing, firms using somewhat less advanced technology. The small-town-based urbanization model is contrary to the theoretical means and aims of urbanization mentioned above. The population scale of most towns is under 50,000. Scale economies are not usually gained by most production firms in these towns. The linkage among production firms is weak, and the infrastructure is relatively poor. There are few agglomeration economies. The economic efficiency, product quality and living standards are much poorer in these towns than in modern cities. On the other hand, these towns use more land area per capita, consume more energy and produce more environmental pollution per production value than modern cities. The sole advantage of town development is that less investment is needed. The towns may be moderately developed as a transition stage when there is a shortage of funds to develop modern industry sectors and cities. But it is not appropriate to regard town development as a dominant process of urbanization. Those towns which have locational advantages should be developed further to become modern cities. It should be clearly recognized that the small-town-based urbanization model may have significant unfavourable effects on the future economic efficiency and living standards in China. One important reason for poor economic efficiency in China is that large-scale production is not well organized and the scale and agglomeration economies provided by the modern technologies are not well utilized.

Second, the demographic and economic conditions of China are not in favour of a small-town-based urbanization approach. China has a large population which accounts for one-fifth of the world's population and is densely populated, especially in the eastern part. The population density of China is about three times the world average. Ten provinces in the eastern part of China have a population density over 300 persons per square km which is about nine times the world average. This demographic condition means that the average city scale may be larger in China than in other countries. Economic linkage is strong among cities in a modern economy and well-developed and convenient transportation and communication systems are required. At the moment, the transportation and communication systems are not sufficient in China and considerable investment is needed to improve these systems. The railway is the main form of transportation but its route network density is low. There are not sufficient highways and vehicles. Many towns may mean long and poor transportation lines, high transportation lost and low economic efficiency.

Third, there is a relation between the city scale and economic efficiency. Agglomeration economies may only be gained by those cities with a population scale over 0.15 million. Many experts believe that the suitable city scale is between 0.2 to 0.5 million. A city in this scale range may become an independent and integral economic centre of a region which can stimulate industry and business development (see Hoover, 1971). More recently, Begovic (1991) examined the theories of optimal city size. An optimal city size is considered as the size at which the net agglomeration economies are maximal. The agglomeration economies are defined as those external economies which result from the size and spatial concentration of production, non-economic activities and physical structures. He then estimated the global and partial optimal city sizes for the global city economy and various economic sectors respectively using the data of 68 Yugoslav cities with a population over 30,000 in the 1981 census. It was found that the global optimal city size is 0.47 million. The partial optimal city sizes range from 0.15 million of the constructing sector to 0.51 million of the wholesale and retail sector.

Fourth, there is a negative relation between city scale and urban problems. There are negative externalities associated with city size which derive from the heavy spatial concentration of population in large cities (Richardson, 1973). It may be beneficial for individuals and firms to move to large cities but may be not beneficial for the society as a whole. This is because their decisions are based on a distorted set of relative prices and may impose external diseconomies on other city residents and firms. Super large cities have heavy traffic, housing and environment pollution problems, and need more urban construction investments. It is not suitable to adopt the large-city-based urbanization model in China.

According to the arguments above, neither of the two extreme urbanization models mentioned above would appear to be the optimal urbanization model for China. In fact, the growth of massive metropolitan areas and primate cities in many developing countries has created serious economic and social problems with which they do not have the resources to cope directly. Thus a growing number of governments in developing countries have been exploring ways of building the capacities of secondary cities (Rondinelli, 1983). These secondary cities refer to cities with populations of at least 100,000 up to but not including the largest city in a country. It is argued that this urbanization strategy may deconcentrate urbanization, reverse polarization, alleviate problems in large cities, and reduce regional inequities.

Similarly, a medium-city-based and large, medium and small cities and towns coordinated urbanization model may be the most effective for China. The proposed urbanization model suggests that the development of medium sized cities with population scale around 0.3 million should be emphasized in the period before the year 2000. The towns and large sized cities should also be moderately developed in the mean time. The medium sized cities will enter a further developing stage after the year 2000 and their population scale may be increased to 0.5-0.6 million. The scales of various cities may be stable after the year 2040 as the population of China will enter a stable stage at that time.

Another challenge facing China in the next three decades is the rapid increase of its labour force. Several studies point out that hidden unemployment and underemployment have become key issues in economic development and reform. Zhang (1992) estimated that there were about 45% of surplus employees in Chinese industry in 1981. He suggested that a system of five or even four working days a week instead of the more usual six should be gradually introduced to increase efficiency. Xin (1991) cites a figure of 178 million hidden unemployment (surplus labourers) in urban and rural areas based on estimates by the Ministry of Employment for the urban firms and the Ministry of Agriculture for the rural areas. According to these estimations, currently there are 20% or 28 million hidden unemployed in urban areas and a massive 150 million in rural areas. Li and Zhang (1991) estimate that 40% or 300-400 million rural labourers need to be redeployed to non-agricultural sectors. They also note the problem of low skill quality in this component of the labour force. Kang (1992) points out a basic contradiction between the development of an advanced industrial structure, which tends to be capital intensive, and the transition of the employment structure which releases a large number of surplus rural labourers. The development of township industry may be regarded as a transition stage to provide jobs in less advanced sectors so permitting modern non-agricultural sectors to be developed subsequently. Bonn and Cartier (1988) have also recently analyzed the urban employment problem, the various measures to count unemployment and the changes in the employment recruitment system in China.

It may be of interest to examine the current employment situation in China. According to official sources (SSB, 1991), about 81% of labour resources were employed in 1990. Among 567 million employees in total only some 26% were urban employees. Some 28 million students accounted for 4% of total labour resources and the 89 million unwaged domestic workers made up a further 13%. About 1.4% of labour resources were unidentified.

The distinction of urban and rural employees needs some discussion here. It is related to the dual employment system in China. Residents are registered either as agricultural population or non-agricultural population. There is a relatively complete system which provides food, price-subsidies, employment service by the state to the non-agricultural population mostly in urban areas. The agricultural population is mainly self-reliant and may belong to a rural collective economic organization. The agricultural population is not permitted to seek employment in formal urban sectors. On the other hand, firms in urban areas may employ some agricultural population in case of need, with the approval of the urban employment authority. The control of rural to urban migration has been somewhat relaxed with the implementation of economic reforms (Leeming, 1993). Some rural construction companies have been allowed to take urban construction contracts. Some peasants now are allowed to move into urban areas, especially small towns, to engage in some service sectors. These individuals are mainly self-employed and are not employed in the modern urban sector (Zweig, 1987; Wu and Xu, 1990). Therefore, it is simply just not sufficient to assess the employment problem in China only in the urban areas while there may be severe underemployment in rural areas. It should also be noted that the distinction between urban and rural employees does not match exactly the distinction between urban and rural populations. Overall, the urban population proportion is slightly higher than the proportion of urban employees as some urban population are registered as agricultural population, thus they are counted as rural employees.

According to official statistics (SSB, 1991), there were 3.8 million job-waiting persons in urban areas in 1990. The urban job-waiting rate was 2.5% in 1990. This is just one aspect of the employment problem in China. It is commonly recognized that most state-owned firms and organizations are over-staffed. As mentioned earlier, it has been estimated that there are about 28 million hidden unemployment in urban areas (Xin, 1991). This problem is the result of the pre-reform government policy of full employment and the paternal relationship between the government and firms. Labour resources were allocated by the government while most firms only had soft economic constraints and did not need to be concerned too much about profit and loss. Public organizations, such as the universities, were willing to increase staff on almost every occasion as wages were paid by the state. Current economic reforms, however, aim to increase competition and productivity. State-owned, as well as other firms, have been given many powers to run their production, employment, investment and marketing for their own profit and eventually become independent economic entities. Public organizations have also been given hard resource constraints and the power to allocate performance-related bonuses for their employees. More and more workers will be employed on a contract basis to break so called ' iron rice bowl ', ' iron chair ' and 'iron wage' guaranteed by the pre-reform employment system. The proportion of contracted workers has been increased from 0.6% in 1983 to 12.1% by 1990. The current employment system reform will eventually release substantial numbers of surplus employees in urban sectors which will be a real challenge to economic reform and development in China (Bonn and Cartier, 1988). The tension between managers and workers made redundant has been increased and some serious crime is thought to have resulted. As a consequence the government now promotes job-creation more actively for redundant workers rather than just sending them home to keep social stability.

Another important aspect of the employment problem in China is the large number of surplus labourers in rural areas resulting from the rapid population growth in the 1950s and 1960s and the tight control of urban-rural migration. Indeed, of course, agricultural productivity will be increased more rapidly if more surplus labourers are released from the agricultural sector. The economic performance of the 1980s provides some further evidence. In the first half of this decade, the number of employees in the primary sector (mainly agricultural) increased annually by 1.3%. The average agricultural GDP growth rate was 8.2% and the labour productivity growth rate was 6.7% in this sector in the same period. In the second half of the 1980s, however, economic growth was somewhat slowed down and the average GDP growth rate was only 4.2% in the primary sector. The number of employees in this sector increased at a somewhat higher rate of 1.8% each year and as a result the labour productivity growth rate in the primary sector was only 2.5% over this period.

The numbers of employees in primary, secondary and tertiary sectors all increased in the 1980s though the tertiary sector recorded a most rapid rate of increase and the secondary sector the second most (table 9-1). The tertiary sector grew at the rate of over 9% per annum over the decade. As a result, the proportion of employees in the primary sector decreased from 69% in 1980 to 60% in 1990 while the proportion of employees increased from 18% to 21% in the secondary sector and from 13% to 19% in the tertiary sector in the same period. This trend in employment structure is also clear in both urban and rural employment. It seems that a shift from the primary and secondary sectors to the tertiary sector is taking place among urban employees while a shift from the primary sector to the secondary and tertiary sectors is taking place among rural employees. The growth rates of both secondary (14.9%) and tertiary (20.0% per annum) activities in rural areas are particularly dramatic as a result of the rapid expansion of township industries.

Table 9-1 Employment structure and employment change in China, 1980-1990

Sector	Primary		Secondary		Tertiary	
Number of employees (million) and percentage proportions						
		%		%		%
China total						
1980	291	69	77	18	55	13
1990	340	60	122	21	105	19
Urban						
1980	8	8	55	52	42	40
1990	7	5	74	50	66	45
Rural						
1980	283	85	35	11	13	4
1990	333	73	87	19	39	8
Growth rate of the number of employees per annum (%)						
China total	1.7		5.8		9.1	
Urban	-1.3		3.5		5.7	
Rural	1.8		14.9		20.0	

Data source: SSB (1991)

The change in employment structure is associated with the change in GDP structure and labour productivity in the three sectors. The proportion of GDP in the primary sector decreased from 30% to 24%, while the proportion of GDP increased in the other two sectors in the 1980s (table 9-2). Labour productivity increased from 471 to 738 Yuan per employee in the primary sector ---- well over 50% for the decade as a whole. Almost the same the level of productivity increase was to be found in the secondary sector as output rose from 2927 to 4583 Yuan per employee. A more modest decennial growth rate in productivity of 42% was indicative of the still labour intensive tertiary sector.

Table 9-2 GDP structure and labour productivity in 1980 and 1990

Sector	Primary	Secondary	Tertiary
GDP structure (%)			
1980	30	49	21
1990	24	52	24
Labour productivity (Yuan per employee)			
1980	471	2927	1723
1990	738	4583	2447

Data source: SSB (1991)

GDP and labour productivity growth determines the level of employment. The overall growth rate of GDP was 9.0% in the 1980s. The GDP growth rate ranged from 6.2% in the primary sector to 9.7% in the secondary sector and 10.7% in the tertiary sector. The annual growth rate of labour productivity as a whole was 5.8%. Interestingly the sector with the greatest output gains was the sector with the smallest productivity gains ---- namely the service sector. The annual growth rate of labour productivity was only 3.6% in this sector while it was 4.6% in the primary and secondary sectors. The decline of the share of employment in the primary sector which had the lowest labour productivity had a significant contribution to the improvement of the overall productivity of the economy. As a result, the economy as a whole had a greater annual growth rate of labour productivity than each of the three sectors.

According to official definitions (SSB, 1991), labour resources include labour population in the working ages and those persons who are in the workforce but beyond working ages. Therefore labour resources are more than labour population in the working ages. The ratio of the amount of labour resources to that of labour population was 1.0344 in 1990. Labour resources or labour supply have been projected on the basis of labour population using this ratio.

It must be noted that the economic performance in the 1980s discussed above has been realized under the circumstance that the number of total employees was growing rapidly at about 3% per year. According to the labour resources projections, labour resources will continue to increase rapidly but at a somewhat slower rate of 1.2% per year in the period 1990-2020 and then begin to decline after 2020. Therefore, if it is assumed that same recent growth rates of GDP and labour productivity in the three sectors be maintained, there will be in fact no employment problem and the long term future may even result in labour shortage. This condition of zero unemployment or labour shortage is due primarily to the difference between the previous growth rate of labour supply and the forecasted lower growth rate of future supply. The condition of hidden unemployment in the urban sector and the underemployment in the rural sector remains unchanged under these assumptions, although it might be expected that in the later period labour demand will draw upon such underused labour. The aims of current economic reforms towards a market economy, however, are to increase productivity, efficiency and competition.

A series of calculations have been made, assuming various other GDP and labour productivity growth rate combinations to assess the levels of employment and unemployment in the next 50 years. The level of unemployment can be estimated assuming GDP in the primary, secondary and tertiary sectors growing at the same rates as those achieved in the 1980s and productivity growth rates of 160% and 180% of those achieved in the 1980s. The annual growth rate of labour productivity is assumed to be 7.4% in both the primary and secondary sectors and 5.8% in the tertiary sector in the first case and 8.3% and 6.5% respectively in the second case. These levels of productivity increase have been chosen so as to illustrate the sensitivity of the resultant levels of unemployment in the future. Under these assumptions, total GDP of China will grow at about 9-10% per year. The GDP growth rate will increase with the decline of the share of the slowly growing primary sector. Table 9-3 presents the estimated levels of unemployment. Under the assumption of productivity growth rates of 160% of those achieved in the 1980s and using the labour resources projections of population projection (A), the level of unemployment is set to rise dramatically in the short term

Table 9-3 Unemployment estimations assuming same GDP growth rates as achieved in the 1980s in primary, secondary and tertiary sectors

Year	Unemployment assuming Productivity growth rates 160% of those in the 1980s		Unemployment assuming Productivity growth rates 180% of those in the 1980s		GDP growth rate (%)
	Number(million)	Rate(%)	Number(million)	Rate(%)	
Population projection (A)					
1995	37	4.9	60	8.0	9.2
2000	44	5.5	92	11.4	9.3
2010	28	3.1	132	14.6	9.4
2020	0	0	107	10.8	9.6
2030	0	0	0	0	9.8
2040	0	0	0	0	9.9
Population projection (B)					
1995	37	4.9	60	8.0	9.2
2000	44	5.5	92	11.4	9.3
2010	26	2.9	130	14.4	9.4
2020	0	0	90	9.3	9.6
2030	0	0	0	0	9.8
2040	0	0	0	0	9.9

Note: estimates for population projection (C) are similar to those for (B)

and then gradually fall to the still substantial 28 million in 2010. The unemployment rate will be 4.9% in 1995, 5.5% in 2000 and 3.1% in 2010. It should be noted that the official urban unemployment rate was 2.5% in 1990. However the important feature is that there will be no unemployment after 2020 as the labour supply begins to decline. If higher productivity growth rates of 180% of those achieved in the 1980s are assumed, the level of unemployment will be much greater. It will be 60 million in 1995, increase to 132 million in 2010 and there will still be 107 million unemployed in 2020. The unemployment rate will be 8.0% in 1995, 14.6% in 2010 and 10.8% in 2020. After that date the labour supply factor will again become operative and unemployment will fall to zero after 2030.

Alternative levels of unemployment can be estimated assuming slower GDP growth rates of 60% of those achieved in the 1980s and assuming productivity growth rates of 100% and 120% of those achieved in the 1980s. The annual growth rate of labour productivity is assumed to be 4.6% in both the primary and secondary sectors and 3.6% in the tertiary sector in the first case and 5.5% and 4.3% respectively in the second case. Under these assumptions, the total GDP of China will grow at about 5-6% per year. Table 9-4 presents the estimated levels of unemployment. The unemployment problem will be much more severe. Under the assumption of the same productivity growth rates as achieved in the 1980s and using the labour resources

Table 9-4 Unemployment estimations assuming GDP growth rates 60% of those achieved in the 1980s in primary, secondary and tertiary sectors

Year	Unemployment assuming Productivity growth rates 100% of those in the 1980s		Unemployment assuming Productivity growth rates 120% of those in the 1980s		GDP growth rate (%)
	Number(million)	Rate(%)	Number(million)	Rate(%)	
Population projection (A)					
1995	52	6.8	75	9.9	5.5
2000	79	9.8	125	15.6	5.5
2010	130	14.3	223	24.5	5.6
2020	144	14.6	287	29.1	5.7
2030	67	6.8	268	27.3	5.7
2040	0	0	233	23.9	5.8
Population projection (B)					
1995	52	6.8	75	9.9	5.5
2000	79	9.8	125	15.6	5.5
2010	128	14.1	221	24.4	5.6
2020	127	13.2	271	28.0	5.7
2030	30	3.2	231	24.7	5.7
2040	0	0	176	19.4	5.8

Note: estimates for population projection (C) are similar to those for (B)

projections of population projection (A), the level of unemployment will be 52 million in 1995, increase to 144 million in 2020 and then decline to 67 million in 2030. The unemployment rate will be 6.8% in 1995, 14.6% in 2020 and 6.8% in 2030. There will be no unemployment in 2040. Assuming higher productivity growth rates of 120% of those achieved in the 1980s, the level of unemployment will be much greater. The unemployment rate will be 9.9% in 1995, 29.1% in 2020 and 23.9% in 2040. Such high unemployment rates may well not be socially acceptable.

The unemployment estimates will all be slightly smaller if the labour resources projections of population projection (B) are used. The unemployment estimations are close for population projections (B) and (C).

These unemployment estimates have been made for China as a whole. It seems that most unemployment will be kept in rural areas in the form of underemployment. The rural areas are the major sources of labour supply and rural to urban migration is tightly controlled by Chinese government. It should be noted that the urban-rural population model assumes full employment and it is unlikely that such dramatic movements of population would occur if there is a high level of urban unemployment. The level of urban unemployment will depend on the release of hidden unemployment itself and the competition between urban redundancy and new labourers from the rural areas. It is likely that urban labourers may be reluctant to take up unskilled posts which may be filled by rural labourers.

A number of measures have been adopted recently in China to increase employment. These include the expansion of service sector; the development of self-employed business; the development of township industry in rural areas; and the development of export industry. It has also been proposed that the system of six working days a week be gradually changed to five. The number of unwaged domestic workers also seems set to be encouraged to rise.

From the urban-rural population projections, the ageing of population in China seems to be moderate in the future compared with other developed countries though it may not be an easy task for China to tackle this problem. For projection (A), the proportion of elderly population will be 21% in 2087. Even for projection (C), it will only be 25% in 2087. However, the ageing of population will be much more severe in some cities and regions which have experienced much lower fertility rates than the national average. Thus multiregional population projections at the provincial level have been carried out to reveal these regional trends in the second part of this research.

Population dynamics in provincial regions

The mechanism of the urban-rural population system and the underlying forces determining the urban-rural population dynamics are relatively clear. A more general multiregional population system consisting of provincial populations of China is analyzed in the second part of this research. The mechanism of this multiregional population system at provincial level and the underlying forces determining the multiregional population dynamics are more complex than those of the urban-rural population system. The evolution of a multiregional population system is determined by the system itself and the environment of the system --- namely, the social, economic and ecological systems. The regional differentials in population dynamics may be explained by population conditions and social, economic and ecological conditions in various regions. The research proceeds by examining the spatial differentials of China's population around 1990 and their trends in the period 1950-1990. Empirical studies are made to examine possible factors which may affect fertility and migration behaviours. Statistical regression models are also estimated to identify the main factors determining regional differentials in the birth rate, death rate, in-migration rate and out-migration rate. And finally a multiregional (provincial level) population model is developed and consistent provincial population projections are made for the period 1987-2087.

The distributions of the total population and the national minority population are two fundamental features in China. The eastern economic zone has high population density but a low proportion of national minorities. The western economic zone has low population density but a high proportion of national minorities. They reflect the vital effects of natural conditions on the growth and distribution of human populations. The eastern economic zone has been able to sustain a high level of population density due to its rich agricultural resources. The distribution of national minority population is the result of historical evolution. The national minority population in the western part of China may have been subjected to less influence of the mainstream culture in the eastern and middle parts of China and are better able to maintain their own identities.

The spatial variations of other demographic indicators are related to the difference in the levels of economic development. The eastern economic zone is the most developed zone in China. Its population has good education but low mortality rate. Its birth and natural increase rates are low. Thus its proportion of elderly population is relatively high and the average household scale is small. The situation is reversed in the western economic zone. The middle economic zone has exactly the middle situation between the eastern and western zones.

Family planning was gradually introduced into the urban areas in the 1960s and rural areas in the 1970s in China. The birth rate of China began to decline slowly after 1963 and rapidly after 1970. The decline of birth rates took place in all regions in the period 1965-1978. Beijing, Tianjin and Shanghai in the eastern economic zone lead the way in the decline of the birth rate. In some regions such as Sichuan, Shaanxi and Xinjiang in the western economic zone, Shanxi and Henan in the middle economic zone, significant decline of birth rates did not happen until 1972. In the eastern economic zone, the rates of the birth rate decline were close in the period 1965-1972 and 1972-1978. However, in most regions in the middle and western economic zone, birth rates declined much faster in the period 1972-1978 than in the previous period 1965-1972. However, birth rates in Tibet, Guizhou and Yunnan in the western economic zone, and Jiangxi in the middle economic zone did not decline fast even in the 1970s.

Most regions recorded increases in birth rates from 1978 to 1981 as a more flexible family planning policy has been adopted in China since the early 1980s. In the period 1981-1990, all regions in the eastern zone, plus Inner Mongolia, Heilongjiang in the middle economic zone and Guizhou, Yunnan, Qinghai, Ningxia and Xinjiang in the western zone had slight decreases in their birth rates. The birth rates in the remaining regions either increased slightly or were stable over the same period. The fertility trend in China in the reform period has been the focus of several recent studies on China's population (Peng, 1991; Greenhalgh, 1986). China has achieved a low level of fertility compared to its low level of economic development by the strong family planning campaigns of the Chinese government. It seems that these effects may be negatively affected by current economic reforms as many administrative powers are being decentralized. However, economic development may raise the cost of children to parents thus leading to further decline of fertility in China. This is confirmed by the trends in regional birth rates, especially in the developed eastern economic zone, in the 1980s mentioned above.

The national death rate of China decreased gradually from 20 ‰ (one per thousand) in 1949 to 6.7‰ in 1990 except for an upturn during the ' Socio-economic crisis ' which occurred around 1960. A number of regions recorded a rapid decline of death rates in the first period 1954-1957. Regional death rates declined more slowly in most regions over the period 1957-1978 and have been stable since 1978. Shanghai recorded an increase in death rate over the period 1972-1990 primarily due to the ageing of its population. For China as a whole, such a process may take place in the next century.

After the foundation of the People's Republic of China, the government gradually introduced a series of measures to control migration. The scale of migration flow has been significantly reduced since the early 1960s. Most rapid decline of in-migration rates occurred in those regions which had high in-migration rates before 1960. These regions including Beijing and Liaoning in the eastern zone, Inner Mongolia, Jilin and Heilongjiang in the middle zone, Ningxia and Xinjiang in the western zone had massive in-migrations in the 1950s. The trends of the regional out-migration rates in the period 1955-1987 are quite close to those of the regional in-migration rates. Most regions had peaks of out-migration rates in the year 1960, then their migration rates declined to low levels by 1965. Net migrations have been reduced to low levels in most regions since 1965 along with the decline of the in-migration and out-migration rates. The absolute regional differentials in net migration rates have been quite small since then.

In the period 1957-1990, population density has been increasing in most regions. However, there is little change in the ranks of regional population density due to the existing huge differentials in such regional population density. Shanghai remains the region with the highest population density while Tibet, Qinghai and Xinjiang have the lowest.

A systematic study of the trends of the spatial variation and the stability of the spatial patterns of major population indicators of China since the 1950s is also carried out in this study. A number of findings have been obtained. First, using coefficients of variation, it was found that spatial variation increases in order from the death rate, birth rate, natural increase rate to inter-provincial out-migration rate, inter-provincial in-migration rate and finally to population density using various data in 1987 and 1990 respectively. One interesting finding is that the spatial differential of inter-provincial out-migration rate is less than half that of inter-provincial in-migration rate. This confirms the theory that out-migrations may depend mainly on the demographic characteristics of the origin regions while migrants may have more freedom to chose favourable destination regions. As a result, out-migrations may be more evenly distributed across regions than in-migrations. The coefficient of variation of birth rate is greater than that of death rate. This probably means that the death rate declines much faster and more evenly across regions than the birth rate. As a matter of fact, the decline of the death rate depends to a large extent on the improvement of nutrition and health service which may be easier to achieve while the decline of birth rate depends in large extent on the change of human behaviour which often comes later. The spatial variation of population density is the greatest of all these population indicators. As mentioned before, the distribution of population is a fundamental feature in China. It may take a long time for any significant change in this aspect to be achieved. However, the spatial differential of population growth still has significant implications for national and regional population changes even though its coefficient of variation is smaller than those of most other demographic indicators. The populations in Beijing, Ningxia and Guangdong were increased by over 17% in the period 1982-1900 while the populations in Heilongjiang, Zhejiang and Sichuan only managed somewhat less than 9% over the same period.

Second, the spatial variation of the birth rate increased in the period 1957-1978 as some regions were leading the way in the decline of fertility. It decreased from 1978 to 1981 as the decline of fertility spread into other parts of the country and has been stable over the period 1981-1990. The spatial variation of the death rate decreased in the period 1954-1990 reflecting the uniform convergence of death rates across regions. The spatial variation of the in-migration rate, the out-migration rate and the net migration rate all decreased in the period 1955-1987 with the overall decline in the levels of migration since 1960. The spatial variation of the inter-provincial in-migration rate was stable in the period from mid-1982 to mid-1987. The spatial variation of population density increased from 1957 to 1965, decreased gradually in the period 1965-1985 and changed only a little from 1985 to 1990. It seems that the distribution of China's population has been changing but slowly.

Third, using correlation matrices to examine the stability of spatial patterns, it was found that there is a change in the spatial pattern of the birth rate between 1957 and 1965 due to the shift of high birth rates to low birth rates in some developed regions such as Shanghai and Zhejiang in the period. The high birth rate in the initial period is due to improved living-standards. However, further improvement in living standards has eventually raised the cost of children to parents and they may prefer to have fewer children. The spatial pattern of the birth rate has been stable since 1965. Some developed regions have been leading the way in the decline of fertility and their birth rates have always been lower than in less developed regions. The spatial patterns of the death rate, out-migration rate and population density have been quite stable since the 1950s. However, the spatial patterns of the in-migration rate and net migration rate are more variable. There is a gradual change in the spatial pattern of in-migration rates between 1975 and 1980. This is due to the changing circumstances in China in the late 1970s when economic reforms were introduced. The spatial pattern of the net migration rate is not stable in the period 1955-1987 as it is the balance between the in-migration and out-migration rate and may be subject to some random factors.

Determinants of regional fertility and mortality levels

Fertility is a most active factor affecting population growth and distribution in the process of population development. The fertility data of Shaanxi, Hubei and Shanghai collected by an in-depth fertility survey in 1985 are employed to make a comparative analysis of fertility levels. Shaanxi is a less developed inland province in western China. Hubei is a medium developed coastal province in northern China. Shanghai is a highly developed coastal municipality in eastern China. This analysis aims to examine the effects of various factors on fertility.

The most developed region (Shanghai) had the smallest number of children per married woman (NCMW) while the least developed region (Shaanxi) had the largest NCMW. The NCMW was 2.80 in Shaanxi, 2.45 in Hebei and 1.54 in Shanghai. The difference in the NCMW between cohort 40-44 and cohort 45+ of married women is used to reflect the scale of fertility change. The finding is that the lower the fertility level the smaller the scale of fertility decline. This means that the further decline of fertility in China may need to be sought in some of the more backward regions. The difference in the NCMW was 0.35 between Shaanxi and Hebei and 0.91 between Hebei and

Shanghai. Of the fertility level difference between Hebei and Shanghai, 57% can be explained by cultural and educational factors, 21% can be explained by urban-rural differences, and no more than 43% may be explained by the economic factor. The NCMW difference by urban rural residence was about 0.50 in Shaanxi and Shanghai and only 0.2 in Hebei. The NCMW difference between those women with no education and those with primary school education was 0.46 in Shaanxi, 0.29 in Hebei and 0.66 in Shanghai. In comparison the NCMW difference between those women with primary school education and those women with middle school plus education women was much greater. The difference was 1.27 in Shaanxi, 1.08 in Hebei and 0.84 in Shanghai. Finally the NCMW difference between managers and professionals, and peasants was 1.01 in Shaanxi, 0.63 in Hebei and 0.83 in Shanghai.

The direct effect of family planning policy is assessed by comparing the desired numbers of children at first marriage whether or not taking into account the family planning policy. The difference may be regarded as the direct effect of family planning policy on fertility level, and was 0.2 in Shaanxi and Shanghai and 0.4 in Hebei. These direct effects are surprisingly small compared with the effects of other factors. However, family planning policy may also have an indirect effect on the decline of the desired number of children at first marriage. This indirect effect is estimated on the basis of desired numbers of children by various years since first marriage and is defined as the difference of the desired number of children between those women first married in the past five years and those first married twenty five years ago. The indirect effects are more impressive --- 0.7 in Shaanxi, 1.4 in Hebei and 0.5 in Shanghai. This indirect effect should be treated with caution as it may also include the effects of other factors such as the overall level of socio-economic development. The sum of the direct and indirect effects of the family planning policy was 0.9 in Shaanxi, 1.8 in Hebei and 0.7 in Shanghai.

In conclusion, the effects of cultural and educational factors and the family planning policy factor on fertility level are the greatest among those of other factors. Each effect is about 1.0. The effect of the types of occupation is about 0.8. The effect of urban-rural differences as well as the effect of regional differences is about 0.5 after excluding the indirect effects of other factors.

The main factors affecting regional differentials of the birth rate and death rate are examined using a stepwise regression analysis. It has been found that income and the proportion of agricultural employees are the two most important factors in determining the regional differences in the birth rate. It has also been found that the proportion of urban population based on the 1982 census definition is the most important factor in determining the regional differences in the death rate. The effects of the level of socio-economic development on birth and death rates are firmly confirmed. Those regions with higher income and higher proportions of non-agricultural employees tend to have lower birth rates. Those regions with higher proportions of urban population based on the 1982 census definition tend to have lower death rates. This is in accord with the urban-rural differentials in mortality. However, the death rate has decreased to a low level in China. Its regional variation is less predictable than that of the birth rate.

It seems clear that social, economic and educational developments need to be coordinated to control population growth effectively. Popular education and the dissemination of family planning policy and population knowledge are two useful measures in the implementation of family planning policy. In terms of population control, a broad family planning programme may do two things. First, it can provide information and advice about the benefits of having fewer children both for the family and for the state. In this way, the desired number of children may be reduced. Second, it can provide sufficient contraception and practical medical services so that couples may only produce the desired number of children.

New migration pattern in the 1980s and determinants of regional in- and out-migration rates

Migration is an important component of population change. Migration causes, migration selectivity and migration structure in China are examined using 1982-1987 migration data. There is clear evidence in China to confirm the common laws of migration found in other countries.

Employment, marriage and joining family are the three major causes of migration in China. Migrations for employment and joining family are more important in city and town in-migrations than in county in-migrations where marriage is the first major cause of in-migration. Migrations for employment and joining family are more important at the inter-provincial level than at the intra-provincial level. Nearly 90% of marriage migrations were intra-provincial. It is found that migration for employment is significantly correlated with retirement migration, migration for study and training and migration for marriage. Migrations for employment, study and training are also significantly correlated with value added per capita reflecting the economic attractions of some developed regions to these migrations.

Young population aged 15-29 represented a much higher proportion of the migration population than of the total population. Gender selectivity was also quite different among the city, town and county populations. The gender ratio (males per hundred females) of the out-migrations from the city population was higher than the gender ratio of the total population. The gender ratios were even much higher in the city to town and city to county migrations where most migrants were male. The gender ratios of the town and county migration populations were much less than the gender ratio of the total population as marriage migration, which is female dominated, is an important part of migrations in the town and county populations. The migration population also had a higher educational level than the total population. The educational level was similar between intra-provincial and inter-provincial in-migration populations of both the town and county populations. The proportion with university education, however, was much higher in the inter-provincial in-migration population than in the intra-provincial in-migration population of the city population. Most occupations, except peasants, had higher proportions in the migration population than in the total population. It seems that occupational selectivity of migration is less clear in the female town and county populations as a significant part of migrations was for marriage.

City populations have a tendency to move to cities. The town and county populations tend to move to towns at the intra-provincial level but move to cities at the inter-provincial level. The intra-provincial migration rates of the county, town and city populations were higher than the inter-provincial migration rates respectively, though the city population had a relatively high inter-provincial migration rate. Shanghai, Beijing, Tianjin, Ningxia, Hebei had high net inter-provincial in-migration rates. Most of these regions except Ningxia are in the more developed eastern economic zone. Qinghai, Heilongjiang, Gansu, Guangxi and Jilin all had high net inter-provincial out-migration rates. Most of these regions, except Guangxi, are in the less developed middle and western economic zones. All regions in the eastern economic zone except for Zhejiang, Fujian and Guangxi had net in-migrations over the period 1982-1987. All regions in the middle and western economic zones, except for Hubei and Ningxia, had net out-migrations over the same period. Development level plays a major role in attracting inter-provincial migrations. Most large inter-provincial migration flows occur between neighbouring provinces indicating the sensitivity of migration to distance. The main migration directions in China in the period 1982-1987 are revealed on the basis of large migration flows excluding those between neighbouring provinces. They are from the less developed middle and western economic zones to the more developed eastern economic zone in China. This migration pattern is completely different from the traditional migration pattern in the pre-reform period 1949-1978. This change is a result of economic reforms since 1978. More flexible measures with regard to migration have been adopted and the strategies of regional development have been shifted to coastal areas in the eastern part of the country.

For a long time since the foundation of the people's republic, the government has emphasized the economic development in the inland provincial regions in China which are less developed. However, a large amount of investment in the less developed regions did not produce substantial economic growth. The economic performance of the middle and western economic zones is poor. It is difficult, however, to be clear what the actual levels of economic development in these areas would have been in the absence of such policies. It was natural to shift the priority of economic development to the eastern economic zone when China attempted to speed up its socio-economic development in the late 1970s. It is recognized that the eastern economic zone has a well-educated and skilled labour force and has easy access to the outside world which has been a stimulating factor in the recent development in China. Economic reforms and open door policies have been implemented much earlier and faster in the eastern economic zone. Many regions in the eastern economic zone, notably Jiangsu, Zhejiang and Guangdong, have gained rapid economic growth since the late 1970s. This, of course, has stimulated migrations from the less developed zones to the more developed eastern economic zone.

The main factors affecting regional differentials of inter-provincial in-migration and out-migration rates are examined using regression analysis. It is found that the level of economic development has the most significant effect on the regional in-migration rate and that the migration index in the pre-reform period and the current in-migration level have significant effects on the regional out-migration rate. Current and previous migration flows have significant contributions to make to the explanation of the regional out-migration rate. The in-migration rate and the migration index in the pre-reform period represent two contrasting kinds of out-migrations. One kind is from those regions which received many migrants in the pre-reform period. This is explained by the migration index in the pre-reform period. Another kind of out-migration is from those regions which currently have high in-migration rates. This, of course, is explained by the in-migration rate. This is in accord with migration theories that a large migration flow from one region to another is often associated with a large flow in the opposite direction. Such a phenomenon occurs as solid information flows develop and relative networks establish which tend to facilitate migrations between two regions.

Population changes in the provincial regions in the future

A multiregional population projection model is developed to make consistent population projections of China at the provincial level in the period 1987-2087. The model is developed on the basis of a set of extended multiregional population accounts and forward demographic rates and has the advantage that population projections can be carried out straightforwardly without an iterative procedure. External migration is also taken into account in the model. Five-year age and time intervals are used in the model.

The model is calibrated using the 1982 census data, 1987 one percent population sample data and other data sources.

Constant mortality, normal fertility and migration rates are assumed for the population projections. Three sets of national total fertility rates are assumed on the basis of three sets of urban-rural total fertility rate assumptions for urban-rural population projections. In projection (A), it is assumed that the national total fertility rate of China will decline from 2.356 in the first five-year period 1987-1992 to 1.850 in the last five-year period 2082-2087. The decline of the national total fertility rate is due to the increasing proportion of urban population as constant urban and rural total fertility rates are assumed in urban-rural population projection (A). Projection (B) assumes lower national total fertility rates for the period 1987-2027 and higher rates for the period 2027-2087 than projection (A). The national total fertility rate of China in projection (B) is assumed to decline from 2.310 in the period 1987-1992 to 1.956 in the period 2012-2017, increase to about 2.2 in the period 2032-2037 and remain unchanged until 2087. The national total fertility rate of China in projection (C) is assumed to decline from 2.31 in the first period 1987-1992 to 1.58 in the last period 2082-2087. The total fertility rate of a region is calculated using its regional to national ratio of total fertility rate in 1990. These regional to national ratios are assumed to be constant. In 1990, the regional to national ratio of total fertility rate was well below 0.8 in Beijing, Tianjin, Liaoning, Heilongjiang, Shanghai, Zhejiang and Sichuan and over 1.20 in Henan, Guangxi, Guizhou, Tibet and Xinjiang.

The projections of national figures produced by the two population models one at the provincial level and one for the urban-rural level are comparable. It is found that the national population trend is a combination of various regional population trends. Some regions, such as Zhejiang, will reach their population peaks as early as the beginning of the next century, while other regions, such as Tibet, will face continuous population growth over the whole projection period.

According to projection (A), the total population of China will increase by about 50% in the period 1987-2042 and then decline slowly until 2087. By the year 2087, the total population will be about 30% more than in 1987. However, population trends vary significantly among regions. Liaoning, Heilongjiang, Shanghai and Zhejiang will have less population in 2042 than in 1987. On the other hand, Henan, Guangdong, Guangxi, Guizhou, Tibet, Ningxia, and Xinjiang will have more than an 80% population increase in the period 1987-2042. However, by the year 2087, Liaoning, Heilongjiang, and Zhejiang will have 50% less population than in 1987. Another seven regions including Beijing, Tianjin, Inner Mongolia, Jilin, Shanghai, Jiangsu and Sichuan will have less population in 2087 than in 1987. On the other hand, Hubei, Guangdong, Guangxi, Yunnan, Shaanxi will have more than 50% but less than 100% population increase in period 1987-2087. Henan, Guizhou, Tibet, Ningxia and Xinjiang will have their population more than doubled in the period 1987-2087. The trends of national and regional total population in projection (B) are close to projection (A).

According to projection (C), the total population of China will increase by 35% in the period 1987-2022, and then decline slowly until 2087. By the year 2087, the total population of China will be only 90% of that in 1987. Liaoning, Heilongjiang, Shanghai and Zhejiang will reach their population peaks by the year 2002; Beijing, Inner Mongolia, Jilin and Sichuan in 2012; Tianjin, Hebei, Shanxi, Jiangsu, Shandong, Hunan, Gansu and Qinghai in 2022; Anhui, Fujian, Jiangxi, Yunnan and Shaanxi in 2032; Guangdong, Guangxi, Ningxia in 2042; and finally Henan, Guizhou and Xinjiang in 2052. The population in Tibet will continue to grow until 2087. Its population will be more than tripled over the period 1987-2087. Sichuan, Liaoning, Jilin, Heilongjiang, Shanghai and Zhejiang will have less population in 2042 than in 1987. On the other hand, only Tibet, Ningxia and Xinjiang will have more than 80% population increase in the period 1987-2042. By the year 2087, Liaoning, Jilin, Heilongjiang, Shanghai, Zhejiang and Sichuan will have 50% less population than in 1987. Another eleven regions including Beijing, Tianjin, Hebei, Shanxi, Inner Mongolia, Jiangsu, Fujian, Shandong, Hunan, Gansu and Qinghai will also have less population in 2087 than in 1987.

The proportions of labour population will be around 50-65% in most regions in the projection period. However, different regions will face different paces of population ageing in the projection period. According to projection (A), some nine regions will have a proportion of elderly population over 20% by the year 2042. Beijing, Liaoning and Zhejiang will have a proportion of elderly population over 30% by the year 2087. On the other hand, some thirteen regions will have a proportion of elderly population under 20% in 2087. The proportion of elderly population in Tibet will be only 7.9% in 2087.

According to projection (B) which assumes a U-shaped fertility trend, all regions will have a peak in the proportion of elderly population in 2062; and their proportions of elderly population will decline over the period 2062-2087. By the year 2087, all regions will have a lower proportion of elderly population in projection (B) than in projection (A). The proportion of elderly population in Zhejiang will be 34.2% in projection (B) instead of 37.7% in projection (A). It seems that there may well be some problems of population ageing in some regions such as Zhejiang.

Projection (C) assumes lower total fertility rates than projections (A) and (B) and as a result the problems of population ageing will be much more severe. Eight regions will have a proportion of elderly population over 25% by the year 2042 and nine regions over 30% by the year 2087. Zhejiang will have a proportion of elderly population as high as 42.8% in 2087. Only five regions including Henan, Guizhou, Tibet, Shaanxi and Xinjiang will have a proportion of elderly population below 20% in 2087. It is clear that there may be more room for the decline of fertility in some regions than others while the problem of population ageing is kept not particularly severe.

In conclusion, China's population will continue to grow before 2040. Most of this growth will come from backward regions. Rapid urbanization and continuing growth of the labour force in the next three decades means China needs to be tough on population control. Fertility may continue to decline in China especially in more developed and already lower fertility regions. But there is little scope left in these developed regions and severe problems of population ageing will soon face some of these regions, particularly Zhejiang. More efforts in family planning need to be directed to the backward regions with high fertility rates. However, social, economic and educational developments need to be coordinated to reduce the fertility rate in China as these developments are the most effective ways to change people's view of childbearing and life-style. Urbanization and modernization will play active roles in this process. The current economic reform and transition toward a market economy, however, may decrease the effect of government's population control efforts. Such efforts need to be maintained, if not intensified, to slow down population growth in China quickly and feasibly as socio-economic development is a long-term process. A U-shaped fertility trend is a feasible option to slow down population growth in the early stage while population ageing is kept to reasonable levels in the later stage. For China as a whole, population ageing may not be severe compared with other developed countries at that time. Some regions with low fertility rates may face the difficult problem of population ageing in future and the problem may be solved by national co-ordination and possible migration of young population from other regions.

The populations in some more developed regions such as Zhejiang, Liaoning and Shanghai will begin to decline around the 2010s. This will radically change their position in terms of population pressure and may facilitate their economic development. However, some less developed regions, such as Tibet, will face continuous population growth in all or most of the years in the next century. The population and employment pressure will no doubt be increasing there. These regions may benefit from their economic integration with other more developed regions via cooperation, trading and migration. However, the family planning programme also needs to be actively promoted and implemented in these less developed regions.

As mentioned before, regional population projections provide useful and important information for socio-economic planning. In the case of the provision of educational and training facilities, the emphasis in some developed regions may be placed on the expansion of the middle-professional schools and higher education to meet the needs of their economic development. These regions usually have been able to deliver sufficient primary and middle school education and the number of the student population will decline. On the other hand, some less developed regions need to emphasize the improvement of the primary school education which is not sufficient and its demand is still growing.

In the case of health care and elderly support for the elderly people, it is more urgent in some developed regions to improve their health services and the elderly support system. An efficient pension system is needed to ensure proper living-standards for the elderly people. Economic development generates wealth but also brings about inflation and raises the labour cost. They have most negative effects on the elderly people who depend on their savings and pensions. It may also be important to maintain the traditional way of the elderly support by working family members.

Population dynamics represents a long-term process. It may take several generations to reach a state of stable zero-growth population. Long-term strategic planning and measures are needed to guide this process and avoid the disturbance of short-term political, social and economic events. With regard to socio-economic development in China, the continuous growth of labour force and rapid urbanization are unavoidable in the next 30-40 years. These may exacerbate problems of labour surplus and capital shortage which already face China today. However, a growing population may also mean an ever-expanding market and may help to stimulate continuous growth of China's economy. It is the duty of the Chinese people to make the most of these advantages and avoid the major disadvantages. It is certainly not beyond their ingenuity.

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Appendix A
Urban population definition in China

The urban population definition in China is based on the administrative areas of the designated cities and towns. According to the urban population definition described below, urban areas in this thesis refer to town areas and city areas excluding counties in the administrative areas of cities; rural areas refer to county areas excluding towns in the administrative areas of counties.

It should be mentioned that people's residence registration are classified as non-agricultural population and agricultural population in China which may not reflect the nature of actual employment (see chapter two).

In the period 1963-1981, the most commonly used urban population definition only includes the registered non-agricultural population in the urban areas. This old definition is called urban non-agricultural population in this thesis. Some agricultural population in the urban areas was included in the urban population statistics in 1950s. In 1982 census, urban population is defined as the urban population in the urban areas described above, thus including the non-agricultural population and agricultural population in the urban areas. This is called the 1982 definition in this thesis.

DPS (1988b) provided a series of urban population statistics for the period 1954-1987. The urban population data and the urban non-agricultural population data were separately provided for the period 1961-1987. The urban non-agricultural population data was not available for the period 1954-1960. SSB (1989) provided a series of urban population statistics for the period 1949-1988 based on the 1982 definition.

In the 1990 population census of China, the State Statistical Bureau of China adopted another middle-way urban population definition. Cities are divided into two types according to whether a city is further divided into city districts or not. All the population, including registered agricultural population and non-agricultural population in the city districts, are counted as urban population. This is in line with the 1982 definition. Only the registered non-agricultural population in the cities which do not have city districts and in towns are counted as urban population. This is in line with the urban registered non-agricultural population definition. SSB (1991) provided another series of urban population data for the period 1949-1990. The urban population in the period 1949-1981 is based on the 1982 definition while the urban population in 1990 is based on the 1990 definition. The urban population for the period after 1982 has been adjusted to match the 1990 figure.

The first standard for city and town designation was provided in a resolution of the State Council of China in 1955: *Resolution on the Standard for the Division of the*

Urban Areas and Rural Areas . A settlement is a town if its population is over 2000 and at least half are registered non-agricultural population, or its population is between 1000 and 2000 and at least 75% are non-agricultural. Any seat of a government at a county level or over is deemed a town. The minimum population for a settlement to be designated as a city in the above resolution is 20,000, though the de facto standard minimum population for a city is 100,000 and this has been used in subsequent practice (see Ma and Cui, 1987)

In 1963 before the 1964 census, a more rigid directive was announced by the State Council. A settlement may be designated as a town if its population is over 3000 and 70% are registered non-agricultural population or its population is between 2500 and 3000 and 85% are non-agricultural. A settlement may be designated as a city if its population is over 100,000 and 80% are registered non-agricultural population. Exceptions are permitted for some important places or in peripheral regions.

In 1984, the criteria for town designation was changed again and was based on the administrative areas of xiang (people's commune before 1983). A xiang may change to a town status if its population is over 20,000 and 10% are registered non-agricultural population in the seat of the xiang government, or its population is under 20,000 but there are a minimum of 2000 non-agricultural population in the seat of the xiang government. In the meantime, a county may change to a city status if the seat of the county government meets the city designation standard.

This appendix mainly draws on SSB (1989; 1991), DPS (1988b), Hu and Zhang (1984).

Appendix B
Alternative simulations of urbanization and sensitivity analysis of parameters in the demo-economic model

1 Alternative simulations of urbanization in China

Urban-rural population projections are carried out in chapter four. The urban-rural population migration and transition is driven by a demo-economic model. Four main parameters of the demo-economic model are the annual growth rates of productivity in agricultural and non-agricultural sectors and income elasticity of consumption of agricultural and non-agricultural products. The average annual growth rates of productivity and income elasticity of consumption in the period 1979-1988 have been used in chapter four for the whole projection period. This section will make alternative simulations of urbanization in China assuming different trends of the growth rates of productivity in agricultural and non-agricultural sectors. All other assumptions are the same as in projection (B) in chapter four.

As a developing country, annual growth rate of productivity is relatively high in China. It was 4.0945% in non-agricultural sector and 4.2918% in agricultural sector in the period 1979-1988. It is possible that the growth rates of productivity may decline in long-term. Simulation (S1) assumes that growth rates of productivity will gradually decline by 50% in the period 1988-2087. Simulation (S2) assumes that growth rates of productivity will gradually decline to zero by 2087. This, perhaps somewhat unrealistic, assumption may be regarded as a benchmark against which to judge the other simulations. Table B-1 shows the major results of simulations (S1), (S2) and projection (B) in selected years.

It is clear that urban population proportion will be lower if lower growth rates of productivity in agricultural and non-agricultural sectors are assumed. According to projection (B), the urban population proportion of China will be 40.5% in 2000, 71.3% in 2040 and 89.3% in 2087. If the growth rates in productivity are gradually reduced by 50% in the period 1988-2087 as in simulation (S1), the urban population proportion of China will be 40.2% in 2000, 67.2% in 2040 and only 81.6% by 2087. If the growth rates of productivity are gradually reduced to zero in 2087 as in simulation (S2), the urban population proportion of China will be 39.8% in 2000, 62.5% in 2040 and only 69.3% by 2087. It is assumed that the urban population will have lower total fertility rate than the rural population before 2030, and both the urban and rural populations will have the same total fertility rate after 2030. Hence, a lower urban population proportion means greater total population. But the differences in total population between projection (B) and simulations (S1) and (S2) are small. The total

Table B-1 Comparison of total population and urban population proportion of projection (B) and simulations (S1), (S2) and (S3)

Year	2000	2020	2040	2060	2087
Total population (millions)					
Projection (B)	1296	1466	1516	1469	1415
Simulation (S1)	1297	1467	1519	1473	1419
Simulation (S2)	1297	1469	1521	1477	1423
Simulation (S3)	1303	1497	1570	1542	1494
Urban population proportion (%)					
Projection (B)	40.5	58.1	71.3	80.9	89.3
Simulation (S1)	40.2	56.0	67.2	74.9	81.6
Simulation (S2)	39.8	53.9	62.5	67.3	69.3
Simulation (S3)	31.1	34.8	36.8	39.1	41.1

Note: Simulation (S1) assumes that growth rates of productivity in both agricultural and non-agricultural sectors will gradually decline by 50% in the period 1988-2087. Simulation (S2) assumes that growth rates of productivity in both agricultural and non-agricultural sectors will gradually decline to zero by 2087. Simulation (S3) assumes that the annual growth rate of agricultural productivity in the projection period will be 50% of that achieved in the period 1979-1988 and that of non-agricultural productivity will be same as that achieved in the same period. The growth rates of productivity in both sectors will remain unchanged in the whole projection period.

population of China in 2087 will be 1415 million, 1419 million and 1423 million according to projection (B) and simulations (S1) and (S2) respectively.

There is no doubt that urban-rural differences in the growth rate of productivity has significant effects on urbanization process. The average annual growth rate of productivity of the agricultural sector was slightly greater than that of the non-agricultural sector in China in period 1979-1988. This high growth rate of productivity in agricultural sector mainly resulted from the release of surplus agricultural work force to non-agricultural sectors and the change in the agricultural production system, namely, the introduction of the production responsibility system. Productivity increases in the agricultural sector in this period mainly resulted from organizational and managerial changes. Further increases in agricultural productivity will rely mainly on the technical progress of agricultural production which will need great capital investment. In simulation (S3), it is assumed that the annual growth rate of agricultural productivity in the projection period will be 50% of that achieved in the period 1979-1988. The growth rates of productivity in both sectors will remain unchanged in the whole projection period. The major result of simulation (S3) is also shown in table B-1. The urban population proportion in simulation (S3) will be much lower than in the other simulations. According to simulation (S3), the urban population proportion of China will increase slowly to 31.1% in 2000, 36.8% in 2040 and reaching only 41.1% by 2087. The total population in simulation (S3) will be much greater than in any of the other simulations and will be 1303 million in 2000, 1570 million in 2040 and 1494 million by 2087. It is clear that great efforts are needed to increase agricultural productivity to speed up urbanization in China.

2 Sensitivity analysis of parameters in the demo-economic model

This section will make a sensitivity analysis of four major parameters in the demo-economic model in terms of total population and urban population proportion. Projection (B) in chapter four is adopted as the base projection. Sensitivity coefficient is defined as the ratio of percentage change in total population or urban population proportion to one percent change in one parameter. There are four total population sensitivity coefficients corresponding to four parameters in demo-economic model. Similarly, there are four urban population proportion sensitivity coefficients. A series of simulations are carried out assuming 10% increase or decrease in one parameter a time using the urban-rural population model in chapter four. The simulation results and the results of projection (B) are used to calculate sensitivity coefficients in selected years in projection period 1988-2087 as shown in table B-2. There are two sets of sensitivity coefficients. Set one is obtained on the basis of simulation results assuming 10% decrease in a parameter. Set two is obtained on the basis of simulation results assuming 10% increase in a parameter.

Total population sensitivity coefficient is positive to the growth rate of non-agricultural productivity and the income elasticity of consumption of agricultural products, but is negative to the growth rate of agricultural productivity and the income elasticity of consumption of non-agricultural products.

The absolute total population sensitivity coefficient to the growth rate of non-agricultural productivity is about half of the sensitivity coefficients to other parameters. According to set (1), the total population sensitivity coefficient is 0.00386 to the growth rate of non-agricultural productivity, -0.00848 to the growth rate of agricultural productivity, -0.00740 to the income elasticity of consumption of non-agricultural products, and 0.00733 to the income elasticity of consumption of agricultural products in 2000. The absolute total population sensitivity coefficient will increase with time due to the accumulative nature of population systems. For example, according to set (1), the total population sensitivity coefficient to the growth rate of non-agricultural productivity will increase from 0.00386 in 2000 to 0.0282 in 2040 and 0.0464 in 2087.

Table B-2 Sensitivity coefficients in selected years

	Set	Year 2000	2040	2087
Total population sensitivity coefficient				
Growth rate of non-agricultural productivity	(1)	0.00386	0.0282	0.0464
	(2)	0.00386	0.0283	0.0467
Growth rate of agricultural productivity	(1)	-0.00848	-0.0632	-0.1040
	(2)	-0.00848	-0.0615	-0.1010
Income elasticity of non-agricultural products	(1)	-0.00740	-0.0507	-0.0834
	(2)	-0.00663	-0.0439	-0.0721
Income elasticity of agricultural products	(1)	0.00733	0.0484	0.0795
	(2)	0.00663	0.0458	0.0754
Urban population proportion sensitivity coefficient				
Growth rate of non-agricultural productivity	(1)	-0.217	-0.323	-0.195
	(2)	-0.215	-0.344	-0.230
Growth rate of agricultural productivity	(1)	0.479	0.794	0.570
	(2)	0.474	0.686	0.393
Income elasticity of non-agricultural products	(1)	0.387	0.524	0.329
	(2)	0.343	0.405	0.222
Income elasticity of agricultural products	(1)	-0.378	-0.445	-0.241
	(2)	-0.350	-0.471	-0.294

Note: Set (1) is based on simulation results assuming 10% decrease in a parameter.
Set (2) is based on simulation results assuming 10% increase in a parameter.

Urban population proportion sensitivity coefficient is negative to the growth rate of non-agricultural productivity and the income elasticity of consumption of agricultural products, but is positive to the growth rate of agricultural productivity and the income elasticity of consumption of non-agricultural products.

The absolute urban population proportion sensitivity coefficient to the growth rate of non-agricultural productivity is smaller than to other parameters. According to set (1), the urban population proportion sensitivity coefficient is -0.217 to the growth rate of non-agricultural productivity, 0.479 to the growth rate of agricultural productivity, 0.387 to the income elasticity of consumption of non-agricultural products, and -0.378

to the income elasticity of consumption of agricultural products in 2000.

The absolute urban population proportion sensitivity coefficient will increase with time first but will decline later. The sensitivity coefficients in 2087 are very close to those in 2000. For example, according to set (1), urban population proportion sensitivity coefficient to the growth rate of non-agricultural productivity will be -0.217 in 2000, -0.323 in 2040 and -0.195 in 2087.

Appendix C
Inter-provincial migration directions

Migration directions and flows are different in various regions and can only be analyzed via origin and destination specific migration flows. Here an inter-provincial migration matrix is used as a basis for an analysis of inter-provincial migration directions and flows in the period 1982-1987 in China. The main destination provinces of out-migrations and origin provinces of in-migrations are identified for each province. These main destination or origin provinces are defined as the four major destination or origin provinces and the additional provinces which have more than 200 in-migrations (1% sample figures) from or out-migrations to the province concerned. It is found that most of the main destination or origin provinces are neighbouring provinces of the province concerned indicating the sensitivity of migration to distance.

Beijing has a high net in-migration rate 2.34%. The main out-migration destination regions are Jiangsu (87---number of migrations), Hunan (73), Shandong (70) and its neighbour Hebei (206). The main in-migration origin regions are Shanxi (204), Shandong (184), Sichuan (178) and its neighbour Hebei (904).

Tianjin has a high net in-migration rate 1.05%. The main out-migration destination regions are its neighbours Hebei (138), Beijing (101), Liaoning (29), Shandong (26). The main in-migration origin regions are Gansu (124), Ningxia (103) and its neighbours Hebei (467), Shandong (70).

Hebei has a high net in-migration rate 0.39%. The main out-migration destination regions are its neighbours Beijing (942), Tianjin (467), Shanxi (339), Inner Mongolia (330), Shandong (227), Henan (215). The main in-migration origin regions are Hunan (1863), Sichuan (335), Heilongjiang (278) Shaanxi (201) and its neighbours Shanxi (595), Inner Mongolia (386), Shandong (230), Beijing (206).

Shanxi has a net out-migration rate 0.06%. The main out-migration destination regions are Beijing (204), Shandong (138) and its neighbours Hebei (595), Henan (197). The main in-migration origin regions are Qinghai (177) and its neighbours Hebei (339), Henan (255), Inner Mongolia (175).

Inner Mongolia has a net out-migration rate 0.18%. The main out-migration destination regions are its neighbours Liaoning (391), Hebei (386), Heilongjiang (187), Shanxi (175). The main in-migration origin regions are its neighbours Hebei (330), Heilongjiang (253), Liaoning (155) and Jilin (145).

Liaoning has a net in-migration rate 0.22%. The main out-migration destination regions are Heilongjiang (342) and its neighbours Jilin (335), Shandong (249), Hebei (198). The main in-migration origin regions are Heilongjiang (1044) and its neighbours

Jilin (593), Inner Mongolia (391), Shandong (296).

Jilin has a net out-migration rate 0.30%. The main out-migration destination regions are Shandong (581), Hebei (148) and its neighbours Liaoning (593), Heilongjiang (405). The main in-migration origin regions are Shandong (329) and its neighbours Heilongjiang (610), Liaoning (335), Inner Mongolia (159).

Heilongjiang has a high net out-migration rate 0.77%. The main out-migration destination regions are Shandong (1380), Liaoning (1044), Hebei (278) and its neighbours Jilin (610), Inner Mongolia (253). The main in-migration origin regions are Shandong (604), Liaoning (342) and its neighbours Jilin (405), Inner Mongolia (187).

Shanghai has a high net in-migration rate 2.38%. The main out-migration destination regions are Beijing (49), Henan (27) and its neighbours Jiangsu (347), Zhejiang (101). The main in-migration origin regions are Jiangxi (190), Anhui (72) and its neighbours Jiangsu (1024), Zhejiang (533).

Jiangsu has a net in-migration rate 0.24%. The main out-migration destination regions are Xinjiang (173) and its neighbours Shanghai (1024), Anhui (276), Shandong (271). The main in-migration origin regions are Xinjiang (450), Sichuan (364), Yunnan (248), Shaanxi (230) and its neighbours Anhui (516), Shandong (358), Shanghai (347), Zhejiang (224).

Zhejiang has a net out-migration rate 0.28%. The main out-migration destination regions are its neighbours Shanghai (533), Jiangsu (224), Fujian (148), Jiangxi (144). The main in-migration origin regions are its neighbours Jiangxi (158), Anhui (147), Jiangsu (146), Shanghai (101).

Anhui has a net out-migration rate 0.17%. The main out-migration destination regions are Shanghai (721) and its neighbours Jiangsu (516), Henan (244), Jiangxi (182). The main in-migration origin regions are Sichuan (189) and its neighbours Jiangsu (276), Henan (162), Zhejiang (129).

Fujian has a net out-migration rate 0.07%. The main out-migration destination regions are Shanghai (129), Jiangsu (122) and its neighbours Jiangxi (180), Guangdong (118). The main in-migration origin regions are Sichuan (125) and its neighbours Jiangxi (157), Zhejiang (148), Guangdong (83).

Jiangxi has a net out-migration rate 0.13%. The main out-migration destination regions are Shanghai (190) and its neighbours Guangdong (199), Hunan (162), Zhejiang (158). The main in-migration origin regions are its neighbours Anhui (182), Fujian (180), Zhejiang (144), Hubei (124).

Shandong has a net in-migration rate 0.26%. The main out-migration destination regions are Jilin (329) and its neighbours Jiangsu (358), Liaoning (296), Hebei (230). The main in-migration origin regions are Heilongjiang (1380), Jilin (581), Sichuan

(286), Gansu (206) and its neighbours Jiangsu (271), Liaoning (249).

Henan has a net out-migration rate 0.07%. The main out-migration destination regions are Xinjiang (363) and its neighbours Hubei (599), Shaanxi (299), Shanxi (255). The main in-migration origin regions are Xinjiang (225), Sichuan (211) and its neighbours Anhui (244), Hebei (215), Shaanxi (209).

Hubei has a net in-migration rate 0.10%. The main out-migration destination regions are Shandong (671), Jiangsu (182) and its neighbours Sichuan (221), Hunan (218). The main in-migration origin regions are its neighbours Guangdong (485), Hubei (218), Guangxi (205), Jiangxi (162).

Hunan has a net out-migration rate 0.27%. The main out-migration destination regions are Hebei (1863) and its neighbours Guangdong (479), Hubei (296), Guizhou (147). The main in-migration origin regions are its neighbours Guangdong (485), Hubei (218), Guangxi (205), Jiangxi (162).

Guangdong has a net in-migration rate 0.23%. The main out-migration destination regions are Sichuan (119) and its neighbours Hunan (485), Guangxi (203), Fujian (83). The main in-migration origin regions are Sichuan (249) and its neighbours Guangxi (1139), Hunan (479), Jiangxi (199).

Guangxi has a high net out-migration rate 0.38%. The main out-migration destination regions are Hebei (188), Sichuan (87) and its neighbours Guangdong (1139), Hunan (205). The main in-migration origin regions are its neighbours Guangdong (203), Yunnan (78), Hunan (76), and Guizhou (51).

Sichuan has a net out-migration rate 0.08%. The main out-migration destination regions are Xinjiang (609), Jiangsu (364), Hebei (335), Guangdong (249), Henan (211) and its neighbours Hubei (444), Yunnan (404), Guizhou (395). The main in-migration origin regions are Xinjiang (432) and its neighbours Yunnan (537), Guizhou (294), Hubei (221), Tibet (202). Tibet is included as a major origin region of the in-migrations of Sichuan province in this case.

Guizhou has a net out-migration rate 0.03%. The main out-migration destination regions are Jiangsu (136) and its neighbours Sichuan (294), Yunnan (141), Hunan (110). The main in-migration origin regions are Shandong (120) and its neighbours Sichuan (395), Yunnan (166), Hunan (147).

Yunnan has a net out-migration rate 0.22%. The main out-migration destination regions are Jiangsu (248), Hebei (162) and its neighbours Sichuan (537), Guizhou (166). The main in-migration origin regions are Zhejiang (109), Hunan (75) and its neighbours Sichuan (404) and Guizhou (141).

Tibet has a out-migration rate 1.67% and no in-migration is observed in this 1% sampling survey. The data about Tibet are not very reliable as only its county population is covered in the sampling data. The main out-migration destination regions are Henan (33), Shaanxi (26), Jiangsu (18) and its neighbour Sichuan (202).

Shaanxi has a net out-migration rate 0.19%. The main out-migration destination regions are Jiangsu (230), Hebei (201) and its neighbours Ningxia (538), Hubei (299), Henan (209), Gansu (202). The main in-migration origin regions are Xinjiang (242), Hebei (166) and its neighbours Gansu (344), Henan (299).

Gansu has a high net out-migration rate 0.45%. The main out-migration destination regions are Shandong (206), Jiangsu (157) and its neighbours Shaanxi (344) and Sichuan (164). The main in-migration origin regions are Henan (110) and its neighbours Shaanxi (202), Xinjiang (140), Qinghai (111).

Qinghai has a high net out-migration rate 1.72%. The main out-migration destination regions are Shanxi (177), Jiangsu (113), Shaanxi (110) and its neighbour Gansu (111). The main in-migration origin regions are Shanxi (70), Shandong (46) and its neighbours Shaanxi (538), Gansu (83).

Ningxia has a high net in-migration rate 0.96%. The main out-migration destination regions are Tianjin (103), Zhejiang (32) and its neighbours Shaanxi (99), Gansu (49). The main in-migration origin regions are Shanxi (70), Shandong (46) and its neighbours Shaanxi (538), Gansu (83).

Xinjiang has a net out-migration rate 0.27%. The main out-migration destination regions are Jiangsu (450), Sichuan (432), Shaanxi (242), Henan (225). The main in-migration origin regions are Sichuan (609), Shandong (363), Jiangsu (173) and its neighbour Gansu (150).

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