FACTOR MOBILITY:

MIGRATION WITH BRAIN DRAIN AND TECHNOLOGY GAIN, TARIFF INDUCED TECHNOLOGY TRANSFER AND FOREIGN DIRECT INVESTMENT BY SMALL FIRMS

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Abstract

This thesis concerns itself with the effects of factor mobility on the economic development of geographically distinct regions.

In Chapter 1, it is shown with a simple model of endogenous growth that brain drain leads to divergence of growth rates. But if return migration is introduced as a source of technology diffusion, a trade-off between brain drain and technology gain arises. Return migration leads to convergence of economic development, if the cost of remaining in the foreign country are relatively high and the transferability of technology is good. This is, because then returnees bring not only along the new technology but also high talent.

In a model, where a less developed country imports high quality products and produces low quality products, there might be a trade off between imports and foreign engagement in technology transfer to the local industry. Chapter 2 shows under which conditions a tariff induces technology transfer. Two cases are considered: market integration and market segmentation in prices. In both cases there exists a tariff that induces technology transfer to the low-quality firm. The positive welfare effect of the quality upgrade is more pronounced in the second case, however, because the tariff induces a reduction in the high-quality firm's price in addition to the improvement of the local quality.

A spatial model of foreign direct investment (FDI) is analysed in Chapter 3. In that framework the distance between production locations increases with the size of the market covered and therefore with firm size. If a surprise-investment-location arises close by, it attracts less investment than if it had been anticipated and mainly from firms in the vicinity. We find empirical support for our model with German industry survey data. Small investing firms go mainly to Central and Eastern Europe (CEE). Medium sized firms are dissuaded from investing in CEE, if they have already invested elsewhere. Big investing firms typically go to CEE and to the rest of the world.

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Introduction

In recent developments of economic theory, the effect of factor mobility on economic development depends critically on the precise assumptions. For both converging and diverging effects theoretical support has been found.

A benchmark for the converging effect has been the competitive model of two countries of equal level of technological development with the only two factors of production, capital and labor (either Heckscher-Ohlin as in Venables, 1997, or Solow as in Barro and Sala-i-Martin, 1995b, Chapter 3). Factors flow between the countries until factor prices and relative factor endowments have equalized. This takes place either through trade in goods only, imbedding the factors of production, and/or through direct flow of at least one of the two factors.[1] In this case, factor mobility and trade lead to a symmetric equilibrium. Income levels and factor prices converge and economic activity is smoothed spatially across the two countries.

However, factor mobility leads to diverging effects in the two other most widely used models of international trade, the specific-factors model (for instance in Neary, 1995) and the Helpman-Krugman model (1985) of international monopolistic competition[2]. Capital and labor can both flow to wealthier regions destabilizing the symmetric equilibrium. The accumulation and mobility of human capital and technology studied in models of endogenous growth, can reinforce these effects (Aghion and Howitt, 1998, Chapter 11 and Lucas, 1988).[3] As a result, we observe diverging patterns of economic development in some regions of the world (Grossman and Helpman, 1991, Chapter 1).

Many aspects of factor mobility are yet unresolved, although the design of policies for trade and integration between regions depends crucially on them. This thesis analyses

[1] In these models a country that is endowed relatively poorly with capital, has a higher marginal productivity of capital. This leads to import of capital intensive goods or of the factor capital until the marginal product has fallen to the level of the other country. At the same time the marginal product of labor rises to the level of the other country, as labor intensive goods and labor are exported.
[2] See Venables (1997) for a detailed description of factor mobility in these models.
[3] Trade theory conventionally takes technology as given, whereas growth theory investigates the interaction of technological progress and factor mobility.

some aspects of factor mobility, both in terms of structure as well as consequences. Each chapter contains a theoretical formalization of a different issue of factor mobility that is discussed informally in the context the economic transition and integration of Central and Eastern Europe (CEE) to the Western economies. Although the models presented here were motivated by the situation in CEE, they do not apply to CEE only. Chapters 1 and 2 deal with technology transfer or the 'trade in ideas'. In Chapter 1, migration and return migration function as vehicles for technology transfer, in Chapter 2, a tariff policy is discussed that may induce technology transfer on firm level. Chapter 3 investigates theoretically as well as empirically, which firms are most likely to undertake foreign direct investment (FDI) in CEE.

Within an exogenous growth model, the loss of human capital due to migration can be offset by the migrants' failure to carry physical capital. But if the loss of human capital influences the accumulation of technological progress endogenously, brain drain might deteriorate the long run growth prospects for people staying behind in the country of emigration. This is especially relevant for CEE. On the one hand, migratory pressure - especially from the well educated - is high (Layard et al., 1992, and Strepetova, 1995). On the other hand, CEE is characterized by an almost obsolete stock of capital and technology, but simultaneously a very high level of education (Gros and Steinherr, 1995, Chapter 6). Even if the labor-capital ratio falls as a result of migration, the capital stock alone is totally inadequate for a substantial improvement of living conditions as well as for an enhancement of technological progress.

The deteriorating effect of brain drain has been recognized in the migration literature. Many causes for the negative effects of human capital loss have been identified. One of the earliest and most obvious being that public expenditure on education is lost as a result of brain drain (Bhagwati and Hamada, 1974).[4] Nevertheless, there are also sources of 'brain gain' resulting from brain drain. Human capital accumulation might be enhanced by the prospect of emigration (Mountford, 1997, and Stark et al., 1997). Alternatively, return migration may be one of the sources of technology transfer

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[4] See also Baldwin and Venables (1994), Haque and Kim (1994), Kwok and Leland (1982), Markusen (1988) and Miyagiwa (1991) for other examples of this mechanism in dynamic as well as in static frameworks.

(Barro and Sala-i-Martin, 1995b, Chapter 8). The size and persistence of return migration flows has always been substantial, which underlines the relevance of the investigation of the effects of return migration on development and growth (Dustmann, 1996).

In Chapter 1, a reduced-form endogenous growth model is used to illustrate the long run effects of a loss of human capital on technological progress. But migration can also be growth enhancing for a lagging economy. Due to return migration new, more advanced knowledge, acquired abroad, is transferred back to the country. High cost of staying abroad combined with high benefits of returning may lead to convergence in growth rates, because the share of talented persons in the group of returnees increases and moreover technology is transferred.

Chapter 2 turns to technology transfer on firm level. To date, the literature on technology transfer on firm level only considers transfers that improve the competitiveness of the local firm (Kabiraj and Marjit, 1998, and Blomström and Wang, 1992).[5] Thus a technology improvement is unambiguously desirable for the local firm.

The model of vertical product differentiation in Chapter 2 challenges this conclusion. Technology transfers occur in the model, if the quality of the locally produced good is improved by know-how that only a foreign firm can supply. [6] A firm may want to produce low quality goods in order to maintain a maximum monopoly power (Shaked and Sutton, 1983). Technology transfers that improve the local quality may therefore not be attractive to that firm, even though their long-run effects are beneficial for the economy as a whole due to the spillovers created by the technology transfers. Government intervention in the form of a protective tariff can be welfare enhancing by

[5] Kabiraj and Marjit (1998) come to the conclusion that a protective tariff induces technology transfer to a less developed economy. In their model a local producer competes in quantities (Nash-Cournot) with an importer that has a production cost advantage. Only the importing competitor can sell the cost-reducing technology to the local producer. There exists a tariff for which the importer's profits are squeezed sufficiently much that the gain of selling the superior technology is larger than the loss due to tougher competition. Blomström and Wang (1992) focus on the effect of local competition on the incentives of a multinational firm to realize a costly technology transfer. They conclude that the local industry should be made more competitive in order to make technology transfer a necessity for the multinational firm.

inducing quality improvement of local production, because of the cost advantage of the local firm caused by the tariff.[7] The model defines the conditions under which a protective tariff leads to a quality improvement of locally produced goods.

In Chapter 3, we show that there might be reasons to believe that German FDI in CEE is particularly conducted by small firms. In order to promote the catch-up of the economies of CEE capital and technology need to be attracted (EBRD, 1998). FDI is a source of both of these factors, but it has remained behind expectations in CEE (EBRD, 1998). So far, Germany has taken the role of the most important single investor and trade partner of CEE, being an economically large country in its direct vicinity. About 30% of all FDI in CEE are by German firms (Hunya and Starkovski, 1998). However, German investments in CEE seem to follow a pattern where big multinational firms invest relatively little in CEE whereas small and medium sized firms are very active in that region (Härtel et al., 1995).

The model in Chapter 3 explains this investment pattern. Firms choose their investment location along a line, supposedly before the iron curtain fell. With a distant dependant fix cost of investment, small firms might not invest at all or invest in locations close to the headquarters, whereas large firms optimally invest in far-off locations, optimizing their global production structure. If an unexpected new investment location appears on the line after firms have taken their initial investment decisions – for example the opening of CEE - investments in that location may be primarily by small firms. This is due to the fact that the conditions in the direct vicinity of small firms have changed dramatically, whereas the change is relatively modest in global terms, hence not affecting the globally optimized production structure of large firms. The model is tested with German industry survey data of the year 1995. Investment patterns do follow the model's prediction in a robust way, even if we control for sectoral effects in a binomial or a multinomial regressions.

This lends itself to the conclusion that CEE is an attractive investment location mainly for small German firms that have not yet invested elsewhere. On the one hand, they

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[6] Technology stands for production technologies as well as modern management skills.
[7] This *business stealing effect* is described in (Jeanneret and Verdier 1996).

face lower cost of investment due to actual and cultural closeness of CEE. On the other hand, larger German firms, that have more experience in investing abroad, prefer other locations, because CEE is relatively expensive compared to far-off developing countries and can easily be served from other locations.[8] If income in CEE rises steadily over time, this situation might persist, even if the investment environment improves.

[8] CEE is considered a relatively expensive investment location because infrastructure and the political situation present high risks, even though actual cost of production are still rather low (Janssens and Konings, 1996)

1. Brain Drain and Technology Gain: The Effect of Human Capital Mobility on Growth

1.1. Introduction

With large migratory pressure from the former communist countries, the issue of brain drain and its effects on the development of the source countries has arisen again. If individuals differ in their level of human capital and the incentives to migrate are more pronounced for the more educated, the ensuing brain drain might hamper economic development and cause a poverty trap. On the contrary, migration and even brain drain may, also foster development by technological catch-up via return migration. The present chapter formalizes these two effects in a simple growth model, and presents the trade-offs. In doing so it combines - and at the same time challenges - findings from three different strands of the literature: brain drain, return migration and endogenous economic growth.

Brain drain refers to the emigration of the relatively productive people from less developed to more advanced economies. Productivity can differ by inherent skills, by acquired education or simply by age. The appearance of brain drain is explained through a combination of higher returns relative to skills abroad and migration cost that may decrease relative to the skill level of an individual. In Russia, for instance, in 1993 out of 114,133 permanent emigrants 67,775 had a high level education, that is almost 60% (Strepetova, 1995).

In the earlier economic literature the consensus was that brain drain, even if small, is detrimental to the source economy, if some externality is connected to human capital (e.g., Bhagwati and Hamada, 1974). The externality can be generated by tax/subsidy distortions. But the education sector can also exhibit economies of scale in skills in form of spillovers (Miyagiwa, 1991) or the economic activity of the highly skilled can generate positive spillovers to the rest of the economy (Markusen, 1988). In both of these cases a "smaller" countries offer less return to skill and hence risk to lose part of the skilled workforce. This leads to output losses for all agents in the source country even in the absence of dynamic effects.

The more recent literature focuses on the potential of a "home-made" brain gain as a result of migration. The prospect of emigration increases incentives to accumulate human capital. This leads to brain gain instead of drain, if the actual loss of human capital due to migration is smaller than the skill formation gain caused by potential outflow. Either emigration restrictions (Mountford, 1997) or return migration (Stark et al., 1997) of emigrants (educated in the source country) may reduce the actual outflow of skilled labor. It remains an empirically question, whether potential emigration can increase incentives for skill formation in the source country sufficiently to initiate positive development effects.

Another source of a gain from migration is return migration of foreign-trained individuals. It is one of three sources of technology diffusion and economic catch-up, the two others being trade and FDI (Barro and Sala-I-Martin, 1995b, Chapter 8). Migration waves are always followed by return migration, of varying size. This is either because the host country imposes this on the immigrants or because they return deliberately. Between 30-50% of European immigrants to the US returned in the early twentieth century and Western Europe has shown substantial return flows in the seventies and eighties (Dustman, 1996). Not surprisingly, return migration seems to rise with falling transport cost and rising job uncertainty in the host country (Baines, 1991, in Dustmann, 1994).

The existing theoretical literature explains deliberate return migration by asymmetric information or risk diversification under uncertainty.[9] Adverse selection of return

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[9] Either the host country employer is not informed about the immigrants' skills, when education is acquired in the source country (Stark, 1995) or the source country employer knows too little about the return migrants' skills, when education is acquired abroad (Kwok and Leland, 1982). In the first case employers learn about the real skills of the immigrants only some time after employment. Initially all immigrants are paid according to the average productivity of the cohort. But once learning has taken place and wages have adjusted to individual productivity, it is not profitable for the less skilled workers to stay abroad. In the second case source country employers cannot judge skill through the veil of foreign education and thus cause an adverse selection of return migrants. Thirdly, Return migration can be a way of hedging against the volatility of the labor markets in

migrants is the result. In the present model return migration also self-selects the less skilled migrants, but it results from an investment in human capital accumulation abroad that increases productivity in the home country.

Given the emphasis placed on human capital accumulation and technological progress for the growth prospects of an economy, it seems logical to look at the roles of migration, brain drain and return migration in a dynamic model of endogenous growth. There are two generations of endogenous growth models.

The first generation, started among others with Lucas (1988), stated that there is real endogenous growth, if the factor of production, that can be accumulated, exhibit at least constant returns. Human capital is one of them. Labor mobility without disproportional loss of human capital (brain drain) from a less developed to a more developed country increases the general capital stock of the remaining workers. As a result conditional convergence of income in the two economies speeds up (Barro and Sala-I-Martin, 1995b, Chapter 9). Baldwin and Venables (1994) show in a model with an externality associated with human capital that disproportional loss of human capital gives rise to a slow inflow of physical capital as well as to a slow transition and catch-up.

The second generation endogenous growth theory engendered by Aghion and Howitt (1992) offered some microeconomic foundations. Here the human capital intensive R&D sector generates technological progress, which drives growth. Returns to R&D are not diminishing in the long run due to spillovers. In this context, economies with a lower level of technological progress tend to stay behind even if they accumulate factor of production, unless technology diffuses. In other words, less developed countries can catch up, if some imitation of new technologies takes place there. This is possible, because imitation is less costly than invention (Barro and Sala-i-Martin, 1995a).

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source and host country (Dustmann, 1997). The third approach does not offer any rationale for the adverse selection of returnees.

The model presented here is a reduced form of a growth model with endogenous technological progress, where agent heterogeneity in skills leads to brain drain. Brain drain is a source of income divergence. But if technology transfer via return migration is introduced, a trade-off between brain drain and technology gain appears. Even though the presented growth model is kept extremely simple, the outcome has multiple equilibria with some interesting traps.

The remainder of the chapter is organized as follows. In section 1.2 the growth mechanism is presented for the closed economies. In sections 1.3 and 1.4 migration is introduced and its detrimental effects on growth are demonstrated. Sections 1.5 and 1.6 show under which conditions return migration can produce a catch-up, and section 1.7 concludes.

1.2. The Model

The model presented here uses technological progress as long run growth machine. There are no explicit skill formation or R&D sectors and no capital accumulation or transfer payments of any sort (taxes, remittances or international borrowing). We allow for these simplifying assumptions, because the focus of this chapter is on the effects of migration on technological progress.[10] The growth mechanism is a reduced form of Aghion and Howitt's (1992) quality ladders with constant return to R&D, where the increments of technological progress depend on the exogenously given

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[10] As long as capital and labor are homogenous and do not influence technological progress, migration has no effect on long run growth (Barro and Sala-I-Martin, 1995b, Chapters 1 and 9). Because the present model ignores physical and human capital accumulation (and thus savings), alike Aghion Howitt (1992) it shows no convergence behavior or ß-convergence in the sense of Barro and Sala-I-Martin (1995b, Chapter 1). The economies are always at steady state, which is determined by technological progress.
Apart from the neoclassical interaction of capital and labor of the Solow-Swan model (Barro and Sala-I-Martin, 1995b, Chapter 1) there are other mechanisms that link migration and capital markets. It is a well-known fact that return migrants' savings as well as remittances from migrants in general play a substantial role in capital formation of less developed countries (Dustmann, 1997). The implications of the Solow-Swan model as well as the effects of remittances and savings of return migrants would strengthen the effect of technology diffusion. The new locational theory predicts the contrary of the neoclassical growth theory: certain core areas that attract labor might as a result also

talent of the inventors The mechanism was taken from a growth model by Murphy, Schleifer and Vishny (1991). When introducing migration and return migration, even this reduced form will generate considerable dynamic effects.

We consider an economy endowed with n agents who are heterogeneous in productive talent and live for one period. Each agent has access to the best available technology in her country. Talent is denoted A and is distributed continuously on the interval $[1,a]$ with a time invariant, finite and strictly positive density function *f(a)* ($\int_1^a f(A) = 1 \quad \forall t;$ and $f(A) > 0$). Time is indexed by the letter t.

The available production technology in period t is denoted by s_t. The individual production function is continuos and monotone with talent and technology as factors of production. It is denoted by *h(.,.)*, where marginal productivities and cross derivatives of talent and technology are positive. Personal marginal output is perfectly appropriable. Each person has an income y_t^A

$$y_t^A = h(s_t, A) \qquad h_s' > 0,\ h_A' > 0 \quad \text{and} \quad h_{sA}'' > 0 \ \forall t \tag{1.1}$$

One simple functional form for *h(s, A)*, that satisfies these conditions is

$$y_t^A = As_t \tag{1.2}$$

Technological progress and growth are generated by knowledge spillovers from the high talented of the previous generation to the entire population of the next generation. The most talented person in the economy puts the prevailing technology to best use and gets remunerated for that fully in her active life. Her application of technology becomes public knowledge for the next generation of users in form of a more advanced technology. The new generation can then put the advanced

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attract capital and vice versa (circular causation, Krugman, 1991, Chapter 1). This would enhance the effect of brain drain.

technology to work according to their talent. The dynamic path of the production technology is therefore

$$s_{t+1} = as_t = a^{t+1}s_0 \tag{1.3}$$

It may seem more plausible to assume that the new technology is a function of some average of human capital available in the economy rather than only the very top level of talent, but for expositional simplicity the simplest technology transfer is assumed here.

Using equation (1.2 and 1.3), per capita income grows at the constant rate γ_{t+1}

$$\gamma_{t+1} = \frac{As_{t+1} - As_t}{As_t} = a - 1 \tag{1.4}$$

Technological progress obviously grows at the same rate.

1.3. Migration

We now suppose that the worlds consists of two countries, Home (source) and Foreign (host), where Foreign is denoted by upper *f*. Foreign has for some exogenously given reasons reached a more advanced level of development than Home. This is represented by s_0 inferior to s_0^f by an exogenously given factor σ_0 ($\sigma_0 < 1$). In the absence of factor mobility equation (1.3) implies that the ratio of technology of the two counties does not change over time (even though the absolute income difference increases).

$$\sigma_0 s_t^f = s_t \qquad \forall t \tag{1.5}$$

As a result in Foreign production technologies are better, people are wealthier and labor income relative to talent is higher. The potential for migration in this model arises solely due to the higher level of technology in Foreign, as capital accumulation is ignored. Each person in Home can apply her talent more productively in Foreign and increase her income.

It is unlikely, however, that a migrant can move to another country without any cost to migration. Migration cost arise for several reasons:[11]

- When moving to another country a person loses time as well as productivity. She has to integrate in a new environment and learn about country specificities (language, culture, administration, etc.) Her own country specific knowledge becomes obsolete. Thus the fact that countries differ makes migration costly in terms of productivity.

- The capacity to integrate in a new environment may well be correlated to the level of productive talent in general. Higher productive talent may stand for a better level of general education including foreign languages and experience. It may also involve a better capacity to learn and to adapt to new situations. In addition higher talent may stand for knowledge that is less country specific, so that it can be applied readily in other countries.[12]

- Leaving the home country may generate disutility due to separation from home, friends and family. In addition, increased uncertainty about future income may reduce the expected value of income earned abroad. Thus, income earned abroad may be valued less than the same income at home.

- Migration naturally creates real search and travelling cost.

These cost also seem to depend negatively on cultural, geographical and technological distance of the two economies. Cultural closeness simplifies integration. Geographical

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[11] See Bhagwati and Hamada (1974), where the cost of migration are fixed. In (Galor and Stark, 1990, 1991) returnees work harder and save more, because utility drawn from consumption in the host country is lower and the return in the host country is higher. In Haque and Kim (1994) migration cost rise with the average level of human capital as a proxy for forgone wages in the time lost due to migration.

[12] Academics, for instance, are usually very mobile internationally. Manual workers on the other hand also seem rather mobile. The same argument might thus also apply the other way around: the lower the level of education the less depreciation of talent takes place due to a move to another country. Possibly the net gain of migration are such that migrants typically select themselves from both end of the talent distribution (Haque and Kim, 1994).

closeness reduces search and separation cost. And technological closeness reduces the loss of productivity.

Let us define for the present model the cost of migration as a continuous function of the variables of the model[13]

$$C_t^M = c(A, s_t, s_t^f) \tag{1.6}$$

If a person migrates from Home to Foreign, she receives a higher return to her talent and pays C_t^M. The net gain from migration is denoted by $G_t^M = g(A, s_t, s_t^f)$. She migrates if the net return from migration exceeds the return from staying home

$$G_t^M = h(s_t^f, A) - h(s_t, A) - C_t^M > 0 \tag{1.7}$$

We speak of brain drain, if migration is less than total (not everybody leaves) and the average level of productive human capital of the group of migrants is higher than that of the non-migrants.

Proposition 1.1: A necessary condition for brain drain is that

(i) Agents are heterogeneous and

(ii) the net gain from migration is positive only for some agents.

Proof:

(i) Suppose the distribution of A is degenerate at $\hat{A}$ such that $f(\hat{A}) = 1$. The net gain from migration is then the same for all agents and either all agents or nobody leaves. Hence there is no brain drain.

(ii) Suppose now that agents are heterogeneous, but the net gain from migration has the same sign for all agents. There is total migration if the net gain is positive and no migration if the net gain is negative, but there is no brain drain.

QED.

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[13] Geographical and cultural distance as well as uncertainty and education are not made explicit in this model.

There is no brain drain in the following example, although the agents are heterogeneous in talent. Assume that the cost of migration consist of the product of A and a function ϕ and the production function is also proportional in A as in equation (1.2).

$$C_t^M = A\phi(s_t^f, s_t) \tag{1.8}$$

Then everybody independently of her talent level A has incentives to migrate as long as

$$\phi(s_t^f, s_t) < s_t^f - s_t \tag{1.9}$$

In this case certain unknown selection criteria will lead to migration, but the more talented do not flow more easily than the others. The sufficient condition for brain drain obviously involves that heterogeneity is in productive human capital and that the net gain from migration rises with productive human capital.

Other models of endogenous growth and brain drain include an educational sector (Haque and Kim, 1994, and Mountford, 1997). This sector serves as a growth machine as in Lucas (1988). In order to generate brain drain, heterogeneity of agents is also required. It explains why certain agents accumulate more human capital than others do.[14] Furthermore, the existence of the educational sector gives rise to the argument that higher return abroad increases incentives for human capital accumulation of agents of the source country (Miyagiwa, 1991). An educational sector would not change the results of our model, however.

[14] As the present model, these models assume differing latent ability. With an explicit educational sector imperfect credit markets and other market imperfections affecting the choice of education could also lead to heterogeneous levels of human capital accumulation, even if agents are initially the same. In this sense explicit human capital accumulation gives room to other arguments. It does, however, not change the basic result that brain drain requires agent heterogeneity.

As the purpose of this chapter is to show the effects of brain drain on long run growth, that is generated by technological progress, for the remainder of the chapter we will concentrate on net gain functions that monotonously rise in talent.

1.4. Migration and Growth

For the simple model developed and the net gain function assumed migration can only lead to loss of human capital. This in turn influences technological progress and growth.

Proposition 1.2: If the net gain from migration is such that that migrants select themselves from the upper level of the talent distribution, growth of technological progress and income in the home country are slowed down. Technology and income levels in the two countries diverge until total migration has taken place.

Proof: The talent level that satisfies inequality (1.7) with equality determines the last non migrant. It is denoted by A_t^M and is a function of the production function and the cost function.

$$A_t^M = \mathrm{A}(s_t^f, s_t) \tag{1.10}$$

If A_t^M exists ($A_t^M \in [1, a]$), then it is unique, because the net gain G_t^M is monotonous. If $A_t^M \in [1, a[$, some loss of human capital takes place due to migration. If A_t^M does not exist, there is either immediate total migration ($G_t^M > 0 \quad \forall A$) or no migration ($G_t^M < 0 \quad \forall A$). If $A_t^M \in [1, a[$, technical progress is slowed, because the higher levels of talent that previously led to the improvements of the prevailing technology have left. After migration, technological progress s_{t+1}^M evolves as follows

$$s_{t+1}^M = A_t^M s_t < a s_t \quad \forall A_t^M < a \tag{1.11}$$

We define an indicator of relative development and convergence $\sigma_t^M = \frac{s_t^M}{s_t^f}$, when agents are mobile across countries. As long as there is no migration, $\sigma_t = \sigma_0$. In that case the countries do neither converge nor diverge. When migration takes place, the countries diverge in relative income and progress as σ_t falls over time.

$$\sigma_{t+1}^M = \frac{s_{t+1}^M}{s_{t+1}^f} = \frac{A_t^M s_t^M}{a\ s_t^f} = \frac{A_t^M}{a}\sigma_t^M \qquad A_t^M < a \tag{1.12}$$

The system has one unstable equilibrium at $\sigma_t^M = 1$ where the countries are equal. When the countries are different as assumed here, the less advanced country's technology will diverge until total migration has taken place. **QED.**

Corollary 1: Emigration to Foreign does not affect growth rates in Foreign, because the top levels of the talent distribution are not affected.[15]

Corollary 2: The per capita growth rate falls as a result of migration.

Proof:

$$\gamma_{t+1}^M = \frac{As_{t+1}^M - As_t^M}{As_t^M} = A_t^M - 1 < a - 1 = \gamma_{t+t} \quad \forall A^M < a \tag{1.13}$$

QED.

Migration leads to a temporary depletion of human capital in the less advanced home country. This in turn hampers technological progress and leads to a continuous widening of the initial gap of technology between the two countries.

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[15] If it were the average level of human capital that determined technical progress, the receiving country would benefit from immigration. For examples of this kind see Haque and Kim (1997). Another effect of inflow of labor that is also excluded here is discussed in Braun (Barro and Sala-I-Martin, 1995b, Chapter 9). Braun introduces explicit congestion effects by having land as a third freely accessible factor of production. The congestion convexifies the model, explaining why less advanced countries are not depopulated.

1.5. Return Migration

Let us now consider labor mobility as a source of technology transfer via return migration. Migrants are said to keep links with their home country. Under certain conditions a migrant returns to her home country in the active part of her life. By doing so she may import more advanced technologies, and hence she possibly supports technological progress in the home country.

In order to model return migration we split the life time of one person *t* into two subperiods, *1* and *2*. In subperiod *1* a person can emigrate to Foreign, in subperiod *2* she can return if she has emigrated before (emigrating only in subperiod *2* is economically implausible as will be shown). The agent faces the same migration cost C_t^M in each subperiod if they are in Foreign.[16] She also produces output twice with the prevailing level of technology. Personal income can take four outcomes ($y_t^{hh}, y_t^{fh}, y_t^{ff}$ and y_t^{hf}). Staying at Home in both periods a person earns

$$y_t^{hh} = 2h(s_t, A) \tag{1.14}$$

In Foreign respectively

$$y_t^{ff} = 2\left[h(s_t^f, A) - C_t^M\right] \tag{1.15}$$

[16] Actual cost of migration probably fall for the second subperiod in Foreign. If the cost of migration are split in one-off cost of searching, moving and integrating on one hand and continuous cost of living away from home on the other hand, the first component should disappear or become negative in the second subperiod. In order to simplify we have kept the cost constant throughout the two subperiods. Results are not affected by this assumption. Arguably the one-off component of the migration cost is much smaller then the long term component.

If she migrates and returns in the second period of her active life, she can repatriate a fraction α of the new technology to Home. Her income is

$$y_t^{fh} = h(s_t^f, A) - C_t^M + h(s_t^\alpha, A)$$
$$\text{where} \quad s_t^\alpha = \alpha s_t^f + (1-\alpha)s_t \quad \text{with } \alpha \in [0,1] \tag{1.16}$$

Returning is cost free. The fraction *(1-α)* of home technology signifies that a returnee producing in Home has to rely partly on local infrastructure and local suppliers. The larger α, the higher are a migrant's incentives to return to home. At $\alpha=1$ full technology transfer takes place and all migrants return.

If she stays in Home in the first subperiod and migrates in the second, she earns

$$y_t^{hf} = h(s_t, A) + h(s_t^f, A) - C_t^M \tag{1.17}$$

Lemma 1.1: No agent migrates only in subperiod 2 of her life ($y_t^{hf} < y_t^{fh}$).

Proof:

$$\begin{gathered} y_t^{hf} < y_t^{fh} \\ h(s_t, A) + h(s_t^f, A) - C_t^M < h(s_t^f, A) + h(s_t^\alpha, A) - C_t^M \end{gathered} \tag{1.18}$$

This always holds for ($s_t^f > s_t$), and this inequality holds for all t and A. **QED.**

Leaving in period *1* costs the same as in period *2*, but gives the agent access to the better technology in both subperiods.

There are three options left: stay Home, migrate&return and emigrate for both periods.

Agents do not migrate at all, if the net return from staying is positive. That is the case if $y_t^{hh} \geq Max(y_t^{fh}, y_t^{ff})$. Return migration takes place in the second subperiod if $y_t^{fh} > Max(y_t^{hh}, y_t^{ff})$. Define A^{hh} as the level of talent of an agent that is indifferent between staying at home and return migrating ($y_t^{hh} = y_t^{fh}$). Agents migrate for both subperiods if $y_t^{ff} > Max(y_t^{fh}, y_t^{hh})$). Define A^{fh} as the level of talent of an agent that is indifferent between returning in subperiod *2* and staying in Foreign in that period ($y_t^{fh} = y_t^{ff}$).

For what follows we will assume that the net gain from migrating in the second subperiod ($y_t^{ff} - y_t^{fh}$) monotonously increases in A.[17]

Lemma 1.2: If ($y_t^{ff} - y_t^{fh}$) increases monotonously in A, then ($y_t^{fh} - y_t^{hh}$) and ($y_t^{ff} - y_t^{hh}$) also increase monotonously in A.

Proof: see Appendix 1A.

We will show now that under certain parameter constellations agents on the lower end of the talent distribution stay at home, agents at the higher end of the talent distribution emigrate for their entire active life and agents in the middle of the talent distribution migrate and return home.

Proposition 1.3: For all t $A_t^{fh} > A_t^{hh}$. Therefore, if $A_t^{hh}, A_t^{fh} \in [1, a[$, a person with talent $A \leq A_t^{hh}$ will not migrate at all. A person talented with $A_t^{hh} < A \leq A_t^{fh}$ will migrate in subperiod *1* and return in the next subperiod. For a person with $A > A_t^{fh}$ migration in both subperiods is profitable.

Proof: From the proof to Lemma 1.2 we know that

$$y_t^{fh} - y_t^{hh} > y_t^{ff} - y_t^{fh} \quad \forall t, \forall A \tag{1.19}$$

[17] This is a slightly stronger assumption about the shape of the cost of migration than we have made in the previous section. There we assumed that the net gain function of migration ($G_t^M = h(s_t^f, A) - h(s_t, A) - C_t^M$) is monotonously increasing in talent. If C_t^M does for instance not vary in A, then the net gain ($y_t^{ff} - y_t^{fh}$) also increases in A.

$$\frac{\delta(y_t^{ff} - y_t^{fh})}{\delta A} = \left.\frac{\delta h}{\delta A}\right|_{s=s_t^f} - \left.\frac{\delta h}{\delta A}\right|_{s_t^*} > 0 \quad \text{as} \quad h'_{sA} > 0 \cdot$$

We also know that the right hand side and the left hand side are monotonously increasing in A. Thus the left hand side of the inequality equals *0* for a lower level of talent (A_t^{hh}) than the right hand side (A_t^{fh}). QED.

Proposition 1.4: For A_t^{hh} *or* $A_t^{fh} \notin [1, \alpha[$ there are several extreme cases:

(iii) if $y_t^{fh} - y_t^{hh} \leq 0 \quad \forall A$, the cost of migration relative to the productivity gain are so high that nobody emigrates.

(iv) if $y_t^{ff} - y_t^{fh} \leq 0 \quad \forall A$ and $\exists A \quad y_t^{fh} - y_t^{hh} > 0$, the cost of migration relative to the gain from returning is so high that all migrants return.

(v) If $y_t^{ff} - y_t^{fh} > 0 \quad \forall A$, the productivity gain relative to the cost of migration are so high that there is total migration.

Proof: see Appendix 1B.

In case of migration the Home economy can lose the highest tail of the talent distribution to Foreign. There is, however, a source of technological catch-up due to the transfer of the more productive technology via return migration.

1.6. Return Migration and Growth

When agents return and introduce a better technology, they generate the potential for convergence. In this model there are two countervailing effects of migration on growth: due to the net gain functions the highly talented are drawn to Foreign. If they do not return, their input into technological progress for future generations is lost. This effect, known as brain drain effect, was described in section 1.4. But the less talented of the migrants may return to home and lead to technology spillovers as $s_t^f > s_t$. This may speed up growth. A priori, it is not clear which effect dominates.

The transfer of technology is assumed frictionless in terms of technology of the next period. At no migration the model behaves as in section 1.4. With return migration, the new technology in Home , s_{1+1}^{**}, results from the product of the talent of the most talented returnee and the latest foreign level of technology[18]

$$s_{t+1}^{**}=\begin{cases} as_t^f & A_t^{hh}\in[1,a[\quad \text{and} \quad A_t^{fh}\notin[1,a[\quad \text{(all return)} \\ A_t^{fh}s_t^f & A_t^{fh}\in[1,a[\quad \text{(some return)} \end{cases} \tag{1.20}$$

Clearly, total return migration leads to immediate convergence of s_{t+1}^{**} and s_{t+1}^f. If only a portion of migrants return, convergence depends on the relation of human capital loss to technology gain. For an interior solution we are confronted with a difference equation in s_{t+1}^{**} and s_t^{**}. In order to study the dynamics and possible equilibria we specify the production function and the cost of migration C_t^M.

Migration cost are assumed to reduce the migrant's level of productive talent. The cost are

$$C_t^M = zs_t^f \quad \text{with} \quad z\in[0,\infty[\tag{1.21}$$

Using equations (1.12), (1.15) and (1.16) and the explicit production function in equation (1.2) the following difference equation in σ_{t+1}^{**} and σ_t^{**} can be derived

$$\begin{aligned} s_{t+1}^{**} &= A_t^{fh}s_t^f && \forall A_t^{fh}\in[1,a] \\ s_{t+1}^{**} &= \frac{zs_t^f}{(1-\alpha)(s_t^f-s_t)}s_t^f && \\ \sigma_{t+1}^{**} &= \frac{z}{a(1-\alpha)(1-\sigma_t^{**})} && \forall\sigma_t^{**}\in[1-\tfrac{z}{(1-\alpha)},1-\tfrac{z}{a(1-\alpha)}] \end{aligned} \tag{1.22}$$

This equation determines the growth path of the economy, when migration and some but not total return migration is taking place. Combining this with the other three cases of migration we get a complete picture of the effects of migration on growth.

[18] It may be more plausible that the foreign technology can only partly determine the local technology's development path. Here again we have chosen the simplest specification without loss of generality.

Depending on respective weight of cost, transferability and the productivity differential, there are four areas of the growth path:

1. Total migration ($A_t^{fh} < 1$). A growth rate in Home does not exist.
2. Some return migration ($1 \le A_t^{fh} < a$). Depending on the solution of the difference equation (1.22) Home's income and productivity converge or diverge (under which conditions, will be discussed later).
3. All migrants return ($A_t^{fh} \ge a$). Home's income and productivity converges within one period.
4. Nobody leaves ($A_t^{hh} \ge a$). Home's growth rate is unaffected and income and productivity do not converge.

The convergence indicator σ_{t+1}^{**} takes the form

$$\text{for} \quad z < (1-\alpha) \quad \sigma_{t+1}^{**} = \begin{cases} (1) \text{ not existant} & \forall \sigma_t^{**} \in]0, 1 - \frac{z}{(1-\alpha)}[\\ (2) \dfrac{z}{a(1-\alpha)(1-\sigma_t^{**})} & \forall \sigma_t^{**} \in [1 - \frac{z}{(1-\alpha)}, 1 - \frac{z}{a(1-\alpha)}[\\ (3)\ 1 & \forall \sigma_t^{**} \in [1 - \frac{z}{a(1-\alpha)}, 1 - \frac{z}{a(1+\alpha)}[\\ (4)\ \sigma_t^{**} & \forall \sigma_t^{**} \in [1 - \frac{z}{a(1+\alpha)}, 1] \end{cases}$$

and

$$\text{for} \quad z \ge (1-\alpha) \quad \sigma_{t+1}^{**} = \begin{cases} (2) \dfrac{z}{a(1-\alpha)(1-\sigma_t^{**})} & \forall \sigma_t^{**} \in]0, 1 - \frac{z}{a(1-\alpha)}[\\ (3)\ 1 & \forall \sigma_t^{**} \in [1 - \frac{z}{a(1-\alpha)}, 1 - \frac{z}{a(1+\alpha)}[\\ (4)\ \sigma_t^{**} & \forall \sigma_t^{**} \in [1 - \frac{z}{a(1+\alpha)}, 1] \end{cases} \quad (1.23)$$

After solving the difference equation in σ^{**} for the relevant ranges (see Appendix 1C) and assuming that $a>4$[19], the function in (1.23) is represented in Figure 1.1. It shows the convergence indicator σ_t^{**} as a function of $\frac{z}{a(1-\alpha)}$, a function that rises in cost and transferability.

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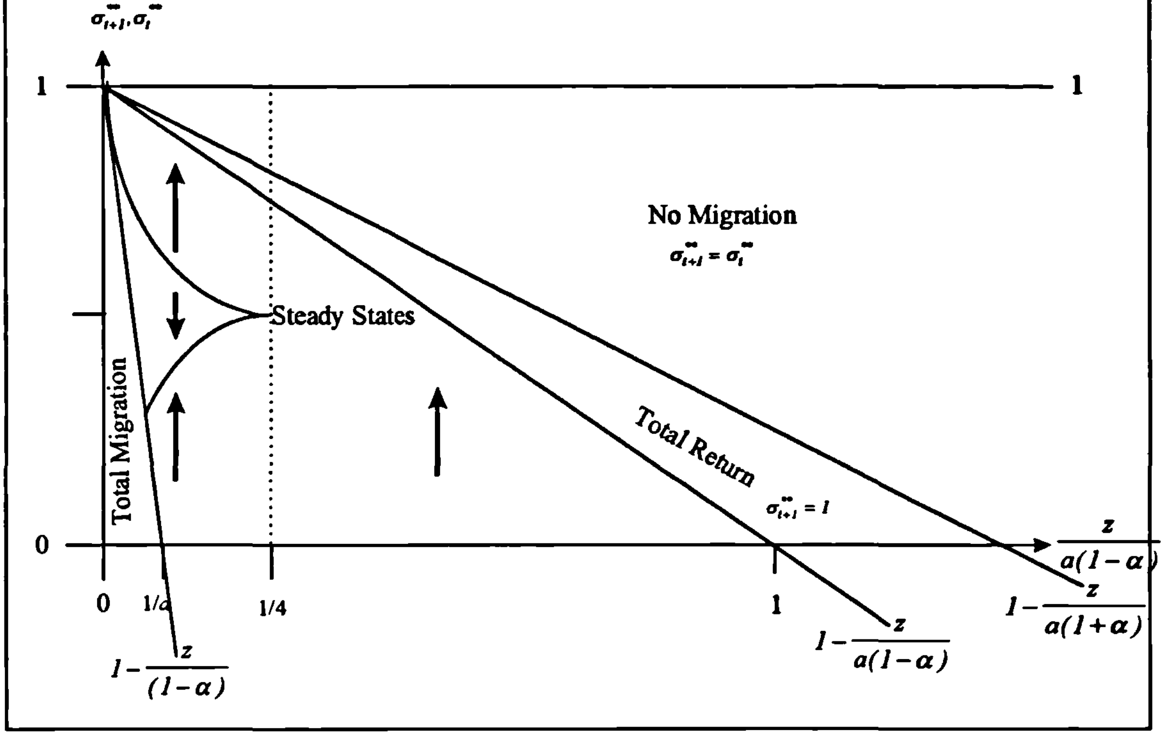
[19] $a>4$ signifies that the foreign growth rate $(a-1)$ and the steps in which productivity progresses are relatively high. In addition, the talent distribution has more variation. Under no migration this implies a more rapidly increasing difference in absolute levels of technology. When a is relatively

Figure 1.1: Return Migration and Growth, if Productive Talent is Reduced Abroad



Rising cost of migration decrease incentives to go in subperiod *1* and incentives to stay in Foreign in subperiod *2*, because high cost also deter from staying. A rising rate of transferability α increases *both* the incentive to migrate *and* the incentive to return. It pushes people to train in Foreign and return to home. Therefore higher cost and transferability of technology reduce actual brain drain.

As long as the cost/transferability parameter $\frac{z}{a(1-\alpha)}$ is high (>¼), returning human capital in combination with technology transfer leads to convergence. This is represented in Figure 1.1 to the right of the vertical line at ¼. At lower levels of $\frac{z}{a(1-\alpha)}$ (<¼) and a large initial technology gap between the two countries there is a set of long term stable equilibria with a constant technology gap. Return migration at lower levels of the talent distribution and the technology spillovers ensure persistence of the

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large (*a>4)* and migration takes place, return migration leads to convergence in smaller steps and brain drain has a more pronounced effect on growth.

gap. This is an interesting trap. the Home country is in some respect benefiting from migration due to the technology transfers, but the loss of human capital taking place at the same time diminishes the impact of the new technologies. Lacking human capital is preventing real convergence. A similar story applies for a set of unstable equilibria in the same region.

At very low levels of the cost/transferability parameter $\frac{z}{\alpha(1-\alpha)}$ and large income gaps the model predicts the disappearance of the home country as a result of migration. In reality this is for several reasons implausible (e.g. limitations at the side of the receiving country, not the entire population is part of the workforce, the marginal productivity of the other factors of production, ignored here, should increase at some point with migration, etc.). An important depletion of human capital and the work force can, however, be observed in rural regions like the Mezzogiorno in Italy or in part of the former Eastern Germany.

For similar countries and high cost/transferability there is either total return migration or no migration at all. Total return ensures immediate convergence, as human capital is not lost but technology is transferred. Migration within the European community or between Europe and the United States may well have this component. Noteworthy is also the case where migration does not produce a positive return to any agent. In Figure 1.1, it lies above and to the right of the $\sigma_t^{**} = 1 - \frac{z}{\alpha(1+\alpha)}$-line. In that case the model predicts a technology gap that persists. This may add to explaining why relatively small gaps in growth and technology tend to persist. If the rate of transferability α rises in relation to the cost z, the area without migration will shrink.

In Appendix 1D we discuss some other types of migration cost functions and show that the fundamental results of this section are robust to changes in the cost function.

1.7. Conclusions

If technological progress is the driving force of growth, developing countries can only converge in income if technology diffuses from the more advanced countries. Return migration of foreign-trained agents is an important source of technology diffusion. In this context, brain drain may only be the first step in allowing less developed countries to imitate modern technological advances. Technology refers here to hard sciences as well as to more business-oriented progress.

Empirical research shows that brain drain is certainly still a real issue with developing countries (Strepetova, 1995), but if incentives to return are right, it may be a source of income convergence. This is because the more talented also are more productive in transferring and applying the new technologies.

We show in a simple growth model with endogenous technological progress, that there is a trade-off between brain drain and technology transfer for developing countries. Brain drain occurs if agents' net gain from migration rises with their level human capital. In the absence of technology transfer brain drain leads to total depletion of human capital in the less developed country. Growth rates diverge. If technology can be transferred partly, there is scope for return migration. The returnees speed up technological convergence, and if the returnees level of talent is not too low, there can be convergence.

Ensuing from the assumptions about the production function and the cost of migration, the possibility of technology transfers and the endogenous growth mechanism, we have two simple results. First, countries that have a small (but not too small) technology gap converge more easily due to (return) migration. Second, the higher the levels of cost of producing in a foreign country and transferability, the more talented people migrate *and* return. Higher levels of human capital in turn render the technology transfer more effective.

Moreover, there can be cases where the income gap relative to migration cost is so low that migration does not take place. then the income gap persist. High technology transferability reduces this effect.

Appendix 1A: Proof to Lemma 1.2

Lemma 1.2: If $(y_t^{ff} - y_t^{fh})$ increases monotonously in A, then $(y_t^{fh} - y_t^{hh})$ and $(y_t^{ff} - y_t^{hh})$ also increase monotonously in A.

(i) To show that $(y_t^{fh} - y_t^{hh})$ increases monotonously in A, it is sufficient to show that $y_t^{fh} - y_t^{hh} > y_t^{ff} - y_t^{fh} \quad \forall t, \forall A$.

$$\begin{aligned} h(s_t^f, A) + h(s_t^\alpha, A) - C_t^M - 2h(s_t, A) &> 2h(s_t^f, A) - 2C_t^M - h(s_t^f, A) - h(s_t^\alpha, A) + C_t^M \\ h(s_t^f, A) + h(s_t^\alpha, A) - C_t^M - 2h(s_t, A) &> h(s_t^f, A) - h(s_t^\alpha, A) - C_t^M \\ h(s_t^\alpha, A) - h(s_t, A) &> 0 \end{aligned} \tag{1.24}$$

The last inequality holds for all t and A.

(ii) To show that $(y_t^{ff} - y_t^{hh})$ increases monotonously in A, it is sufficient to show that $y_t^{ff} - y_t^{hh} > y_t^{ff} - y_t^{fh} \quad \forall t, \forall A$.

$$\begin{gathered} (y_t^{ff} - y_t^{hh}) > \tfrac{1}{2}(y_t^{ff} - y_t^{hh}) \\ \text{and} \\ \tfrac{1}{2}(y_t^{ff} - y_t^{hh}) > y_t^{ff} - y_t^{fh} \\ h(s_t^f, A) - h(s_t, A) - C_t^M > h(s_t^f, A) - h(s_t^\alpha, A) - C_t^M \\ h(s_t^\alpha, A) - h(s_t, A) > 0 \end{gathered} \tag{1.25}$$

The last inequality holds for all t and A. **QED**.

Appendix 1B: Proof to Proposition 1.4

For the proof we first establish

Lemma 1.3: If $y_t^{hh} \geq Max(y_t^{fh}, y_t^{ff})$, then $y_t^{fh} > y_t^{ff}$.

Proof: This proof is by contradiction. Assume $y_t^{hh} \geq Max(y_t^{fh}, y_t^{ff})$ holds, but $y_t^{fh} < y_t^{ff}$. Then

$$\begin{aligned}
& y_t^{hh} \geq y_t^{ff} \\
& h(s_t, A) \geq h(s_t^f, A) - C_t^M \\
& \text{but also} \\
& h(s_t^\alpha, A) > h(s_t, A) \geq h(s_t^f, A) - C_t^M \\
& \text{hence} \\
& y_t^{fh} > y_t^{ff}
\end{aligned} \tag{1.26}$$

which is contradicted by our assumption. **QED.**

If staying Home in both subperiods is more profitable than migrating, return migration is also more profitable than staying in the second subperiod.

Proposition 1.4: For A_t^{hh} *or* $A_t^{fh} \notin [1, a[$ there are several extreme cases:

(i) if $y_t^{fh} - y_t^{hh} \leq 0 \quad \forall A$, the cost of migration relative to the productivity gain are so high that nobody emigrates.

(ii) if $y_t^{ff} - y_t^{fh} \leq 0 \quad \forall A$ and $\exists A \quad y_t^{fh} - y_t^{hh} > 0$, the cost of migration relative to the gain from returning is so high that all migrants return.

(iii) If $y_t^{ff} - y_t^{fh} > 0 \quad \forall A$, the productivity gain relative to the cost of migration are so high that there is total migration.

Proof:

(i) If $y_t^{fh} - y_t^{hh} \leq 0 \quad \forall A$, then Lemma 1.3 states that $y_t^{ff} - y_t^{hh} \leq 0 \quad \forall A$. Hence there is no migration.

(ii) If $y_t^{ff} - y_t^{fh} \leq 0 \quad \forall A$ and $\exists A \quad y_t^{fh} - y_t^{hh} > 0$, there is clearly no long term migration.

(iii) If $y_t^{ff} - y_t^{fh} > 0 \quad \forall A$, then the proof of Lemma 1.2 states that $y_t^{fh} - y_t^{hh} > 0 \quad \forall A$. Hence there is total migration.

QED.

Appendix 1C: Solution to the Difference Equation (1.23)

For the given range σ_{t+1}^{**} evolves according to a difference equation. To find the steady states of this equation we solve it for $\sigma_{t+1}^{**} = \sigma_t^{**}$.

$$\sigma_{t+1}^{**} = \frac{z}{a(1-\alpha)(1-\sigma_t^{**})} \qquad \forall \sigma_t^{**} \in [1-\tfrac{z}{(1-\alpha)}, 1-\tfrac{z}{a(1-\alpha)}[$$

$$\Rightarrow \tag{1.27}$$

$$\sigma_{1/2}^{ss} = \frac{1}{2} \pm \frac{1}{2}\sqrt{1-\frac{4z}{a(1-\alpha)}} \qquad \forall \sigma^{ss} \in [1-\tfrac{z}{(1-\alpha)}, 1-\tfrac{z}{a(1-\alpha)}[$$

where $\Delta = 1 - \dfrac{4z}{a(1-\alpha)}$.

This is solved in the usual way. For $\Delta > 0$, there can be two steady states. $\sigma_1^{ss} = \frac{1}{2} + \frac{1}{2}\sqrt{1-\frac{4z}{a(1-\alpha)}}$ and $\sigma_2^{ss} = \frac{1}{2} - \frac{1}{2}\sqrt{1-\frac{4z}{a(1-\alpha)}}$ $\forall \sigma^{ss} \in [1-\frac{z}{(1-\alpha)}, 1-\frac{z}{a(1-\alpha)}[$. The first is stable, the second unstable.[20] For $\Delta = 0$, the steady state is a saddle point at $\sigma^{ss} = \frac{1}{2}$. The economies converges to that steady state, if the initial $\sigma_t^{**} < \frac{1}{2}$ and diverge away if $\sigma_t^{**} > \frac{1}{2}$. For $\Delta < 0$, there is no steady state in the given range.

[20] An equilibrium is stable if to the left of it $\sigma_{t+1}^{**} > \sigma_t^{**}$ (σ_{t+1}^{**} grows) and to the right of it $\sigma_{t+1}^{**} < \sigma_t^{**}$ (σ_{t+1}^{**} falls). It is unstable if the opposite is true. A saddle point converges from one side only.

Appendix 1D: Different Cost Functions of Migration

Two other functions will be presented for the cost of migration that are also non proportional to talent. First we assume that the cost of migration depends on the technology gap rather than reducing productive talent directly. A higher technology gap may cause more adaptation cost for the migrant, because she has to learn more in order to be able to apply the modern technologies productively. Such cost have the shape of

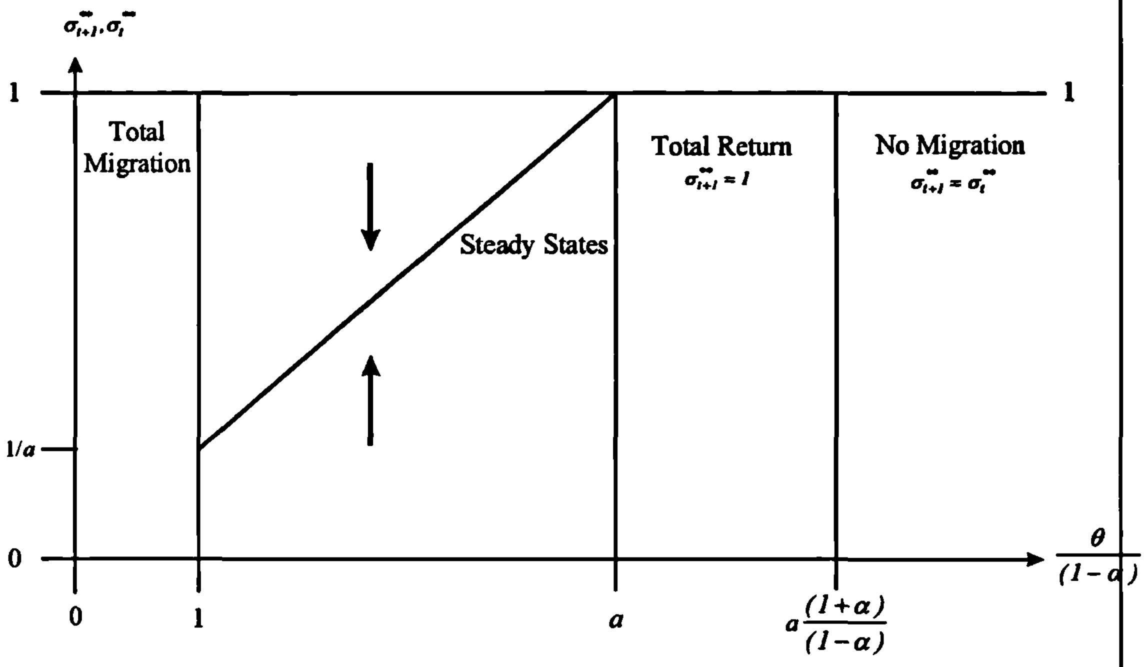
$$C_t^M = \theta(s_t^f - s_t) \qquad \text{with} \quad \theta \in]0,\infty[\tag{1.28}$$

Because the cost rise together with the productivity gain, the decision to migrate does not depend on the technology gap, but only on the cost relative to the transferability of technology. Equation (1.23) becomes

$$\sigma_{t+1}^{**} = \begin{cases} (1)\ \text{not existant} & \forall \theta \in]0,(1-\alpha)[\\ (2)\ \dfrac{\theta}{a(1-\alpha)} & \forall \theta \in [(1-\alpha),(1-\alpha)a[\\ (3)\ 1 & \forall \theta \in [(1-\alpha)a,(1+\alpha)a[\\ (4)\ \sigma_t^{**} & \forall \theta \in [(1+\alpha)a,\infty[\end{cases} \tag{1.29}$$

Figure 1.2 shows that the fundamental results are the same with respect to the effect of the cost of migration and the transferability parameter. Function (1.29,2) generates stable equilibria for its range, that rise with the cost/transferability parameters. The size of the initial technology gap is not inversely related to convergence. It has no impact on the chance of convergence, because a larger technology gap creates higher cost, which motivates more return migration.

Figure 1.2: Return Migration and Growth, if Migration Cost Rise with the Technology Gap



The level of talent may be added as a scaling factor to the cost function, such that the cost of integration fall with the level of talent.

$$C^M = \tfrac{\lambda}{A}(s_t^f - s_t) \quad \text{with} \quad \lambda \in]0,\infty[\tag{1.30}$$

This will increase the area where return migration with technology transfer does not compensate for the loss of human capital, because a larger portion of the talented find profitable to remain in Foreign for both periods of production. Function (1.29) becomes

$$\sigma_{t+1}^{**} = \begin{cases} (1)\ \text{not existant} & \forall\lambda \in]0,(1-\alpha)[\\ (2)\ \sqrt{\dfrac{\lambda}{a^2(1-\alpha)}} & \forall\lambda \in [(1-\alpha),(1-\alpha)a^2[\\ (3)\ 1 & \forall\lambda \in [(1-\alpha)a^2,(1+\alpha)a^2[\\ (4)\ \sigma_t^{**} & \forall\lambda \in [(1+\alpha)a^2,\infty[\end{cases} \tag{1.31}$$

Secondly, cost of migration are assumed to depend on the level of talent inversely.

The rationale is the same as in the previous case. A more talented person might find it easier to integrate and to become productive in a new environment. We express the cost in terms of depreciation of productive talent due to migration. For some levels of the cost parameter μ and talent the cost of migration may even be equal to zero. Hence return when producing in Foreign is

$$y_t^{ff} = \begin{cases} 2As_t^f \frac{A}{\mu} & \mu > A \\ 2As_t^f & 0 < \mu \leq A \end{cases} \tag{1.32}$$

The convergence parameter σ_{t+1}^{**} takes the form

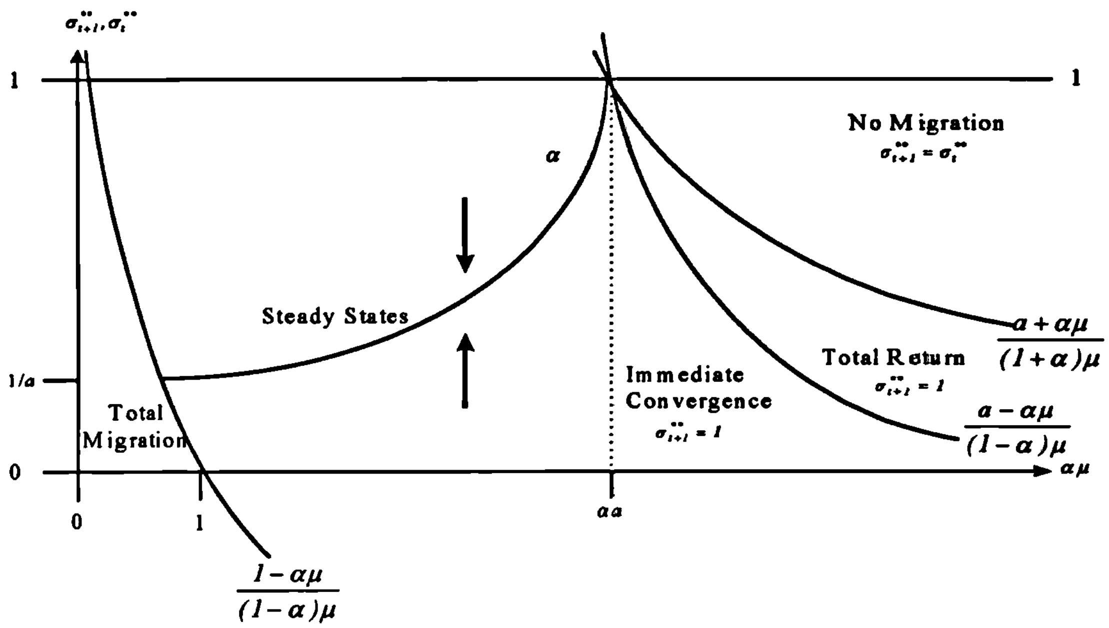
$$\alpha\mu < 1 \quad \sigma_{t+1}^{**} = \begin{cases} (1) \text{ not existant} & \forall \sigma_t^{**} \in]0, \frac{1-\alpha\mu}{(1-\alpha)\mu}[\\ (2)\ \frac{\alpha\mu}{a} + \frac{(1\ \alpha)\mu}{a}\sigma_t^{**} & \forall \sigma_t^{**} \in [\frac{1-\alpha\mu}{(1-\alpha)\mu}, \frac{a-\alpha\mu}{(1-\alpha)\mu}[\\ (3)\ 1 & \forall \lambda \in [\frac{a-\alpha\mu}{(1-\alpha)\mu}, \frac{a+\alpha\mu}{(1+\alpha)\mu}[\\ (4)\ \sigma_t^{**} & \forall \lambda \in [\frac{a+\alpha\mu}{(1+\alpha)\mu}, 1] \end{cases}$$

and (1.33)

$$\alpha\mu > 1 \quad \sigma_{t+1}^{**} = \begin{cases} (2)\ \frac{\alpha\mu}{a} + \frac{(1-\alpha)\mu}{a}\sigma_t^{**} & \forall \sigma_t^{**} \in [0, \frac{a-\alpha\mu}{(1-\alpha)\mu}[\\ (3)\ 1 & \forall \lambda \in [\frac{a-\alpha\mu}{(1-\alpha)\mu}, \frac{a+\alpha\mu}{(1+\alpha)\mu}[\\ (4)\ \sigma_t^{**} & \forall \lambda \in [\frac{a+\alpha\mu}{(1+\alpha)\mu}, 1] \end{cases}$$

Presented in Figure 1.3, this case is similar to the two other cases. The equilibria in function (1.33,2) are stable. Noteworthy is only that for $\mu \geq a$ the depreciation factor of talent is so high that the talent level of the returning migrants in combination with the technology transfer always ensures immediate convergence.

Figure 1.3: Return Migration and Growth, if Migration Cost Depead Inversely on Talent



The two versions presented here (cost that depend on the technology gap and cost that depend inversely on the talent levels of the individuals) both lead to similar results as the first cost function presented in section 1.6. As long as productivity is distributed heterogeneously in the economy and the cost of migration are not proportional to the level of talent of the migrant, human capital loss can lead to divergence in growth rates. Nevertheless return migration can reverse that effect due to technology transfers.

2. Can Technology Transfer be enhanced by a Tariff, if Products are Vertically Differentiated?

2.1. Introduction

The transfer of technology is an important issue of developing economies. When trade and FDI take place between asymmetric countries, the technological growth in the less developed country might actually be hampered. This is because the initial conditions are such that the less developed country has a comparative advantage in low quality and low technology products, engendering static gains from trade but also dynamic disadvantages in terms of technological development. This mechanism has been modeled by Flam and Helpman (1987), Stokey (1991) or Young (1991) among others. Motta et al. (1997) use a model of vertical product differentiation to show that leapfrogging of the less developed countries' industry is very unlikely.

One way of avoiding this development trap, is to attract technology transfer from more developed countries. Technology transfer is a source of catch-up, as the imitation of existent technologies should be faster and less costly than the creation of new technological progress. This mechanism is explicitly modeled in Barro and Sala-i-Martin (1995a) and Findley (1978).

In order to attract technological transfers and benefit from them, the receiving country has to offer the right conditions. The empirical and theoretical literature underlines the importance of factors such as education of the local workforce and local infrastructure. Empirical results can be found in Evenson and Westphal (1995). Rodriguez-Clare (1998) shows that multinational firms place more high technology production facilities, if more diversified inputs are available in the local industry. This in turn generates positive spillovers to the local economy. Blomström and Wang (1992) come to a similar conclusion. In their model a higher level of quality of the local industry induces multinationals to invest in costly technology transfer in order to be competitive on the local market. The obvious policy advice is to further the local infrastructure and educational levels.

Kabiraj and Marjit (1998) take a different approach. They argue that in a world of Cournot-Nash competition between a more productive firm from a more developed country and a less productive firm in a less advanced country a tariff can induce the high productivity firm to sell its knowledge to the other firm. This is because the tariff transfers some profits of the productive firm to the less productive firm. Thus the gain from selling the better technology rises. The tariff policy seems much easier to realize than the support of the local education and infrastructure, because it does not need to be financed.

Kabiraj and Marjit's model ignores the fact that producing the lower quality products might be more profitable, because the country benefits form its comparative advantages. Motta et al. (1997) model this idea in a world of vertical product differentiation. The country that in autarky produces a low quality product will most probably continue to do so in free trade. This is because firms want to diversify their products in order to maximize monopoly power.

The present chapter shows that in a world of vertically differentiated products a tariff can induce the low quality firm to spend the fixed cost of upgrading its quality. The tariff increases in some sense the production cost of the importing high quality firm. This shifts the low quality firm's incentives away form product differentiation, because it can generate additional profits by undercutting the other firm's price with better quality products. It is assumed that only technology transfers from more developed countries via FDI or licensing can realize quality upgrades at reasonable cost.

It is shown under which conditions a tariff induces technology transfer. Two cases are considered. Markets are integrated for the foreign firm in the first case, so that it will not react in prices to the quality upgrade of the local firm. In the second case, markets are segmented in prices, so that the foreign firm interacts strategically with the local firm. In both cases there exists a tariff that induces technology transfer to the local firm. The positive welfare effect of the quality upgrade is more pronounced in the second case, however, because the tariff induces a reduction in the foreign firm's price in addition to the improvement of the local quality.

The remainder of the chapter is organized as follows. Section 2.3 presents the model without price interaction. Section 2.4 introduces strategic interaction of the two firms. Section 2.5 concludes.

2.2. The Model

We assume a small transforming economy with a substantial need for restructuring and technological catch-up (Home). As a result of both of these factors, the quality of its entire output as well as income levels lag behind those of the rest of the world. Technological know-how, necessary to improve the quality of the local product, is a local public good and does not automatically diffuse from the rest of the world to the small economy.

The model is a partial equilibrium model. Factor markets are ignored and only one industrial sector is studied. In this sector products are vertically differentiated. One foreign and one local firm serve this sector, each firm supplying one quality.[21] For historic reasons the foreign firm produces a quality level higher than the locally produced quality (Motta et al., 1997).

We consider a three-stage game. In the first stage, the government of Home chooses the tariff level t. In the second stage, the local firm chooses its quality given import prices and import quality. The chosen quality level is determined by the level of technology transfer on a one-to-one basis.[22] In the third stage, after technologies have been chosen, the local and the foreign producer compete in prices. The game is solved by backward induction in the standard way.

We first consider the case where the world market is integrated in prices and the foreign firm does not vary its price as a result of competitive pressure of the local firm. I. e., the local firm chooses the quality level in the second stage as well as the

[21] The foreign and the local market are integrated in terms of quality. This amounts to the assumption adopted by Venables (1990) that the firm adopts a single capacity for the whole production but chooses different prices in each market.

[22] This implies that high quality also requires high technological and other intangible know-how compared to low quality production. This assumption seems warranted by the theoretical and

prices in the third stage given import prices and quality. Second, we relax that assumption and allow for strategic interaction in price setting between the two firms. The foreign level of quality remains exogenous.[23] For both cases we can show that there exists a range of positive tariff levels which induce the local quality to be improved. In the case of integrated markets, the tariff induced quality upgrade only increases welfare under certain conditions. With strategic interaction between the two firms welfare in Home unambiguously rises in the tariff level, because the tariff not only improves quality but also reduces the price of the imported good.

2.3. Exogenous Import Prices

The home market is fully integrated with the foreign market in terms of prices as well as in terms of quality, so that the foreign firm charges the same price on all markets. Given market integration and the marginal size of the home market compared to Foreign, we can consider the foreign level of price as exogenous to the small economy. In addition we rule out that any firm can serve the entire home market as a monopolist or can be driven out of the market, as this will most probably be avoided by anti-trust regulations. The small country can, however, levy and enforce a tariff t on imports.

For the demand side a simple model of vertical differentiation (Tirole, 1988, Chapter 7) is adopted. Consumers in Home buy either one or zero units of one of the available goods. The consumer's utility is separable in quality and income

$$U = \begin{cases} \theta s - p & \text{if the consumer buys good of quality s} \\ 0 & \text{if the comsumer does not buy} \end{cases} \tag{2.1}$$

empirical literature on North-South trade (see for instance Flam and Helpman, 1987 or Krugman, 1980).

[23] The foreign firm can have incentive to either improve its quality above the initial level or to leapfrog to a lower quality level. The first case can be excluded by the assumption that the foreign level of quality results from the state-of-the-art technological know-how and cannot be increased at reasonable cost. The second case is excluded by the fact that the firm only supplies one quality and that the home market is relatively small compared to the foreign market, because the high quality position yields higher profits (Tirole, 1988, Chapter 7).

s is a positive real number describing the quality of the good. p is the price of the good and θ a taste or an income parameter.[24] θ is uniformly distributed with density S=1 and lies between $[0, \bar{\theta}]$.

The quality level available in Foreign is denoted by s^*. It is assumed to be higher than in Home, either because of higher taste for quality or higher income or else because of a higher initial quality endowment resulting from natural conditions prevailing in Foreign (Motta et al., 1997). The imported quality is sold in Home at price p^*+t. Therefore there are two qualities on offer on the local market: the imported international good s^* and the low local quality good s, where $s \in [0, s^*]$. The consumers decide whether to buy at all and choose between the qualities. For a positive demand for both qualities in the small country two conditions need to be satisfied:

Assumption 2.1: $0 < p^* < \bar{\theta} s^*$.

Under this assumption the imported product can be afforded by at least some consumers in Home, as long as $t=0$.

Assumption 2.2: $0 \leq t < \bar{\theta} s^* - p^*$

Further we restrict the model to non-prohibitive tariffs, such that the local firm is always under competitive pressure from abroad.

The demand for the imported good is

$$D^*(p, p^*, t, s, s^*) = \bar{\theta} - \left(\frac{p^*+t-p}{s^*-s}\right) \tag{2.2}$$

[24] θ can be interpreted (1) as a taste parameter. In that case consumers with a higher θ are willing to pay a higher price for a given level of s, no matter what their income is. (2) If the utility function is $U=s-(1/\theta)p$, θ can be interpreted as the marginal rate of substitution between quality and income. A wealthier person has a lower marginal utility of income or a higher θ.

All consumers, for whom $\theta > \theta^* = (p^*+t-p)/(s^*-s)$, prefer the imported good to the local good. All consumers, for whom $\theta < \theta_l = p/s$, prefer not to buy at all. Hence the local producer faces the following demand function

$$D(p,p^*,t,s,s^*) = \left(\frac{p^*+t-p}{s^*-s}\right) - \frac{p}{s} \tag{2.3}$$

2.3.1. The Price Equilibrium

At the price setting stage (stage three) the local firm maximizes revenues $R = (p-c)D(p,p^*,t,s,s^*)$ with respect to p, taking qualities, importer's price p^* and the tariff level t as given. The marginal cost c of production are assumed to be zero. Maximizing the local producer's revenues with respect to p yields the optimal price $\hat{p}$

$$\hat{p} = \frac{s(p^*+t)}{2s^*} \tag{2.4}$$

Substituting $\hat{p}$ into the demand functions for the local and the imported product in equations (2.2) and (2.3), we get equilibrium demands

$$\begin{aligned} \hat{D} &= \frac{p^*+t}{2(s^*-s)} \\ \hat{D}^* &= \overline{\theta} - \frac{(p^*+t)(2s^*-s)}{2s^*(s^*-s)} \end{aligned} \tag{2.5}$$

The importer's equilibrium demand $\hat{D}^*$ is zero, if $\theta^* = \overline{\theta}$. This defines $s^M(t)$ as the level of quality at which the local producer has squeezed the importer out of the market for a given tariff level.

$$s^M(t) = s^* \frac{2(\overline{\theta}s^*-p^*-t)}{(2\theta s^*-p^*-t)} \tag{2.6}$$

$s^M(t)$ decreases in the tariff level. Clearly, the higher the cost advantage caused by the tariff, the lower is the quality level at which the local supplier absorbs the entire high-income segment of the market. Given the range of t, $s^M(t) \in [0, s^* \frac{2(\theta s^* - p^*)}{(2s^* - p^*)}]$.

Equilibrium local revenues are

$$\hat{R} = \frac{s(p^* + t)^2}{4s^*(s^* - s)} \quad for \quad s < s^M(t) \tag{2.7}$$

Revenues for $s \geq s^M(t)$ are not considered here, as local monopoly is excluded from the analysis by assumption. As to be expected, local demand and revenues rise with increasing trade barriers, whereas import demand falls.

2.3.2. The Optimal Quality

The local producer cannot improve the quality of her product $\underline{s}$ without foreign assistance. The foreign technology can be bought by license, from a consultant or else a foreign investor, that owns the technology, can be invited. The quality improvement could be purely in production technology as well as in management skills or other less tangible assets. A seller of knowledge makes a take-it-or-leave-it offer taking the entire surplus and an investor repatriates profits.[25] Quality improvement is associated with some installation and adaptation cost $K(s) = k(s - \underline{s})$, where s is the chosen level of quality and $\underline{s}$ is the initial level of quality of the local producer.

In the second stage of the game (after the local government has chosen t), the local firm faces following optimization problem

$$\underset{s}{Max}\,\pi = \hat{R}(s, s^*, p^*, t) - K(s) \tag{2.8}$$

Given that the foreign firm does not decrease its price or increase its quality as a result of competitive pressure from the local firm, offering an improved local quality and undercutting the price always increases the local producer's revenues.

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[25] We assume that he importer cannot monopolize the home market by buying the local firm.

$$\frac{\delta \hat{R}}{\delta s} = \frac{(p^* + t)^2}{4(s^* - s)^2} > 0 \qquad \text{for} \quad s < s^M(t) \tag{2.9}$$

Quality will be improved until the marginal benefit of modernization equals the marginal cost of it. The first and second order conditions for a maximum are

$$\underbrace{\frac{\delta \hat{R}(\hat{s}, s^*, p^*, t)}{\delta s}}_{MB} - \underbrace{K'(\hat{s})}_{MC} = 0 \qquad (FOC)$$

$$\text{and} \tag{2.10}$$

$$\frac{\delta^2 \hat{R}(\hat{s}, s^*, p^*, t)}{\delta s^2} - K''(\hat{s}) < 0 \qquad (SOC)$$

Lemma 2.1: A unique interior solution to this optimization problem exists, if the following sufficient conditions are satisfied:

(i) *K(s)* is increasing and continuously differentiable in *s*.

(ii) $K'(s = 0) < \dfrac{\delta \hat{R}(s = 0, s^*, p^*, t)}{\delta s} \qquad \forall s^*, \forall p^*, \forall t$

(iii) $K'(s^M(t)) > \dfrac{\delta \hat{R}(s^M(t), s^*, p^*, t)}{\delta s} \qquad \forall t < t^M, \forall s^*, \forall p^*$

where t^M is the solution of $K'(s^M(t)) = \dfrac{\delta \hat{R}(s^M(t), s^*, p^*)}{\delta s}$

(iv) $K''(s) > \dfrac{\delta^2 \hat{R}(s, s^*, p^*, t)}{\delta s^2} \qquad \forall s^*, \forall p^*, \forall t$

Proof: see Appendix 2A.

Lemma 2.1 states the sufficient conditions securing that a unique optimum exists for $s \in [0, s^M(t)[$, as long as the Government chooses a tariff level $t \in [0, t^M[$. If the government chooses $t \geq t^M$, the firm will choose an $s \geq s^M(t)$. This will drive the importer out of the market. The government can avoid this by choosing $t \in [0, t^M[$.

2.3.3. The Choice of Tariff

We show now that there exists a tariff level at which the locally produced level of quality increases, and both products remain on the market. Hence the tariff induces a technology transfer. In a second step, we show that the government can under some conditions increase social welfare by levying a positive tariff, so that the induced technology transfer also is socially beneficial.

Proposition 2.1: The optimal level of quality chosen by the local supplier $\hat{s}$ increases in the tariff level t with the foreign firm remaining in the market, as long as $t \in \left[0, t^M\right[$.

Proof: For Proposition 2.1 to hold it needs to be the case that

$$\frac{\delta \hat{s}}{\delta t} = -\frac{\delta E / \delta t}{\delta E / \delta s} = -\frac{\delta^2 \hat{R}(\hat{s}, s^*, p^*, t) / \delta s \delta t}{\delta^2 R^2(\hat{s}, s^*, p^*, t) / \delta s^2 - K''(\hat{s})} > 0 \tag{2.11}$$

where E is first order condition of the local producer's optimization problem (condition (2.10)). This is the case as:

(i) The numerator of equation (2.11) is positive:

$$\frac{\delta^2 \hat{R}}{\delta s \delta t} = \frac{(p^* + t)}{2(s^* - s)^2} > 0 \qquad \textit{for} \quad s \le s^M(t) \tag{2.12}$$

Hence, the local producer's incentives to improve local quality increase with a tariff, as long as the tariff does not drive the importer out of the market ($t \in \left[0, t^M\right[$).

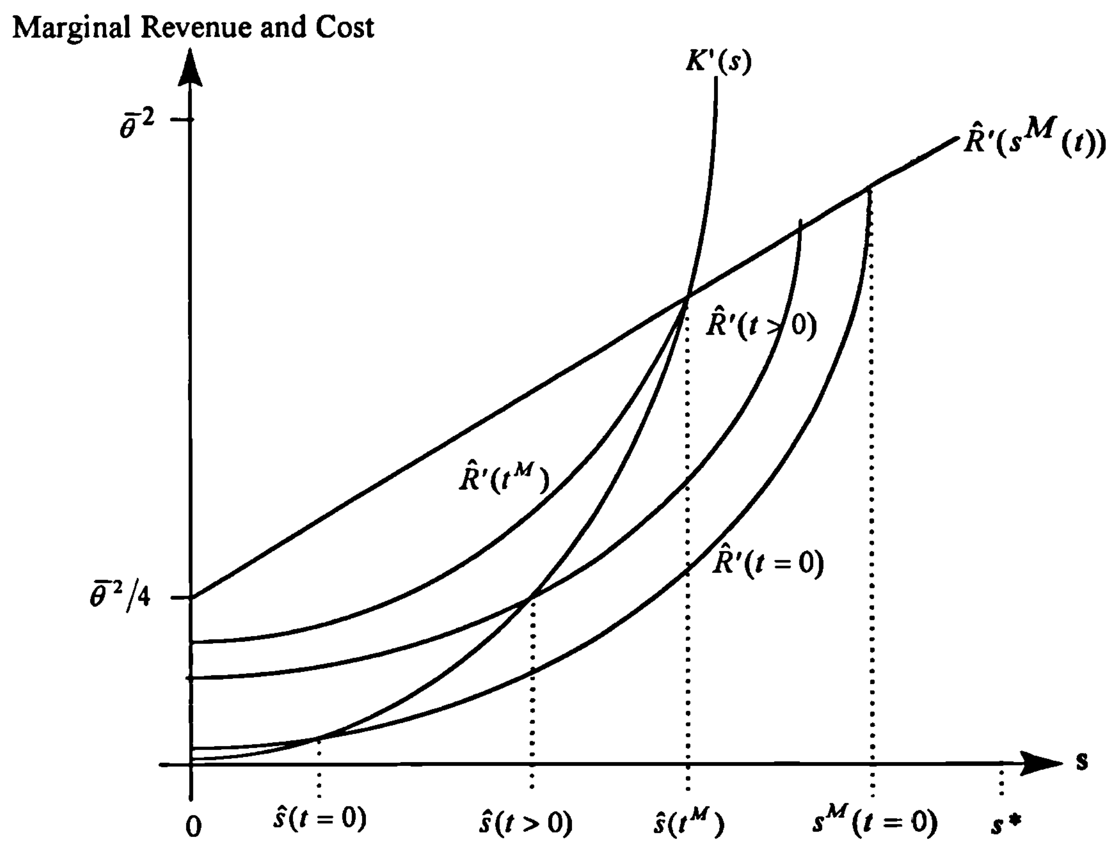
(ii) The denominator of equation (2.11) is negative. This is the second order condition for a maximum of the local producer's optimization problem (condition (2.10)). Lemma 2.1 secures that the second order condition is always satisfied.

Hence, as long as the importer is not squeezed out of the market ($t \in \left[0, t^M\right[$), local quality rises with the tariff level. **QED.**

From equation (2.9) we know that the local producer's marginal revenues rise in the level of quality for $s \in \left[0, s^M(t)\right[$, because the increased quality increases the local supplier's demand and the expense of the importer's demand. As t rises, the price of the high-quality product rises. This shifts yet more demand to the local product. Thus, a higher tariff shifts the marginal revenue curve upward for each level of quality. At a given level of quality, marginal revenues have increased and the local producer finds it more profitable at given cost to improve quality. The intersection of the marginal cost curve and the marginal revenue curve lies at a higher level of quality as a result of the increased tariff level.

Graphically, the local firm's profit maximization in the second stage of the game can be represented in the following way for $t < t^M$:

Figure 2.1: The Optimal Supply of Quality with Exogenous p*



At tariff level $t=0$, the local firm chooses quality $\hat{s}(t=0)$. If the tariff on the foreign good is $0 < t < t^M$, the firm improves the quality to $\hat{s}(t>0)$. At $t = t^M$, the firm chooses the quality level $\hat{s}(t^M)$ and squeezes the importer out of the market . Thus, a higher price for the imported good protects the local supplier and increases the incentives to raise the quality of the local good.[26]

The benevolent government will now decide, if the tariff-induced technology transfer is welfare enhancing. In a general equilibrium model of trade a tariff reduces output in the export sector as it draws factors to the import sector. A tariff thus reduces imports as well as exports and the static benefits of trade in a full employment economy. This general equilibrium effect might be somewhat less pertinent when there is high unemployment and capital is imported.

In the present welfare analysis the potentially positive effects of the technology transfer on the whole economy are not considered, as the transfer is not explicitly modeled. The profit of the quality investment goes to the foreign contractor, no matter what the tariff is, so it can be ignored. Thus welfare considered here consists of the surplus of the consumers affected by the tariff and tariff revenue. It takes the following form (for $\theta^* = \frac{p^*+t-p}{s^*-s}$ and $\theta_l = \frac{p}{s}$)

$$W = \int_{\theta^*}^{\bar{\theta}} (s^* - \tfrac{1}{\theta} p^*)\delta\theta + \int_{\theta_l}^{\theta^*} (\hat{s} - \tfrac{1}{\theta} p)\delta\theta + t(\bar{\theta} - \theta^*) \tag{2.13}$$

which can be solved to

$$W = \tfrac{1}{2}\hat{s}(\theta^{*2} - \theta_l^2) - p(\theta^* - \theta_l) + \tfrac{1}{2}s^*(\bar{\theta}^2 - \theta^{*2}) - p^*(\bar{\theta} - \theta^*) \tag{2.14}$$

For the demand function assumed here the tariff revenues disappear, because they are exactly offset by the loss of surplus of the wealthy consumers due to the increased price of the imported good. The tariff works like a tax on the consumers of the imported good. We can differentiate the welfare function with respect to t to see the effect of a tariff. In the case of the exogenous import price this yields

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[26] Equation (2.9) shows that marginal revenues also rise in the level of the world market price p^*. Hence, a higher p* obviously gives the local producer more incentives to increase her quality even without a tariff.

$$\frac{\delta W}{\delta t} = \underbrace{\tfrac{1}{2}\frac{\delta \hat{s}}{\delta t}(\theta^{*2} - \theta_l^2) + \tfrac{1}{2}\hat{s}(2\theta^* \frac{\delta \theta^*}{\delta t} - 2\theta_l \frac{\delta \theta_l}{\delta t}) - \frac{\delta \hat{p}}{\delta t}(\theta^* - \theta_l) - \hat{p}(\frac{\delta \theta^*}{\delta t} - \frac{\delta \theta_l}{\delta t})}_{\text{Change in surplus of the low income consumers}} \tag{2.15}$$
$$\underbrace{- \frac{\delta \theta^*}{\delta t}(\theta^* s^* - p^*)}_{\text{Change in surplus of the high income consumers net of tariff revenues}}$$

Given $\frac{\delta \hat{s}}{\delta t} > 0$ (Proposition 2.1), it can be easily verified that the derivatives have the following signs (see Appendix 2C for $\frac{\delta \hat{p}}{\delta t}$)

$$\frac{\delta \hat{p}}{\delta t} > 0, \quad \frac{\delta \theta^*}{\delta t} > 0, \quad \frac{\delta \theta_l}{\delta t} > 0, \quad \text{and} \quad \frac{\delta \theta^*}{\delta t} - \frac{\delta \theta_l}{\delta t} > 0, \tag{2.16}$$

The lower income consumers' welfare change is ambiguous. As some low-income consumers are not served any more as the price rises, the utility gain of increased quality level may not be large enough to compensate the losses. The high-income consumers' welfare, however, unambiguously falls as they now pay a higher price for the same good, as long as they still buy it. That is offset by the tariff gains by the government, so it does not appear in equation (2.15). In addition, some high-income consumers consume the local product as a result of the increased tariff. They are also made worse off. If the first effect of the tariff is positive and offsets the second, total welfare increases. (2.15) can be simplified to

$$\frac{\delta W}{\delta t} = \tfrac{1}{2}\frac{\delta \hat{s}}{\delta t}(\theta^{*2} - \theta_l^2) - \frac{\delta \theta^*}{\delta t} t - \frac{\delta \hat{p}}{\delta t}(\theta^* - \theta_l) \tag{2.17}$$

We can now determine under which condition welfare increases as a result of a positive tariff

Proposition 2.2: For an initial level of $t=0$ the government has an incentive to raise the tariff level t, as this is welfare enhancing if

$$\frac{\delta \hat{s}}{\delta t} > \frac{2s(s^* - s)}{p^* s^*} > 0 \tag{2.18}$$

Proof: See Appendix 2A.

Condition (2.18) states that welfare increases in t at $t=0$, if the impact of the tariff on the level of quality is sufficiently strong. Clearly the flatter the marginal cost curve of quality improvement and/or the more marginal revenue reacts to a change of tariff, the more positive is the welfare effect of a tariff.

In the next section, we will see that our results are not changed if there is strategic interaction in price setting, but not in quality. The quality level chosen by the local producer also increases with the tariff level for $t \in \left[0, t^M\right[$. The main difference will be that a tariff generates not only a technology transfer, but also drives down the importer's price thus generating further welfare gains. Both versions of the model are extreme cases and the importer's price setting behavior most probably lies somewhere in between.

2.4. Strategic Interaction in Prices

We now consider the same model with the only difference that the importer can price discriminate between Home and Foreign, because markets are fully segmented. He will do so in order to maximize his profits of Foreign and Home. As a result, there will be strategic interaction between the two players in stage three of the game. As before only non-prohibitive tariff levels are considered. The equivalent of Assumption 2.2 now is (Assumption 2.1 is obviously dropped):

Assumption 2.2a: $0 \leq t < \overline{\theta} s^*$

2.4.1. The Price Equilibrium

The demand structure is unchanged (equations (2.2) and (2.3)), but prices will differ due to the strategic interaction of the two firms. At the price setting stage both firms determine their reaction functions by maximizing revenues $R = pD(p, p^*, t, s, s^*)$ with respect to p, taking qualities and tariff level t as given

$$p^R = \frac{s(p^* + t)}{2s^*}$$

$$p^{*R} = \tfrac{1}{2}[(s^* - s)\bar{\theta} + p - t] \tag{2.19}$$

The resulting Nash equilibrium in prices is

$$\hat{p} = \frac{s(s^* - s)\bar{\theta} + st}{4s^* - s}$$

$$\hat{p}^* = \frac{2s^*(s^* - s)\bar{\theta} - (2s^* - s)t}{4s^* - s} \tag{2.20}$$

As to be expected, the local producer's price increases with the tariff level t, whereas the importer's price falls with t. The decrease in p^* is smaller that the increase in t, so that the consumers of the imported product face a price rise as in the previous case. But now the importer finances some of the tariff revenues. The level of quality at which the local producer has squeezed the importer out of the market $s^M(t)$ now equals

$$s^M(t) = s^* \frac{2(\bar{\theta}s^* - t)}{(2\bar{\theta}s^* - t)} \qquad s^M(t) \in [0, s^*] \tag{2.21}$$

Simple calculation shows that $\hat{p}^*$ becomes zero, if $s = s^M(t)$. The importer is ready to reduce his price to zero before being driven out of the local market (marginal production cost equal zero). Equilibrium local revenues for $s < s^M(t)$ are

$$\hat{R} = \frac{s^* s[(s^* - s)\bar{\theta} + t]^2}{(4s^* - s)^2 (s^* - s)} \tag{2.22}$$

Without tariff, the local producer's revenue function equals zero for s–0 and s=s* and has a maximum at s=4 7s*. If the tariff level is zero, the firms differentiate their products in order to increase their monopoly power (Shaked and Sutton, 1981).

2.4.2. The Optimal Quality

We now determine again the local producer's quality choice, given the cost of technology transfer. The local firm's optimization problem in the second stage of the game is as before

$$\underset{s}{Max}\,\pi = \hat{R}(s,s^*,t) - K(s) \tag{2.23}$$

Revenues do not necessarily rise with the level of quality chosen for a given tariff as in the previous case. For $s \leq \frac{4}{7}s^*$ marginal revenues are positive for all levels of t. For $s > \frac{4}{7}s^*$ and t relatively small or zero the derivative can become negative, but at $s = s^M(t)$ it is positive for all t (see Appendix 2B for the derivatives). If the "cost advantage" caused by the tariff is not very pronounced the local supplier's revenues may fall for some range of s close to $s^M(t)$, as price competition becomes fiercer. Due to the cost advantage, marginal revenues are always positive at $s = s^M(t)$ and larger than marginal revenues at all other points on the curve for $s < s^M(t)$, however. Hence the local firm has an incentive to locate its quality close to the competitor and "steal his business" by undercutting his price (Jeanneret and Verdier, 1996).

The first and second order conditions for a maximum are, with a two times differentiable cost function

$$\underbrace{\frac{\delta\hat{R}(\hat{s},s^*,t)}{\delta s}}_{MB} - \underbrace{K'(\hat{s})}_{MC} = 0 \qquad (FOC)$$

and (2.24)

$$\frac{\delta^2\hat{R}(\hat{s},s^*,t)}{\delta s^2} - K''(\hat{s}) < 0 \qquad (SOC)$$

Lemma 2.1a: A unique interior solution to this optimization problem exists, if Lemma 2.1 holds.

Proof: If Lemma 2.1 holds, it is straightforward to show that there is a unique interior solution for all $t \in [0, t^M[$. QED.

Lemma 2.1a states the sufficient conditions securing that the first and second order conditions (2.24) are satisfied for $s \in [0, s^M(t)[$, as long as the Government chooses a tariff level $t \in [0, t^M[$.

2.4.3. The Choice of Tariff

We show now that strategic interaction in prices does not change the results of section 2.3.3. A tariff increase leads to quality improvement of the local firm's product and both products remain on the market, if $t \in [0, t^M[$. Hence the tariff also induces technology transfer. The difference to the previous results will be that the government can bring down the importer's price. Social welfare rises unambiguously as the local quality improves and some of the importer's profits are skimmed.

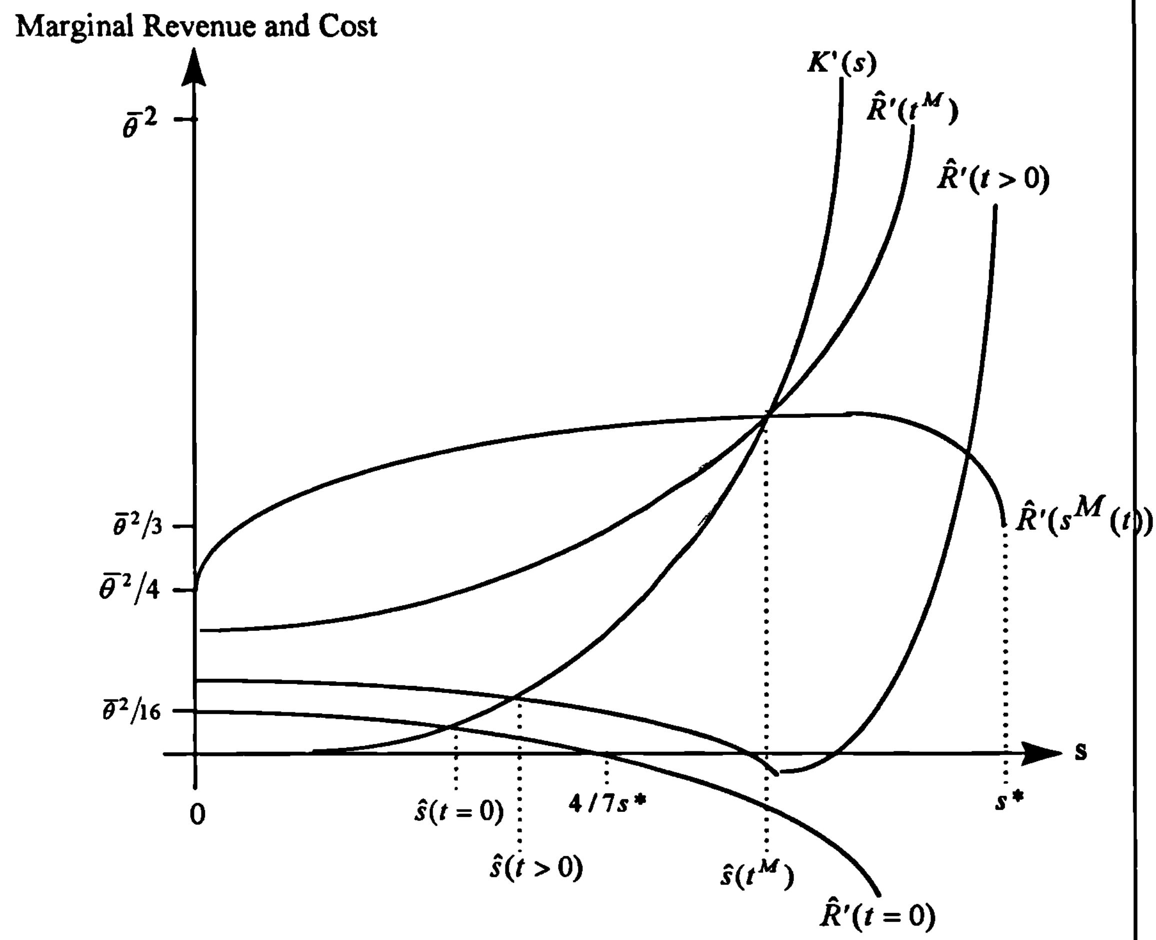
Proposition 2.1a: If both suppliers compete in prices, the optimal level of quality chosen by the local supplier $\hat{s}$ increases in the tariff level t, as long as $t \in [0, t^M[$.

Proof: see Appendix 2B.

As the local producer increases her quality price competition between the two firms becomes tougher. The tariff, however, gives the local producer a cost advantage over the importer so that she finds it profitable to undercut the importer's price and steal some of his market.

Graphically, the local firm's profit maximization in the second stage of the game now looks as follows for $t < t^M$:

Figure 2.2: The Optimal Supply of Quality with Endogenous p*



At tariff level *t–0*, the local firm chooses local quality $\hat{s}(t=0)$. If the tariff of the foreign good is $0<t<t^M$, the firm improves the quality up to the higher level of quality $\hat{s}(t>0)$. At $t=t^M$, the firm chooses the quality level $\hat{s}(t^M)$ and squeezes the importer out of the market. Thus, a higher price for the imported good protects the local supplier and increases the incentives to raise the quality of the local good. This holds, although the marginal revenue functions are not monotonously increasing.

The benevolent government will now decide, if the tariff-induced technology transfer is welfare enhancing. Differentiating the welfare function (equation (2.14)) with respect to *t* yields

$$\frac{\delta W}{\delta t} = \underbrace{\tfrac{1}{2}\frac{\delta \hat{s}}{\delta t}(\theta^{*2} - \theta_l^2) + \tfrac{1}{2}\hat{s}(2\theta^*\frac{\delta \theta^*}{\delta t} - 2\theta_l\frac{\delta \theta_l}{\delta t}) - \frac{\delta \hat{p}}{\delta t}(\theta^* - \theta_l) - \hat{p}(\frac{\delta \theta^*}{\delta t} - \frac{\delta \theta_l}{\delta t})}_{\text{Change in surplus of the low income consumers}}$$
$$\underbrace{-\frac{\delta \theta^*}{\delta t}(\theta^* s^* - p^*) - \frac{\delta p^*}{\delta t}(\bar{\theta} - \theta^*)}_{\text{Change in surplus of the high income consumers net of tariff revenues}} \qquad (2.25)$$

The derivatives have ambiguous signs apart from the importer's price, which obviously falls as a result of an increased tariff ($\frac{\delta \hat{p}^*}{\delta t} < 0$, see Appendix 2C). The government's market power drives down p^*, which has a positive effect on welfare. In addition the local product's price rises by less due to tougher price competition. Equation (2.25) can be simplified to

$$\frac{\delta W}{\delta t} = \tfrac{1}{2}\frac{\delta \hat{s}}{\delta t}(\theta^{*2} - \theta_l^2) - \frac{\delta \theta^*}{\delta t}t - \frac{\delta \hat{p}}{\delta t}(\theta^* - \theta_l) - \frac{\delta \hat{p}^*}{\delta t}(\bar{\theta} - \theta^*) \qquad (2.26)$$

Proposition2.2a: If suppliers interact strategically in prices, for an initial level of $t=0$ the government has an incentive to raise tariffs, as it increases welfare.

Proof: See Appendix 2B.

This model has shown that there exists a tariff that induces technology transfer. If the foreign firm engages in price competition, the social cost of the technology transfer in terms of price increases for both products are, however, more limited than in the case where the importer does not react in prices. In the case of price competition, there exists a tariff that unambiguously increases welfare.

2.5. Conclusions

The industrial production in a less developed country is often of lower quality than in a more advanced country. This makes consumers worse off and can hamper long run development, because technological progress is slower. Technology transfer from advanced firms can help to engender catch-up.

Technology transfer is said to be attracted by securing high levels of human capital and good infrastructure, in order to offer fertile ground to foreign firms in the less developed local economy. While this is certainly very sound policy advice, it is possibly not easy to finance in a relatively poor country. Thus import tariffs have been suggested to generate technology transfers.

Technology transfer in the existent literature tends to lower the production cost in industries with undifferentiated products. The present model considers the impact of tariffs on the quality choice of the local firm, when the local and the imported products are vertically differentiated, and the local industry produces the low-quality product due to its disadvantageous initial conditions.

If products are vertically differentiated, and production cost are equal, the producer of the low-quality good maximizes monopoly power and profits by differentiating the product. The introduction of a tariff, however, increases the production cost of the importer's products on the local market. This gives the local firm incentives to increase its quality and steal some of the importer's business by undercutting import prices. If technology transfer is connected with increasing fixed cost, a tariff policy of the local government induces technology transfer and also increases social welfare in most cases. The tariff policy is more effective in terms of welfare, if the importer reacts in prices, because the tariff induces a reduction in the high-quality firm's price in addition to the improvement of the local quality. The tariff should not be too high, however, because that would turn the local supplier into a monopolist, which reduces his incentives to improve quality.

This model determines the conditions under which technology transfer can be induced. Given that a tariff policy is easily feasible, It might be an alternative way of attracting technology and enhancing development.

Appendix 2A: Exogenous p^*

Lemma 2.1: A unique interior solution to the optimization problem in (2.8) exists, if the following sufficient conditions are satisfied:

(i) $K(s)$ is increasing and continuously differentiable in s.

(ii) $$K'(s=0) < \frac{\delta \hat{R}(s=0, s^*, p^*, t)}{\delta s} \qquad \forall s^*, \forall p^*, \forall t$$

(iii) $$K'(s^M(t)) > \frac{\delta \hat{R}(s^M(t), s^*, p^*, t)}{\delta s} \qquad \forall t < t^M, \forall s^*, \forall p^*$$

where t^M is the solution of $K'(s^M(t)) = \dfrac{\delta \hat{R}(s^M(t), s^*, p^*)}{\delta s}$

(iv) $$K''(s) > \frac{\delta^2 \hat{R}(s, s^*, p^*, t)}{\delta s^2} \qquad \forall s^*, \forall p^*, \forall t$$

Proof:

(i) As $\dfrac{\delta \hat{R}(s=0, s^*, p^*, t)}{\delta s}$ is continuously differentiable, the marginal profit function $\dfrac{\delta \pi}{\delta s} = \dfrac{\delta \hat{R}}{\delta s} - K'(s)$ will also be continuously differentiable.

(ii) This condition secures that profits rise initially.

(iii) $s^M(t)$ defines the quality level at which the importer is squeezed out of the market for any t. It is decreasing in t. For all $t < t^M$ K is defined such that $\dfrac{\delta \pi(s^M(t))}{\delta s} < 0$.

(iv) This condition secures uniqueness of the interior solution, if conditions (i)-(iii) are satisfied.

QED.

Proposition 2.2: For an initial level of *t 0* the government has an incentive to raise the tariff level *t*, as it is welfare enhancing if

$$\frac{\delta \hat{s}}{\delta t} > \frac{2s(s^*-s)}{p^*s^*} > 0 \tag{2.18}$$

Proof: For an initial tariff level of *t=0* welfare rises in *t* if

$$\frac{\delta W}{\delta t} = \tfrac{1}{2}\frac{\delta \hat{s}}{\delta t}(\theta^{*2} - \theta_l^2) - \frac{\delta \hat{p}}{\delta t}(\theta^* + \theta_l) > 0 \tag{2.27}$$

For (2.27) to hold, it is sufficient that (see Appendix 2C for $\frac{\delta \hat{p}}{\delta t} > 0$)

$$\begin{aligned} &\tfrac{1}{2}\frac{\delta \hat{s}}{\delta t}(\theta^* + \theta_l) - \frac{\delta \hat{p}}{\delta t} > 0 \\ &= \left[\frac{p^*(3s^*-2s)}{2s^*(s^*-s)} - \frac{p^*}{2s^*}\right]\frac{\delta \hat{s}}{\delta t} - \frac{s}{2s^*} > 0 \end{aligned} \tag{2.28}$$

with $(\theta^* + \theta_l) = \frac{p^* - \hat{p}}{s^* - \hat{s}} + \frac{\hat{p}}{\hat{s}} = \frac{p^*(3s^*-2s)}{2s^*(s^*-s)}$. (2.28) is the case if

$$\frac{\delta \hat{s}}{\delta t} > \left[\frac{2s(s^*-s)}{p^*s^*}\right] \tag{2.29}$$

QED.

Appendix 2B: Endogenous $p*$

If suppliers interact strategically in prices, marginal revenues are not necessarily increasing in the quality level. For a given tariff marginal revenues are

$$\frac{\delta\hat{R}}{\delta s}=\frac{s*}{(4s*-s)^3}\left[s*\bar{\theta}^2(4s*-7s)+2\bar{\theta}t(4s*+s)+\frac{t^2}{(s*-s)^2}(4s*^2+ss*-2s^2)\right] \quad \textit{for } s<s^M(t)$$

(2.30)

For $s\leq 4/7\, s*$ marginal revenues are positive for all levels of *t*. For $s>4/7\, s*$ and *t* relatively small the derivative can become negative. Marginal revenues are, however, always positive at $s=s^M(t)$. The marginal revenue function at $s=s^M(t)$ follows a function *f(t)*

$$f(t)=\frac{\delta\hat{R}(s^M(t))}{\delta s}=$$

$$\frac{\bar{\theta}^2 s*^2}{(4*-s^M(t))^2}\left[(4s*-7s^M(t))+\frac{4(4s*+s^M(t))(s*-s^M(t))}{(2s*-s^M(t))}+\frac{4s*(4s*^2+s^M(t)s*-2s^M(t)^2)}{(2s*-s^M(t))^2}\right]$$

(2.31)

f(t) is positive for all $t\in[0,\bar{\theta}s*]$. The first derivative of the function *f(t)* first rises and then falls in $s^M(t)$. *f(t)* takes the values $\bar{\theta}^2/4$ for $s=0$ and $\bar{\theta}^2/3$ for $s=s*$, remaining positive in that range. *f(t)* builds the frontier between the cases where the local producer supplies the market together with the importer and where she is the only supplier. It shows that marginal revenue at $s=s^M(t)$ is always larger than at *s 0.*

Proposition 2.1a: If both suppliers compete in prices, the optimal level of quality chosen by the local supplier $\hat{s}$ increases in the tariff level t, as long as $t \in \left[0, t^M\right[$.

Proof: For Proposition 2.1a to hold it needs to be the case that

$$\frac{\delta\hat{s}}{\delta t} = -\frac{\delta E / \delta t}{\delta E / \delta s} = -\frac{\delta^2 \hat{R}(\hat{s}, s^*, t) / \delta s \delta t}{\delta^2 R^2(\hat{s}, s^*, t) / \delta s^2 - K''(\hat{s})} > 0 \qquad (2.32)$$

where E is first order condition of the local producer's optimization problem (condition (2.24)). This is the case if:

(i) The numerator of equation (2.32) is positive. Marginal revenue rises with the level of tariff adopted by the government as long as the importer does not get squeezed out of the market

$$\frac{\delta^2 \hat{R}}{\delta s \delta t} = \frac{s^*}{(4s^* - s)^3}\left[2\bar{\theta}(4s^* + s) + 2t\frac{4s^{*2} + s^* s - 2s^2}{(s^* - s)^2}\right] > 0 \quad \text{for} \quad s < s^M(t) \qquad (2.33)$$

Hence, the local producer's incentives to improve local quality increase with a tariff, as long as the tariff does not drive the importer out of the market.

(ii) The denominator of equation (2.32) is negative. This is second order condition for a maximum of the local producer's optimization problem (condition (2.24)). Lemma 2.1a secures that the second order condition is always satisfied.

Hence as long as the importer is not squeezed out of the market ($t \in \left[0, t^M\right[$), local quality rises with the tariff level. **QED.**

Proposition 2.2a: If suppliers interact strategically in prices, for an initial level of $t=0$ the government has an incentive to raise tariffs, as it increases welfare.

Proof: Welfare increases in tariff level for $t=0$

$$
\begin{aligned}
\frac{\delta W}{\delta t} &= (\theta^* - \theta_l)\left[\tfrac{1}{2}(\theta^* + \theta_l)\frac{\delta\hat{s}}{\delta t} - \frac{\delta\hat{p}}{\delta t}\right] - \frac{\delta\hat{p}^*}{\delta t}(\bar{\theta} - \theta^*) \\
&= \bar{\theta}\left[\frac{(3s^* - 2s)}{2(4s^* - s)} - \frac{(4s^{*2} - 8ss^* + s^2)}{(4s^* - s)^2} + \frac{12s^{*2}}{(4s^* - s)^2}\right]\frac{\delta\hat{s}}{\delta t} - \frac{s}{(4s^* - s)} + \frac{2(2s^* - s)}{(4s^* - s)} \qquad (2.34) \\
&= \frac{\bar{\theta}s^*(28s^* + 5s)}{2(4s^* - s)}\frac{\delta\hat{s}}{\delta t} + (4s^* - 3s) > 0 \quad \forall s, s^*
\end{aligned}
$$

where

$$
(\theta^* + \theta_l) = \frac{\hat{p}^* - \hat{p}}{s^* - \hat{s}} + \frac{\hat{p}}{\hat{s}} = \frac{\bar{\theta}(3s^* - 2s)}{(4s^* - s)},
$$

$$
(\theta^* - \theta_l) = \frac{\bar{\theta}s^*}{(4s^* - s)} \text{ and } (\bar{\theta} - \theta^*) = \frac{2\bar{\theta}s^*}{(4s^* - s)}.
$$

QED.

Appendix 2C: The Impact of a Tariff on Prices

In the case of exogenous import prices the price, of the local product increases with the tariff level (given that $\frac{\delta \bar{s}}{\delta t} > 0$)

$$\frac{\delta \hat{p}}{\delta t} = \frac{p^*}{2s^*}\frac{\delta \bar{s}}{\delta t} + \frac{s}{2s^*} > 0 \tag{2.35}$$

In the case of strategic interaction, the price of the local product increases with the tariff level (given that $\frac{\delta \bar{s}}{\delta t} > 0$) in most cases

$$\frac{\delta \hat{p}}{\delta t} = \frac{\left[\bar{\theta}(4s^{*2} - 8ss^* + s^2) + 4s^* t\right]}{(4s^{*2} - s)^2}\frac{\delta \bar{s}}{\delta t} + \frac{s}{(4s^* - s)} \tag{2.36}$$

The importer's price obviously falls with the tariff level as by assumption $0 < t < \bar{\theta} s^*$

$$\frac{\delta \hat{p}^*}{\delta t} = \frac{2s^*(t - 3s^*\bar{\theta})}{(4s^{*2} - s)^2}\frac{\delta \bar{s}}{\delta t} - \frac{(2s^* - s)}{(4s^* - s)} < 0 \tag{2.37}$$

3. Foreign Direct Investment in Central and Eastern Europe: Do Mainly Small Firms Invest?

3.1. Introduction

The structure of German firms' foreign direct investment (FDI) in Central and Eastern Europe (CEE) reveals the spatial aspect of FDI: German small firms' investment takes place more than proportionally in CEE. Large German firms, on the other hand, show relatively little interest in CEE (Härtel et al., 1995); Notwithstanding that big firms invest more in CEE than small firms in absolute terms. Large firms, however, have a higher propensity to invest in general (Dunning, 1993).

In this chapter, we will argue theoretically and empirically, that CEE represents an interesting production location mainly for such firms that have not yet invested abroad, and are located close by. This implies (1) that many small German firms, that have never invested abroad before, do invest in CEE; (2) that some firms would have invested in CEE under perfect foresight, but do not now, because they have already invested in other regions of the world. (3) The biggest firms invest in both the classical investment locations *and* in CEE.

This approach explains why FDI in CEE has lagged behind expectations so far. In addition, it implies that the economic integration at the borders between transition countries and Western Europe must be booming. This has consequences in terms of labor markets, technology spillovers and growth. Comparable developments might be taking place in the South of the United States after the creation of NAFTA.

In the second part of the chapter, the model is presented. CEE has several features, that we have modeled: for many German firms CEE is located in their direct neighborhood. This should reduce the transaction cost (monitoring, coordination, collection of experience and information) of FDI considerably (Hoesch, 1996). CEE also offers lower production cost paired with considerable risk (Lankes and Stern, 1998). Moreover, we can safely assume, that CEE was not considered as a production location before, and that the opening of CEE came as a surprise to all firms (German and others). Section 3.3 presents the results that will be tested. The empirical test of the model in sections 3.4 and 3.5 is based on a survey of 2065 German firms in the industrial sector. The survey only contains information about production locations. There is no information about the project's purpose (horizontal versus vertical FDI).[27] We conclude in section 3.6 with some remarks about possible future research on this topic.

3.2. The Model

The theoretical literature on FDI is based on the confrontation of fixed cost of production (concentration) and transport cost (proximity) (Brainard, 1993, and Markusen, 1995). We adopt this approach and add firms size and distance. The different FDI behavior of large firms and small firms is modeled in a world where transport cost depend on distance as well as on the amount transported (iceberg cost). While trading with the rest of the world, firms collect information and experience about possible production locations elsewhere. Cost and return on FDI depend on the cost structure of the firm as well as on distance between the firm and the investment location. In addition, we introduce an unexpected time lag of appearance of production locations. The Model can lead to the following structure of FDI:

1. The further away the investment location, the larger is the average investing firm.
2. If an investment opportunity arises *„close by“* and *unexpectedly* after all firms have taken their investment decisions, firms, that have not invested previously, might be attracted by this new opportunity due to its proximity. Moreover, some of the previous investments will be suboptimal under perfect foresight. Given, however, that production locations cannot be shifted without cost, the new production location will receive less investments than should be expected.

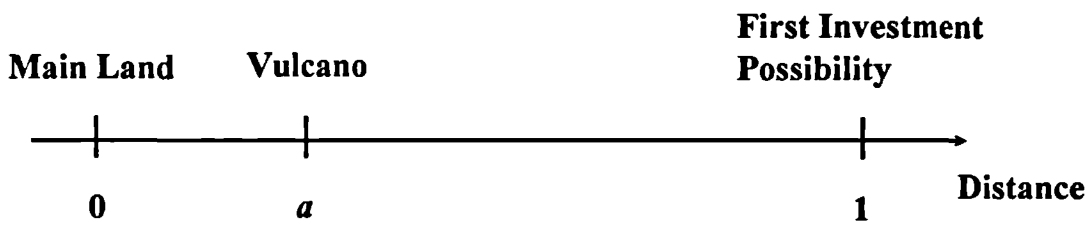
3.3. Assumptions

Assumption 3.1: The world consists of an infinite line starting at point 0. Initially, there are only two production locations on the line, one in 0 (the main land) and the

[27] See Markusen et al. (1996) for a definition of horizontal and vertical FDI.

other in 1. Later, another production location (the vulcano) appears in location a ($0<a<1$). Prior to investing, firms need to collect information and experience about a production location.

Figure 3.1: Geography



Assumption 3.2: There is a large number of firms n. Each firm i produces at constant marginal cost $c_i \in [c_{min}, c_{max}]$, where $c_{min} > 0$. The firms with lower marginal cost are assumed to be the bigger firms.[28] All firms function as local monopolies on all points on the line.[29]

Assumption 3.3: The transport cost per unit and distance traveled are δt, where δ is the distance traveled.

Assumption 3.4: Consumers are located along the infinite line and have unit demand per period. Their reservation price is θ, for $\theta > c_{max}$.[30]

---

[28] In an oligopolistic Cournot market, like there could be on the main land, a firm with smaller constant marginal cost would cover a larger part of the market.

[29] E.g., they sell different products, travel at different times, or along a different line.

[30] The firms face Bertrand competition at each point: the indigenous unit cost of production is $(\theta + \varepsilon)$. Thus the locals buy one unit per period from the firms at a price θ, paying with natural resources (e.g. gold), they posses.

Firm i's profit per unit sold is $(\theta - c_i - \delta t)$, where θ is the price of one unit of goods. The profit margin decreases with unit production cost and distance traveled.

Lemma 3.1: The maximized profit per period of a firm producing only in location 0 (without any investment) is

$$\pi_{ij}^{no\,Invest} = A_i = \int_0^{\delta_i} (\theta - c_i - \delta t)\, d\delta = \tfrac{1}{2}\delta_i^2 t \tag{3.1}$$

for $j = 1,2,3$ periods and $\delta_i = \dfrac{\theta - c_i}{t}$.

Proof: The firm sells until marginal return equals marginal cost at $\delta_i = \dfrac{\theta - c_i}{t}$.

With this form of transport cost, firms with lower marginal cost of production maintain positive marginal profits for a longer distance on the line, implying also higher total profits.

Assumption 3.5: There are three periods in time. Firms have perfect foresight about everything apart from the appearance of the Vulcano a.

Period 1. Firms are born with knowledge about location 0. They produce in location 0, ship and sell their products and collect experience and information.

Period 2. Some firms invest in location 1. After investment in location 1 has taken place, location a appears unexpectedly. All firms produce, ship, sell and collect information and experience.[31]

Period 3. Some firms invest in location a. All firms produce, ship and sell.

Assumption 3.6: Investing *abroad* (in locations 1 and a) creates fixed cost. These fixed cost consist of two components:

[31] With an infinite time horizon, the story could, for instance, be that location a will appear with certainty, but in every period the probability of appearance is the same. Over an infinite time horizon that reduces the probability of appearance of a in each period to zero.

(i) The cost of information and experience EI_i^k, where $(k = a, 1)$

$$EI_i^k = \begin{cases} \int_{\delta_i}^{k} (\theta - c_i - \delta t) d\delta & \delta_i < k \\ 0 & \text{otherwise} \end{cases} \tag{3.2}$$

(ii) The fixed cost of building the factory in location k [32]

$$FA^k = \tfrac{3}{8} kt \tag{3.3}$$

Given $\delta_i = \dfrac{\theta - c_i}{t}$, the total cost of foreign investment in location k are

$$C_i^k = \begin{cases} EI_i^k + FA^k = \tfrac{1}{2}(k - \delta_i)^2 t + \tfrac{3}{8} kt & \delta_i < k \\ FA^k = \tfrac{3}{8} kt & \delta_i \geq k \end{cases} \tag{3.4}$$

An investment abroad requires knowledge about the local situation: this may include information about the legal system, the language as well as the culture, the market, other firms etc. If a firm sells its products somewhere, it at the same time collects experience and information necessary to set up production facilities there. Otherwise it somehow has to pay for information and experience.[33]

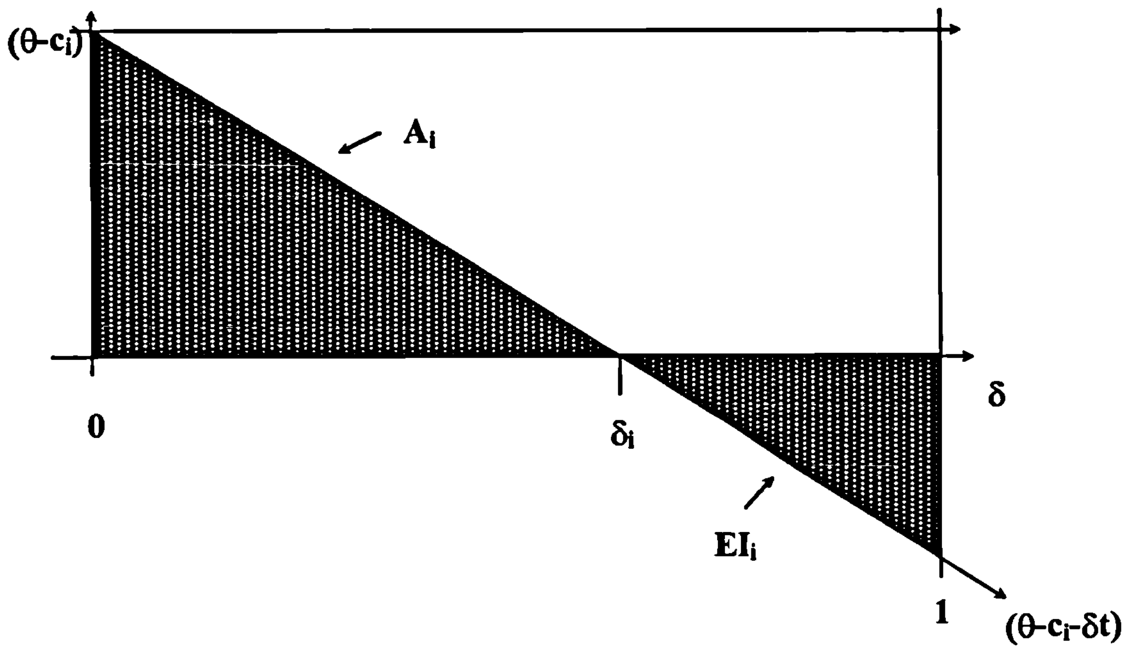
The cost of investment are rising in k and in c_i. The further away the investment location, and the higher marginal cost of production, the higher are the cost of collecting experience and information about these locations. A positive externality arises here, because lower marginal cost not only generate higher per unit profit, but they also reduce this component of the fixed cost of foreign direct investment.

[32] The number 3/8 was chosen for expositional simplicity. See Appendix 3E for the more general model where the cost of setting up the factory also vary.

[33] It is assumed here that information and experience are highly firm specific, so that they cannot easily be bought from another firm.

Graphically profits and cost of information and experience are represented here:

Figure 3.2: Profits and Cost of Investment in Location 1 in Period 1



3.4. Results

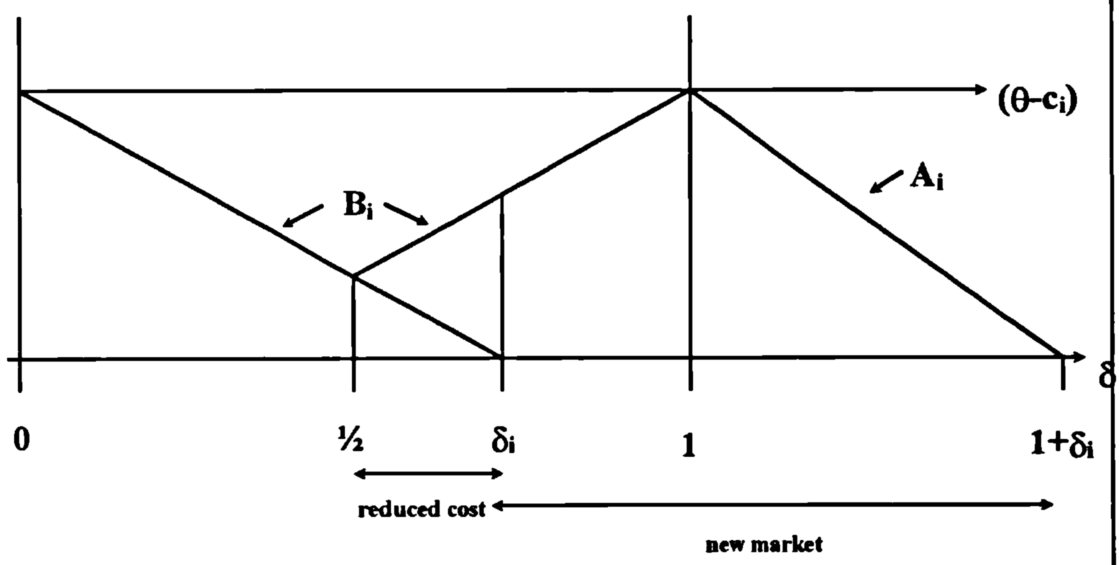
3.4.1. Intertemporal Profit Maximization when only Location 1 Exists

In period 1, firms maximize their profit over all three periods, not taking into account the arrival of location a in period 2. For certain firms it is worth incurring fixed cost of investment in period 1 in order to set up a factory in location 1. The investment enables them to sell out of locations 0 and 1 in periods 2 and 3.

An investment in location 1 increases marginal profit in two ways: on the one hand, it extends the market, as the investing firm can now reach up to $1+\delta_i$ on the line. This effect is equivalent to the typical market effect of FDI in Markusen et al. (1996). On the other hand, the production site in location 1 reduces transport cost for some areas that were already served from the main land. Thus, trade in periods 2 and 3 generates additional profits for these areas on the line. This is a proximity argument of FDI (Brainard, 1993). There is, however, no factor cost difference in the classical sense to motivate FDI in this model.

In this framework, the larger δ_i, the more important becomes the proximity advantage over the market reach advantage of an investment in location 1. In addition, the cost of information and experience are inversely related to δ_i (Figure 3.3).

Figure 3.3: Profits after Investment in Periods 2 and 3



Proposition 3.1: In the beginning of period 2 all firms with $\delta_i > \frac{1}{2}$ invest in location 1.

Proof: see Appendix 3A.

This first result corresponds to the stylized fact that mainly large firms invest abroad. In addition, they also become bigger by doing so.

3.4.2. The Zero Probability Event: Production Location in *a*

In period 3, each firm can consider to invest in location a. The cost of investing there are lower than for location 1. Time left to sell, however, is also shorter, namely, only period 3.[34] The investment decision taken in period 1 about location 1 diversifies the firms' interest in investing in location *a*. Firms that have already invested in location 1 only benefit in terms of transport cost from investing in location *a*, whereas firms that only produce on the main land can reach a larger market when investing in location *a*. (Big) Firms that have invested in location 1 are from now on called F_1 $(\Rightarrow \delta_1 \geq \frac{1}{2})$, the others (small) are F_0 $(\Rightarrow \delta_0 < \frac{1}{2})$.

3.4.2.a. The Gain of Investing in Location *a* for Type-0-Firms

Adapting their profit maximization to the change of situation at the end of period 1, type-0-firms compare net profits without investment in location a, $\Pi_0^{no\,Invest\,a}$, to profits minus cost of investing, $\Pi_0^{Invest\,a}$, for the remaining two periods. F_0 invest in location *a*, if $\Pi_0^{Invest\,a} > \Pi_0^{no\,Invest\,a}$. Small firms face a similar optimization problem for location a as they did in period 1 for location 1. If $\delta_0 < a$, they have to pay extra cost of information and experience in order to invest in location *a*.

Proposition 3.2: F_0 realize additional profits from investing in location a, only if $0 < a < 4\delta_0 - \frac{3}{2}$, implying $a < \delta_0$. The gains from investing in location a are $G_0^a = \Pi_0^{Invest\,a} - \Pi_0^{no\,Invest\,a} + C_0^a$.

Proof: see Appendix 3B.

A relatively high δ_0 is necessary to make an investment in location a profitable, so that only a small proportion of F_0-firms invest there. The total amount sold, as well as

[34] Period 3 could also stand for the remaining future until infinity discounted at a given discount rate *r*, where *r* is positive and smaller than unity as usual. In that case, profits of period 3 would have to be divided by *r*. This would as expected increase their value, but it would not change the fundamental results of the model. Thus for the sake of mathematical simplicity we have ignored the intertemporal discount rate for periods 2 and 3 and the future.

marginal profit depend positively on δ_0. If δ_0 becomes too small, gains fall short of the fixed cost of investment.

3.4.2.b. The Gain of Investing in Location *a* for Type-1-Firms

For F_1 investment in location a does not impose any extra cost of information and experience. The firm travels along the new land anyhow. But there is no market coverage gain connected with investing in location a. All increases in profits due to investment in a are driven by transport cost reduction. F_0-firms invest in *a*, if $\Pi_1^{Invest\ a} > \Pi_1^{no\ Invest\ a}$.

Proposition 3.3: Independently of the size of δ_1, F_1 invest in location a, if $a < \frac{1}{4}$. The additional profit from investing in location a are $G_1^a = \Pi_1^{Invest\ a} - \Pi_1^{no\ Invest\ a} + C_1^a$.

Proof: see Appendix 3C.

Only if the new investment location is close enough to the main land, can relatively high marginal gains from investing exceed relatively low cost of setting up a factory.

3.4.2.c. The Structure of Investment in *a*

By comparing the two gain functions G_0^a and G_1^a and the cost of investment, the structure of investment in location a can be derived.

Proposition 3.4: There are three possible outcomes depending on the distance of location a from the main land:

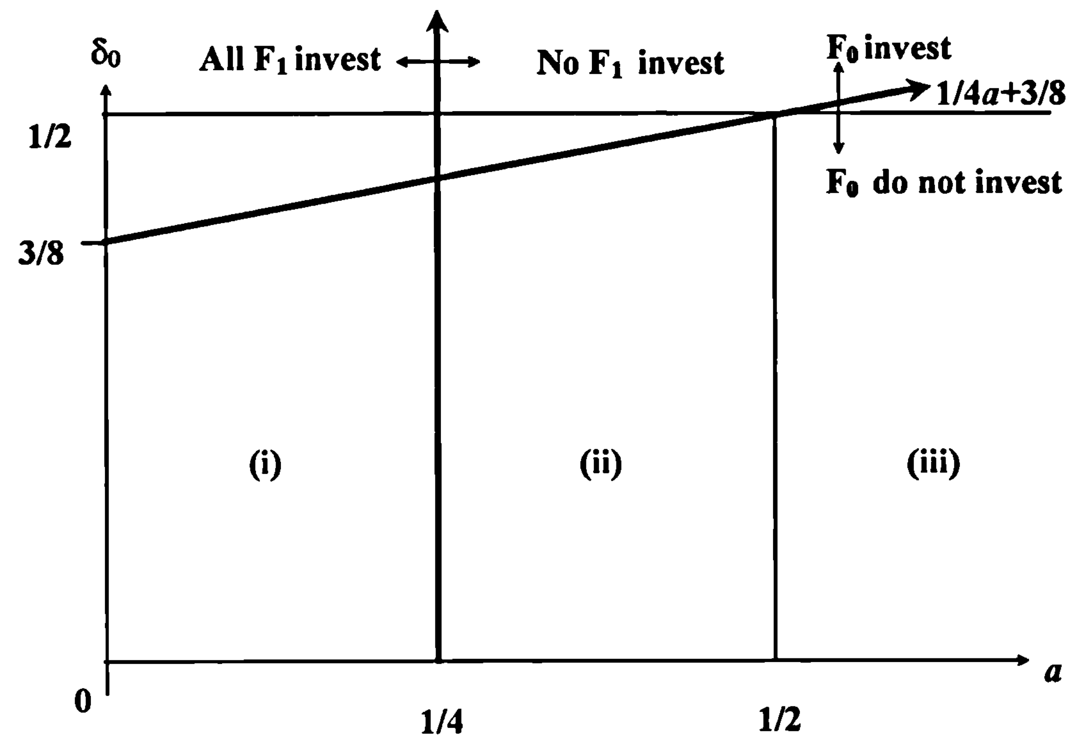
(i) F_1 invest in location a ($G_1^a > C_1^a$), if $a < \frac{1}{4}$. All small firms, for which $\delta_0 > \frac{1}{4}a + \frac{3}{8}$ ($G_0^a > C_0^a$), also invest there.

(ii) No F_1 invest in location a ($G_1^a \le C_1^a$), if $a > \frac{1}{4}$. All small firms, for which $\delta_0 > \frac{1}{4}a + \frac{3}{8}$ ($G_0^a > C_0^a$), do invest there.

(iii) None of the firms invest in location a ($G_1^a \le C_1^a$) and ($G_0^a \le C_0^a$), if $a \ge \frac{1}{2}$.

Proof: Follows from Propositions 3.2 and 3.3. **QED**.

Figure 3.4: The Structure of Investment in Location a



If location a appears close to the main land, the cost of investment are low and the marginal gain from saving transport cost is high for the large firms. Thus they invest in the new location. Only a portion of the small firms invest there: only for the bigger small firms the gain exceeds the cost of investment.

If a erupts not so close to the main land, but still far from location 1, the large firms do not invest. A portion of bigger F_0-firms, however, does invest.

3.4.3. The Firms, that Would Have Invested in Location a

Had location a existed in period 1, some of the firms that have invested in location 1, might have preferred to invested in location a (only).

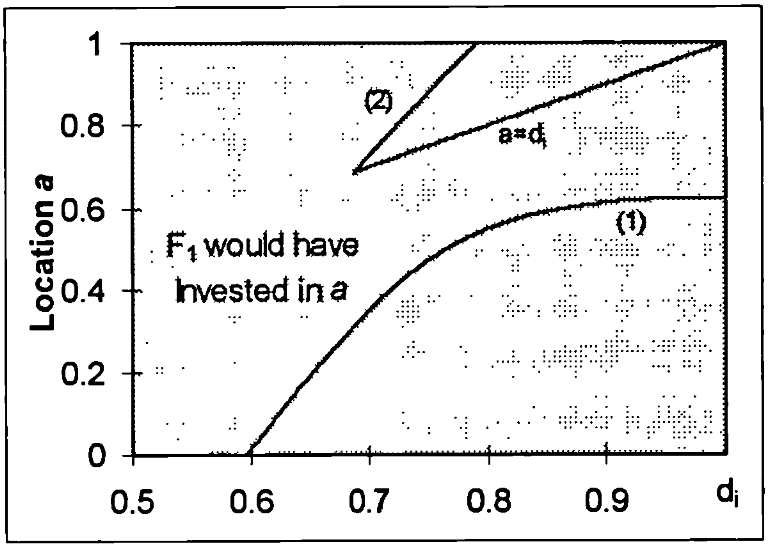
Proposition 3.5: If location a already exists in period 1, some of the F_1 $(\delta_i > \frac{1}{2})$ will find it more profitable to invest in location a than in location 1. A F_1-firm would have invested in location in period 1, if

$$a > \begin{cases} (1) \quad (2\delta_i - \tfrac{3}{8}) + \sqrt{5(\delta_i^2 - \tfrac{3}{2} + \tfrac{37}{64})} & a \le \delta_i \\ (2) \quad 3\delta_i - \tfrac{11}{8} & a > \delta_i \end{cases} \tag{3.5}$$

Proof: see Appendix 3D.

The area, in which F_1-firms would have invested in location a, in the a, δ-space looks like this:

Figure 3.5: F_1-Firms, that would have Invested in Location a



The model predicts that the further away location a is located (becoming a better substitute to location 1), the more F_1-firms would have invested there. For any possible location of a at least some medium sized F_1-firms would have invested there, had the location existed before. Those firms do, however, not invest there in period 2, because they have already invested in location 1 and shifting production locations is very costly.

3.5. Results to be Tested

If Central and Eastern Europe can be compared with an eruption of $\frac{1}{4} \leq a < \frac{1}{2}$, then we should observe (1) that small firms are relatively more attracted by CEE as production location than big firms and (2) that having already invested somewhere in the world dissuades some medium sized firms from investing in CEE.

3.6. The Data

The empirical analysis is done with survey data from the Ifo Investionstest of spring 1995, containing information for the year 1994. The Investitionstest is a six-monthly survey of Western German firms in the industrial sector. The survey contains 2065 observations and covers about 47% of total investment and 36% of total employment in the industrial sector. The purpose of the survey is to estimate and evaluate investment of the Western German industry. In spring 1995, a short question about firms investments abroad was added to the survey. It was asked, where in the world firms have production facilities.[35]

As the actual purpose of the survey is to draw conclusions about investment in Western Germany, large firms are oversampled in the survey. For the hypothesis of this paper this is unfortunate, because it reduces the variation in the group of small firms in the regressions, and the unweighted data underestimates the importance of SME's activities in CEE.[36]

The average size of investing firms in the survey is larger than that of non-investing firms and increases with the distance of the investment location and the number of projects (see Table 3.4 in Appendix 3F). In addition, the above mentioned stylized facts are repeated in this survey: only 3% of the small and 8% of the medium sized

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[35] We do know neither how much capital was invested, nor how many projects a firm has per country. It can be assumed that larger firms invest more capital per project. The amount of capital invested might, however, be a blurry indicator of the economic impact of the project, as production locations abroad are often locally financed or joint ventured. Moreover, strategic alliances with very little or no capital involved can have similar effects and are not at all included in this survey.

[36] SME's activity is most probably also underestimated in this survey because SMEs tend to use strategic alliances more extensively than bigger firms (Kaufmann et al., 1990).

firms (SME) have production locations outside Germany.[37] The share of investing SME's, that produce in CEE, however, is very high (62% and 43%, respectively). Large firms have, as was to be expected, a much higher tendency to produce abroad, but their investment activities in CEE are relatively less pronounced than those of the SME's (see Table 3.1 in Appendix 3F).

Figure 3.6 shows that the rate of investing *only* in CEE decreases with the size of the investing firms, whereas the rate of investing in far-off regions (Africa, Americas, Asia and Australia) increases with size. The rate of investment in Western Europe looks similar. The rate of investing in CEE (including also firms that invest elsewhere), however, first falls with size, parallel to the rate of investing *only* in CEE, but then slightly picks up again. Possibly a large share of small firms would not have invested outside Germany at all, if CEE had not erupted. The kink in the rate of investment in CEE could stand for the fact that having invested somewhere else dissuades medium sized firms from investing in CEE as well.

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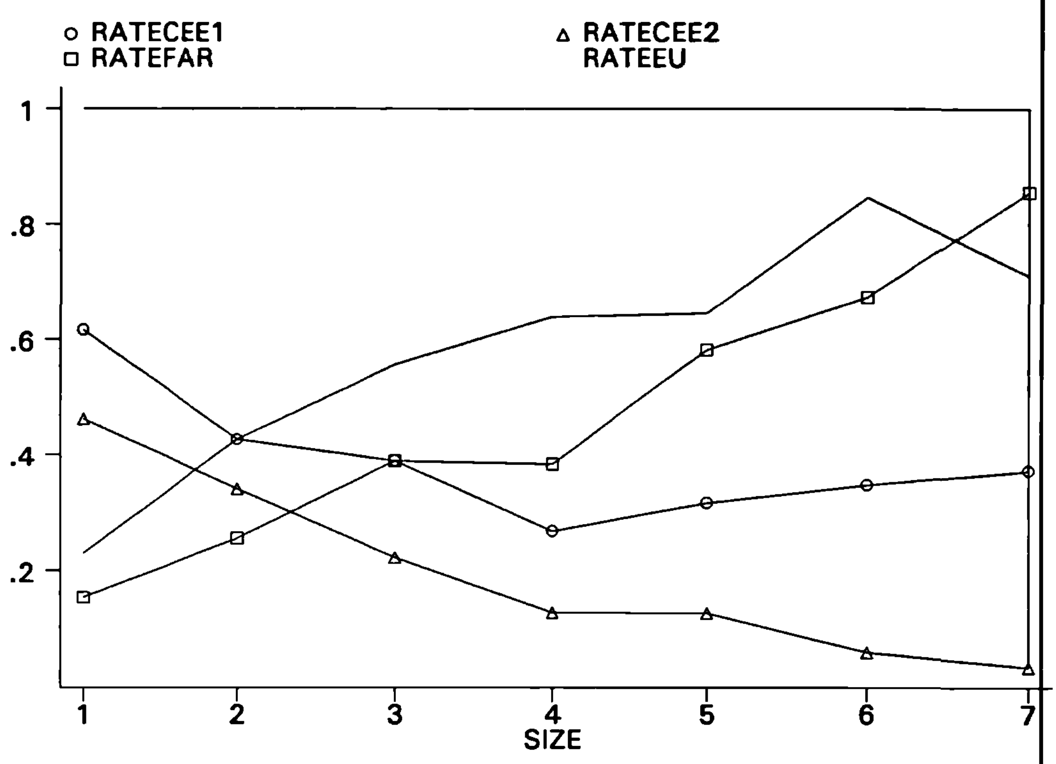
[37] Size is always in terms of employment (and logs of employment) of 1994 in Germany. Alternatives would have been turnover or investment in Germany. All three of them are very highly correlated (all correlation coefficients were above 0.87).

Figure 3.6: Investment Rates in CEE and in Far-Off Regions by Size



Ifo Investitionstest and own calculations

RATEFAR is the rate of investment in far-off regions (Americas, Africa and South East Asia), RATECEE1 is the rate of investment in CEE, RATECEE2 is the rate of investment *only* in CEE, and RATEEU is the rate of investment in Western Europe.

Even the unweighted data shows that already in 1994 CEE was an important investment location for German industrial firms.[38] Only Western Europe attracted a higher share of firms' investment. Almost half of the firms, that invest in CEE, invest *only* there. For the other regions of the world apart from Western Europe that number is much smaller (see Table 3.3 in Appendix 3F). When weighting the survey results with the actual firm size distribution in the German industry, the economic importance of CEE for SME's becomes clear: 70% of all German firms investing in production locations in CEE are SME's. Weighted in terms of number of projects in CEE, about

50% of all German industry's investment in production locations in CEE are done by SME's (see Table 3.2 in Appendix 3F). Kaufmann and Menke (1997) estimated for the year 1996 that as much as three quarters of German projects in CEE come from SMEs.

3.7. Regression Results

The following regressions will serve to further support our first very simple empirical results. In a first step, we are going to illustrate the significance of size when it comes to investing in production locations outside Germany. Then we will look at the subgroup of firms that have invested in CEE. Although size plays a less obvious role for members of the subgroup, the effect of having already invested somewhere else on the probability of investing in a production location in CEE is clearly negative.

3.7.1. Binomial Logit

First, we estimate the probability of setting up a production location outside Germany given size and sector of the firm. Then we estimate the probability of investing in CEE in the subsample of all investing firms. For this purpose we estimate a Logit Model (Greene, 1993, Chapter 21) with the Maximum Likelihood estimation procedure. We define a set of dummies:

$PL1_{ik}=1$ if firm i *has a production location in* k, *and $PL1_{ik}=0$ if firm* i *does not produce there.*

k stands for

- Production locations outside Germany
- Production Locations in CEE
- Production locations in far-off regions (Africa, Americas, Australia and Asia)
- Production locations in Western Europe
- Production locations far-off regions *and* in Western Europe

---

[38] In the survey of 1995, studied here, 7% of all firms had production locations in CEE (see Table 3.3 in Appendix 3F), according to the same survey a year earlier 14% of German industrial firms invested in CEE in production and distribution (Hoesch and Lehmann, 1994).

$PL1_{ik}$=1 if

$$\Pi_i^{Invest\ k} + \varepsilon_i^{Invest\ k} \geq \Pi_i^{no\ Invest\ k} + \varepsilon_i^{no\ Invest\ k} \tag{3.6}$$

If the disturbances $(\varepsilon_i^{no\ Iinvest\ k} - \varepsilon_i^{Iinvest\ k})$ are standardized to follow a logistic distribution with $E(\ldots) = 0$ and $V(\ldots) = 1$, and Λ represents the cumulative distribution, then the probability of investing in location k is

$$\begin{aligned} P(PL1_{ik} = 1) &= P[(\varepsilon_i^{no\ Iinvest\ k} - \varepsilon_i^{Invest\ k})\tfrac{\pi}{\sigma\sqrt{3}} < (\Pi_i^{Invest\ k} - \Pi_i^{no\ Iinvest\ k})\tfrac{\pi}{\sigma\sqrt{3}}] \\ &= \Lambda[(\Pi_i^{Invest\ k} - \Pi_i^{no\ Invest\ k})\tfrac{\pi}{\sigma\sqrt{3}}] \end{aligned} \tag{3.7}$$

The model predicts that net profits of investment in location k depend on firm specific variables such as size and whether investment has already taken place elsewhere, and on location specific variables such as the distance and the production cost. As mentioned before, the available data contains little information about both of these categories of variables, but it still fits the assumptions of the model quite well.

In a first regression, we estimated the probability of having a production location outside Germany with the entire sample (see Table 3.7 in Appendix 3F). The regression confirms that size of firms drives investment abroad. Even within the sectors the bigger firms tend to invest abroad.[39]

Then the probability of investing in CEE was estimated in the subsample of investing firms. For this purpose we assume that most of the investments in CEE in the data have taken place after most of the investments in the other regions of the world. This seems plausible, because the survey contains the stock of investment locations in the world up to 1994. Most probably, only very few of the investments outside CEE were made in the time period between 1990 and 1994, when almost all of the investment in CEE must have taken place.

Simply size in different specifications, when controlling for sectors, does not explain investment in CEE very well. If production locations in other regions of the world are included as explanatory variables (they are lagged by assumption) these as well as size turn significant, and the general significance of the estimates rises considerably (see Table 3.7 in Appendix 3F). It looks as if it is not necessarily the small investing firms, that locate in CEE, but that those which have not invested in other regions of the world tend to invest in CEE with a higher probability.

3.7.2. Multinomial Logit

In order to test the robustness of our first results, two multinomial Logit were estimated. For that purpose we define $PL2_i$ in the following way:

- $PL2_i$=0 if firms *i* has no production locations
- $PL2_i$=1 if firm *i* has a production location *only* in CEE
- $PL2_i$=2 if firm *i* has production locations in CEE *and* elsewhere
- $PL2_i$=3 if firms *i* has production locations everywhere *but* in CEE

If $PL2_i$=0, the profits of that choice has to be larger than those of all other choices for firms *i*. The same has to be true respectively for the other cases. If the disturbances can be standardized to follow a logistic distribution with $E(\ldots) = 0$ and $V(\ldots) = 1$, a multinomial Logit can be estimated (Maddala, 1983, Chapter 2). Two types of probabilities were estimated. One with the entire sample and one only with the subsample of 411 investing firms. Results are reported in Table 3.8 in Appendix 3F. Apart from the reasonable fit of the data, the results of multinomial Logits are difficult to interpret. For that reason we have simulated the regression results for the default sector (as only a few sectors have single significance) and all possible sizes in Figure 3.11 and 3.12 in Appendix 3F.

Both pictures tell a slightly different story from the binomial Logit regressions: when all observations are considered, it becomes clear that investment takes place mainly with the big firms. When only the investing firms are considered, the small investing firms go to CEE *only,* the big investing firms do both. For the medium sized firms,

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[39] Table 3.5 shows that the size varies within the sectors, even if the size distribution across sectors clearly also varies.

however, all three options are equally weighted. In this size category the decision seems to depend on other missing variables.

3.8. Conclusions

Small German firms have few production locations outside Germany, but if they invest, it tends to be only in one location and with a high probability in CEE. Thus CEE seems to offer locational advantages such as proximity and cost advantages to these firms that classical investment locations do not have. Big firms tend to have production locations further away, and in many places including also CEE as part of a multinational corporate strategy. For medium sized firms, however, other factors seem to play a role. In the model presented here, the fact that a firm has already invested somewhere else, can keep it from investing in a new location. We find empirical support for these theoretical findings in the binomial Logit regressions. In addition, the degree of globalization of the firms that is not picked up by size or the sectors might drive some medium sized firms to invest in all regions of the world.

Furthermore, we find that the weight of SME's investment in CEE is substantial. In 1994 only four years after the opening of these countries, up to 50% of the German industry's investments in production locations in CEE came from SMEs, notwithstanding that the typical small firm activities are strategic alliances and distribution investments rather than production investments. The results corroborate that proximity plays a role in the investment decisions of especially the small firms.

Further research should focus on the implications for local labor markets and growth of the regions concerned with of integration of CEE. So far there is little information about the character of the investments, as well as about the strategic alliances in these regions. We cannot say at this point whether jobs are exported, or whether integration increases international competitiveness of these regions, so that jobs are actually protected and growth is created.

Appendix 3A: Investment in Location 1

Proposition 3.1: In the beginning of period 2 all firms with $\delta_i > \frac{1}{2}$ invest in location 1.

Proof: If firm i does not invest in location 1, its profits over the three periods are (equation (3.1))

$$\Pi_i^{no\ Invest} = \sum_{j=1}^{3} \pi_{ij}^{no\ Invest} = 3A_i \tag{3.8}$$

If firm i invests in location 1, it receives $\pi_{i1}^{Invest} = A_i - C_i$ in period 1. In periods 2 and 3, respectively, firm i receives $\pi_{ij=2,3}^{Invest} = 3A_i$ if $\delta_i \leq \frac{1}{2}$, or $\pi_{ij=2,3}^{Invest} = A_i + 2B_i$ if $\delta_i > \frac{1}{2}$. Where

$$B_i = \int_0^{\frac{1}{2}} (\theta - c_i - \delta t) d\delta = \frac{1}{2}(\delta_i - \frac{1}{4})t \tag{3.9}$$

Thus profits after investment in location 1 are

$$\Pi_i^{Invest} = \sum_{j=1}^{3} \pi_{ij}^{Invest} = \begin{cases} \underbrace{A_i - C_i^1}_{period1} + \underbrace{3A_i}_{period2} + \underbrace{3A_i}_{period3} = 7A_i - C_i^1 & \delta_i \leq \frac{1}{2} \\ \underbrace{A_i - C_i^1}_{period1} + \underbrace{2B_i + A_i}_{period2} + \underbrace{2B_i + A_i}_{period3} = 3A_i + 4B_i - C_i^1 & \delta_i > \frac{1}{2} \end{cases} \tag{3.10}$$

Firm i invests in location 1, if the incremental profit from investing in location 1 is positive.

$$\Pi_i^{Invest} > \Pi_i^{no\ Invest} \tag{3.11}$$

If $\delta_i \leq \frac{1}{2}$, (3.11) implies

$$
\begin{aligned}
7A_i - C_i^1 > 3A_i \quad &\Rightarrow \\
4A_i > C_i^1 \quad &\Rightarrow \\
2\delta_i^2 t > \tfrac{1}{2}(1-\delta_i)^2 t + \tfrac{3}{8}t & \\
\delta_i^2 + \tfrac{2}{3}\delta_i - \tfrac{7}{12} > 0 &
\end{aligned}
\tag{3.12}
$$

This inequality only holds for $\delta_i > \frac{1}{2}$. Thus, it is not profitable for these firms to invest in location 1.

If $\delta_i > \frac{1}{2}$, (3.11) implies

$$
\begin{aligned}
3A_i + 4B_i - C_i^1 > 3A_i &\Rightarrow \\
4B_i > C_i^1 &\Rightarrow \\
2(\delta_i - \tfrac{1}{4})t > &\begin{cases} \tfrac{1}{2}(1-\delta_i)^2 t + \tfrac{3}{8}t & \tfrac{1}{2} < \delta_i \leq 1 \\ \tfrac{3}{8}t & 1 < \delta_i \end{cases}
\end{aligned}
\tag{3.13}
$$

These inequalities are satisfied for all $\delta_i > \frac{1}{2}$. Thus, these firms invest in location 1. **QED**.

Appendix 3B: Small Firm Investment in Location a

Proposition 3.2: F_0 realize additional profits from investing in location a, only if $0 < a < 4\delta_0 - \frac{3}{2}$, implying $a < \delta_0$. The gains from investing in location a are $G_0^a = \Pi_0^{Invest\ a} - \Pi_0^{no\ Invest\ a} + C_0^a$.

Proof: If firms do not invest, profits are as expected in period 1

$$\Pi_0^{no\ Iinvest\ a} = \sum_{j=2}^{3} \pi_{0j}^{no\ Invest\ a} = 2A_0 \tag{3.14}$$

If a firm does invest, there are three different profit functions depending on the location of a. The further a is located, the higher are the cost and the higher are the gains in terms of new markets, but the lower in terms of reduced transport cost. if a erupts beyond δ_0, the firm faces cost of information and experience. if a erupts beyond 2 δ_0, the gains in terms of market size are exhausted, but the cost in terms of experience and information continue to rise. Profits from investing in a are

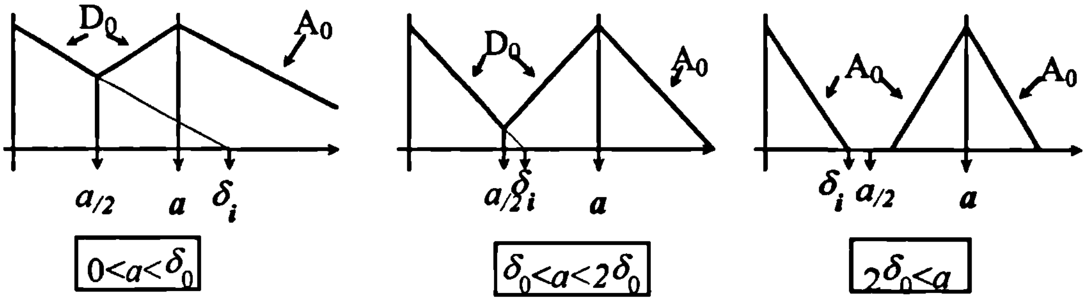
$$\Pi_0^{Invest\ a} = \sum_{j=2}^{3} \pi_{0j}^{Invest\ a} = \begin{cases} \underbrace{A_0 - C_0^a}_{Period 2} + \underbrace{2D_0 + A_0}_{Period 3} & 0 < a \le 2\delta_0 \\ \underbrace{A_0 - C_0^a}_{Period 2} + \underbrace{3A_0}_{Period 3} & 2\delta_0 < a \end{cases} \tag{3.15}$$

where

$$D_i = \int_0^{\frac{a}{2}} (\theta - c_i - \delta t) d\delta = \tfrac{1}{2}(a\delta_i - \tfrac{1}{4}a^2)t \tag{3.16}$$

Graphically, the three cases of investment of a small firm in location a can be represented in the following way:

Figure 3.7: Small Firm Profits after Investment in Location a



It is profitable for firms 0 to invests in location a, if

$$\Pi_0^{Invest\ a} > \Pi_0^{no\ Iinvest\ a} \tag{3.17}$$

(3.17) implies the following inequalities

$$\left.\begin{matrix} \underbrace{2A_0 + 2D_0 - C_0^a}_{\Pi_0^{investa}} \\ \underbrace{4A_0 - C_0^a}_{\Pi_0^{investa}} \end{matrix}\right\} > \left\{\begin{matrix} \underbrace{2A_0}_{\Pi_0^{noinvesta}} & 0 < a \le 2\delta_0 \\ \underbrace{2A_0}_{\Pi_0^{noinvesta}} & 2\delta_0 < a \end{matrix}\right.$$

$$\Rightarrow$$

$$\left.\begin{matrix} 2D_0 \\ 2A_0 \end{matrix}\right\} > \left\{\begin{matrix} C_0^a & 0 < a \le 2\delta_0 \\ C_0^a & 2\delta_0 < a \end{matrix}\right. \tag{3.18}$$

$$\Rightarrow$$

$$\begin{matrix} (1) \\ (2) \\ (3) \end{matrix} \left.\begin{matrix} (a\delta_0 - \frac{1}{4}a^2)t \\ (a\delta_0 - \frac{1}{4}a^2)t \\ \delta_0^2 t \end{matrix}\right\} > \left\{\begin{matrix} \frac{3}{8}at & 0 < a \le \delta_0 \\ \frac{1}{2}(a-\delta_0)^2 t + \frac{3}{8}at & \delta_o < a \le 2\delta_0 \\ \frac{1}{2}(a-\delta_0)^2 t + \frac{3}{8}at & 2\delta_0 < a \end{matrix}\right.$$

(1): For $a \le \delta_0$, (3.17) implies

$$\begin{aligned} \underbrace{(a\delta_0 - \tfrac{1}{4}a^2)t}_{G_0^a} > \underbrace{\tfrac{3}{8}at}_{C_0^a} \quad &\Rightarrow \\ \delta_0 - \tfrac{1}{4}a > \tfrac{3}{8} \quad &\Rightarrow \\ a < 4\delta_0 - \tfrac{3}{2} & \end{aligned} \tag{3.19}$$

as $\delta_0 < \frac{1}{2}$ (Proposition 3.1), $4\delta_0 - \frac{3}{2} \le \delta_0$ is true, so that inequality (3.19) can be satisfied. Thus small firms invest in location a, if $a < 4\delta_0 - \frac{3}{2}$.

(2): For $\delta_0 < a \le 2\delta_0$, (3.17) implies

$$\underbrace{(a\delta_0 - \tfrac{1}{4}a^2)t}_{G_0^a} > \underbrace{\tfrac{1}{2}(a-\delta_0)^2 t + \tfrac{3}{8}at}_{C_0^a} \tag{3.20}$$

It is clear from (3.19) that this inequality cannot hold for the range $\delta_0 < a \le 2\delta_0$. Thus these small firms do not invest in a.

(3): For $2\delta_0 < a$, (3.17) implies

$$\begin{aligned} \underbrace{\delta_0^2 t}_{G_0^a} > \underbrace{\tfrac{1}{2}(a-\delta_0)^2 t + \tfrac{3}{8}at}_{C_0^a} \quad &\Rightarrow \\ \underbrace{\delta_0^2 t - \tfrac{1}{2}(a-\delta_0)^2 t}_{J} > \underbrace{\tfrac{3}{8}at}_{F} & \end{aligned} \tag{3.21}$$

We can show that this inequality does not hold either, by showing that $J < \underbrace{(a\delta_0 - \frac{1}{4}a^2)t}_{H} < F$ for $2\delta_0 < a$. From (3.19) we know that $H < F$ for that range.

It remains to be shown that

$$\underbrace{\delta_0^2 t - \tfrac{1}{2}(a-\delta_0)^2 t}_{J} < \underbrace{(a\delta_0 - \tfrac{1}{4}a^2)t}_{H} \qquad \text{if} \quad 2\delta_0 < a \tag{3.22}$$

At $a = 2\delta_0$, $H > J$ and as the functions do not have another intersection after $2\delta_0$, $H > J$ is also true for all $a > 2\delta_0$

$$H_{a=2\delta_0} = \delta_0^2 t > \tfrac{1}{2}\delta_0^2 t = J_{a=2\delta_0} \tag{3.23}$$

and for the range $2\delta_0 < a$, the slopes of both functions are negative, one decreasing faster than the other

$$\frac{\partial H}{\partial a} = \delta_0 - \tfrac{1}{2}a < 0 \quad \text{and} \quad \frac{\partial J}{\partial a} = \delta_0 - a < 0 \qquad \text{for} \quad 2\delta_0 < a \tag{3.24}$$

Thus $J < H < F$ for $2\delta_0 < a$.

It has been shown that small firms in the range $a > \delta_0$ do not invest in location a, whereas small firms in the range $a \leq \delta_0$ do invest there, if $a < 4\delta_0 - \frac{3}{2}$. **QED**.

Appendix 3C: Large Firms Investment in Location *a*

Proposition 3.3: Independently of the size of δ_1, F_1 invest in location a, if $a < \frac{1}{4}$.

The additional profit from investing in location *a* are $G_1^a = \Pi_1^{Invest\ a} - \Pi_1^{no\ Invest\ a} + C_1^a$.

Proof: For F_1-firms no investment in location a leads to

$$\Pi_1^{no\ Invest\ a} = \sum_{j=2}^{3} \pi_{1j}^{no\ Invest\ a} = 4B_1 + 2A_1 \tag{3.25}$$

F_1-firm profits when investing in *a* are the following

$$\Pi_1^{Invest\ a} = \sum_{j=2}^{3} \pi_{1j}^{Invest\ a} = \underbrace{2B_1 + A_1 - C_1^a}_{Period\ 2} + \underbrace{2D_1 + 2E_1 + A_1}_{Period\ 3} \tag{3.26}$$

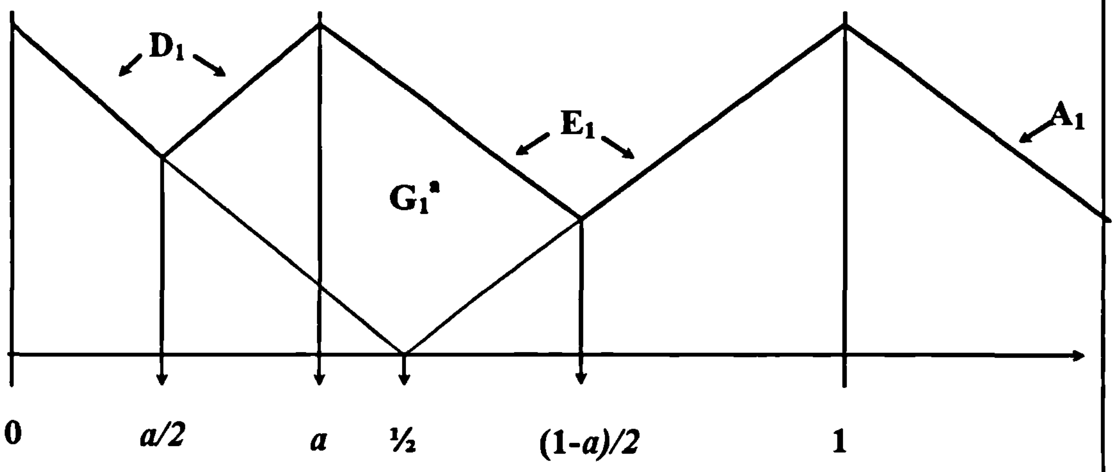
where

$$E_1 = \int_a^{\frac{1-a}{2}} (\theta - c_1 - \delta t)\, d\delta = \tfrac{1}{2}\left[(1-a)\delta_1 - \tfrac{1}{4}(1-a)^2\right]t \tag{3.27}$$

Where the additional profits from investing in location *a* are (Figure 3.8)

$$G_1^a = 2(D_1 + E_1 - B_1) = \tfrac{1}{2}a(1-a)t \tag{3.28}$$

Figure 3.8: Profits in Period 3 after Investment in Location a



Firms 1 invests in location a, if

$$\Pi_1^{Invest\ a} > \Pi_1^{no\ Invest\ a} \tag{3.29}$$

(3.29) implies

$$\begin{aligned} 2A_1 + 2B_1 + 2D_1 + 2E_1 - C_1^a > 4B_1 + 2A_1 \quad &\Rightarrow \\ 2(D_1 + E_1 - B_1) > C_1^a \quad &\Rightarrow \\ \underbrace{\tfrac{1}{2}a(1-a)t}_{G_1^a} > \underbrace{\tfrac{3}{8}at}_{C_1^a} & \end{aligned} \tag{3.30}$$

This inequality is satisfied for all $a < \frac{1}{4}$. **QED.**

For F_1 the gain arises only from reduced transport cost. Additional profits do not depend on δ_1, because as long as $\delta_1 \geq \frac{1}{2}$ the area that represents the additional profits of investment in a only varies with a. A small a leads to a smaller gain but also signifies a lower cost of investment. As a grows larger than $\frac{1}{4}$ cost rise above the gain. This leads to the rather stark result that either all or none of the F_1 invest in a.[40]

[40] In reality the very big firms invest in many locations and also in CEE (Lankes and Venables, 1996). This possibility is excluded here. Under the assumption that the fixed cost of setting up the factory vary across firms (e. g. according to sectors, see Hatzius, 1997), one could get a more pluralistic result, where among equally sized firms behavior differs.

Appendix 3D: The Firms, that Would Have Invested in Location *a*

If location a had existed already in period 1 (or had at least been expected to appear), some firms that might have invested only there rather than only in location 1. The reason being that the fixed cost of investment are lower there.

Proposition 3.5: If location a exists in period 1, some of the F_1 ($\delta_i > \frac{1}{2}$) will find it more profitable to invest in location a than in location 1. A F_1-firms invests in location a in period 1, if

$$a > \begin{cases} (1) \quad (2\delta_i - \frac{3}{8}) + \sqrt{5(\delta_i^2 - \frac{1}{2} + \frac{37}{64})} & a \leq \delta_i \\ (2) \quad 3\delta_i - \frac{11}{8} & a > \delta_i \end{cases} \tag{3.5}$$

Proof: A firm would have preferred to invest in location a in period 1, if

$$\Pi_i^{Invest} < \Pi_i^{Invest\ a\ in\ P1} = \begin{cases} \frac{3}{2}\delta_i^2 t + 2a(\delta_i - \frac{1}{4}a)t - \frac{3}{8}at & a \leq \delta_i \\ \frac{3}{2}\delta_i^2 t + 2a(\delta_i - \frac{1}{4}a)t - \frac{3}{8}at & -\frac{1}{2}(a-\delta_i)^2 \; a > \delta_i \end{cases} \tag{3.31}$$

where $\Pi_i^{Invest} = \frac{3}{2}\delta_i^2 t + 2(\delta_i - \frac{1}{4})t - \frac{3}{8}t - \frac{1}{2}(1-\delta_i)^2$ for $\frac{1}{2} < \delta_i < 1$ (equation (3.10)). If $\delta_i \leq \frac{1}{2}$, the firms would not invest in location 1 in any case (Proposition 3.1). If $\delta_i > 1$, the firm would invest in location 1 in any case, as the gain is higher than the extra cost.

$$\begin{aligned} \frac{3}{2}\delta_i^2 t + 2a(\delta_i - \tfrac{1}{4}a)t - \tfrac{3}{8}at &< \tfrac{3}{2}\delta_i^2 t + 2(\delta_i - \tfrac{1}{4})t - \tfrac{3}{8}t \qquad 1 < \delta_i \\ a &< 4\delta_i - \tfrac{7}{4} \qquad \text{is the case for } 1 > a \end{aligned} \tag{3.32}$$

Thus, solving equation (3.31) for a gives equation (3.5). **QED.**

Figure 3.5 represents the area in the a,δ-space, where firms would have preferred to invest in location a. For the large F_1-firms location a would never have been an alternative to location 1.

Appendix 3E: When the Fixed Cost of Investment Vary

The purpose of this appendix is to justify the choice of parameters $FA^1 = \frac{3}{8}t$, and to show that $FA^1 = \frac{3}{8}t$ is a special case of a more general model with variable cost of setting up a production location. When these cost are allowed to vary results support several investment structures in location a.

Proposition 3.6: We call δ_0^{Max} the cut-off between the F_0 and F_1-firms. The biggest firm that does not invest in location 1 has $\delta_0 = \delta_0^{Max}$. We call x the coefficient of the fixed cost of setting up a production location (so far $x = \frac{3}{8}$). δ_0^{Max} is a function of x and has the following form

$$\delta_0^{Max} = \begin{cases} \sqrt{\frac{4}{9} + \frac{2}{3}x} - \frac{1}{3} & 0 \le x \le \frac{3}{8} \quad \Rightarrow \quad \frac{1}{3} \le \delta_0^{Max} \le \frac{1}{2} \\ 3 - \sqrt{7 - 2x} & \frac{3}{8} < x \le \frac{3}{2} \quad \Rightarrow \quad \frac{1}{2} < \delta_0^{Max} \le 1 \\ \frac{1}{4} + \frac{1}{2}x & \frac{3}{2} < x \quad \Rightarrow \quad 1 < \delta_0^{Max} \end{cases} \tag{3.33}$$

There exist four different regions in the a, x-space (Figure 3.9):

(i) Some F_0 and all F_1-firms invest if $G^a_{\delta_0^{Max}} > C^a_{\delta_0^{Max}}$ and $G_1^a > C_1^a$. That is the case if $a < f(x, \delta_0^{Max}(x))$ and $a < 1 - 2x$.

(ii) Only F_1-firms invest if $G^a_{\delta_0^{Max}} \le C^a_{\delta_0^{Max}}$ and $G_1^a > C_1^a$. That is the case if $f(x, \delta_0^{Max}(x)) \le a < 1 - 2x$.

(iii) Only some F_0-firms invest if $G^a_{\delta_0^{Max}} > C^a_{\delta_0^{Max}}$ and $G_1^a \le C_1^a$. That is the case if $1 - 2x \le a < f(x, \delta_0^{Max}(x))$.

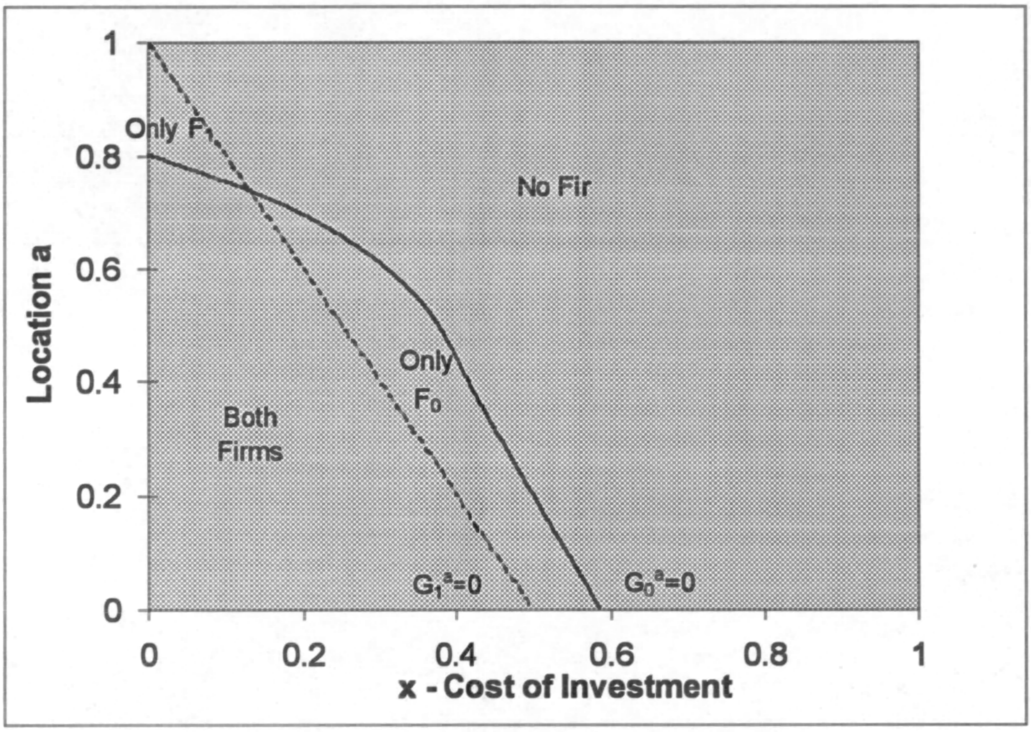
(iv) No firms invest if $G^a_{\delta_0^{Max}} \le C^a_{\delta_0^{Max}}$ and $G_1^a \le C_1^a$. That is the case if $a \ge f(x, \delta_0^{Max}(x))$ and $a \ge 1 - 2x$.

Where $G^a_{\delta_0^{Max}}$ and $C^a_{\delta_0^{Max}}$ are respectively the gain and the cost of investment in location a of a F_0-firm with δ_0^{Max}.

Proof: Equation (3.33) follows from Appendix 3A when replacing $\frac{3}{8} = x$. The inequalities in Proposition 3.6 follow from Appendix 3B and equation (3.30) in Appendix 3C, taking $\frac{3}{8} = x$. QED.

Figure 3.9 shows the four regions in the a, x-space:

Figure 3.9: The Structure of Investment when the Cost of Investment Vary



Given the linear cost structure of the model, the fixed cost of investment (FA^1) have to be relatively high in order to generate the case that small firms invest in location a and large firms do not invest there. Decreasing cost make more firms invest in location 1 in period 2 and increase the incentives to invest in more than one location. Thus, low cost leads to the case that both categories of firms invest in location a, if it is not to far-off, or that only F_1-firms invest there, if a is further away. The intuition seems clear: the larger the cost of investing the more firms remain local producers initially. These firms are then attracted by location a, as investment there is relatively cheap and their return still interesting. For the firms, that have already invested further away, however, the cost of yet another investment in location a exceeds the return. If the cost are very high, no firm invests in location a. For expositional simplicity we have chosen the special case of FA^1 such that $\delta_0^{Max} = \frac{1}{2}$.

Appendix 3F: Tables and Figures

Table 3.1: Investment Structure in the World by Size Categories

	less than 50 employees	50-199 employees	200-499 employees	500-999 employees	1000-1999 employees	2000-3999 employees	4000 or more employees	Total
Firms, that have production locations outside Germany (absolute numbers in brackets)	3% (13)	8% (47)	17% (72)	33% (86)	42% (79)	52% (52)	66% (62)	20% (411)
of these, firms that have								
- production locations in CEE (Czech Republic, Hungary, Poland and Slovakia)	62%	43%	39%	27%	32%	35%	37%	35%
- production locations in far-off Regions (Americas, Asia, Australia and Africa)	15%	26%	39%	38%	58%	67%	86%	51%
- production locations in Western Europe	23%	43%	56%	64%	65%	85%	71%	63%
Average number of countries	1.2	1.5	2.1	2.3	3.2	4.5	5.8	3.2

Ifo Investitionstest 1995 and own calculations

Table 3.2: Investment Structure in CEE Weighted by Employment of 1994

	less than 50 employees	50-199 employees	200-999 employees	1000 or more employees	Total
Total employment in industry in 1994 (in 1000 persons)	615.1	1479.6	2123.1	2014.2	6263.0
of which is covered by the Ifo-Investionstest	2%	5%	15%	92%	36%
weighted investment structure in CEE in terms of firms	37%	33%	25%	5%	
weighted investment structure in CEE in terms of projects	24%	25%	35%	17%	

Ifo Investitionstest 1995 and own calculations

Table 3.3: Investment Locations in the World

	% of total sample	% of all investing firms	*Only* in:
Production facilities abroad	20%	100%	
In CEE (CR, H, P and SK)	7%	35%	16%
In other Ex-Communist countries[41]	2%	12%	3%
In Western Europe	13%	63%	21%
In USA and Canada	6%	31%	5%
In East Asia	6%	29%	4%
South and Middle America	4%	20%	1%
In Africa and the Rest	1%	2%	0%

Ifo Investitionstest and own calculations

[41] The other Ex-Communist countries, where firms had invested, were: Belarus, Bulgaria, Croatia, Kasachstan, Latvia, Lithuania, Macedonia, Romania, Russia ad Ukraine. They were not included in the CEE-group, because they are geographically further away from Germany.

Table 3.4: Average Number of Employees of Investing and Non-Investing Firms

Average size of firms (employees)	in no. Of prs.
All	1091
Not investing	551
Investing	3264
Investing *only* in CEE	1188
Investing *only* in Western Europe	1153
Investing in at least two Regions	4552
Investing in CEE	3673
Investing in Western Europe	3755
Investing far-off and not in CEE	4250
Investing far-off and in CEE	8090

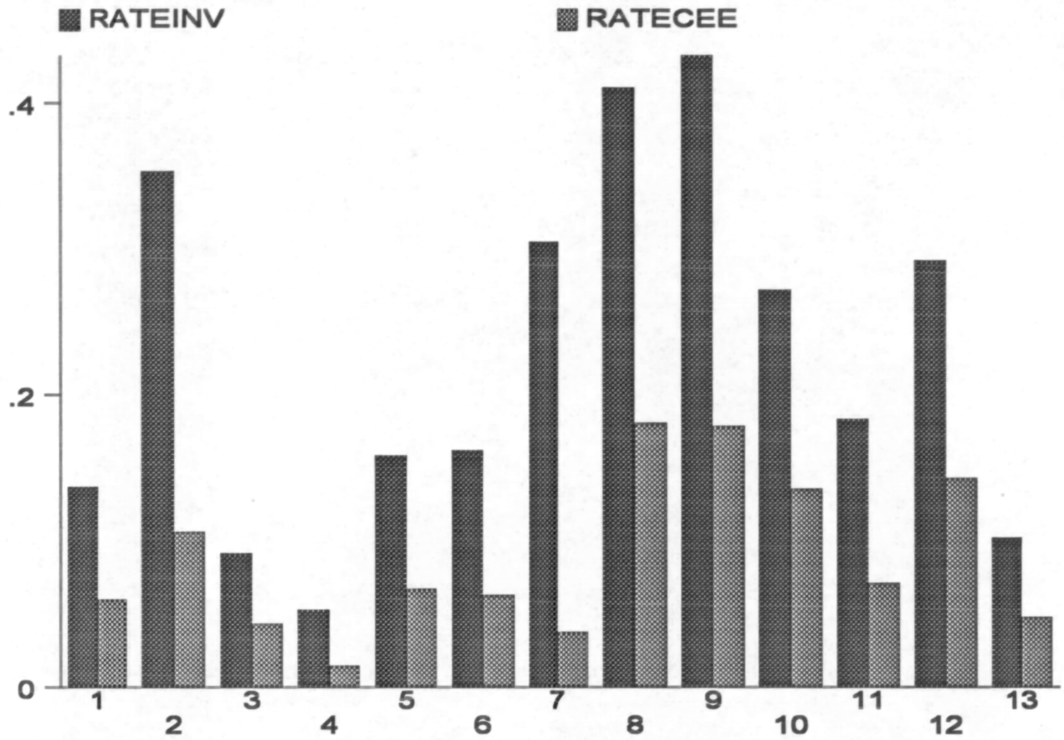
Ifo Investitionstest and own calculations

Table 3.5: The Sectoral Distribution of Firms and Employment

No.	Sector	Number of Observations				Employment, all Firms			
		Invest in World	Invest in CEE	Invest in CEE *only*	All Firms	Mean	Std.Dev.	Min.	Max.
1	Mining	30	13	10	219	763	2 412	9	29 873
2	Chemicals	30	9	3	85	3 689	9 292	6	53 447
3	Timber	17	8	7	187	196	323	4	2 540
4	Paper, Printing & Publishing	15	4	2	286	326	713	1	7 796
5	Rubber Man Made Fibers	19	8	5	120	550	1 305	1	13 000
6	Metal Articles	39	15	10	241	401	685	5	4 644
7	Mechanical Engineering	90	11	4	296	1 164	2 539	19	27 200
8	Motor Vehicles	25	11	4	61	9 902	24 843	8	14 9838
9	Electrical Engineering	51	21	3	118	2 389	6 010	19	58 900
10	Precision Engineering, Optics, Etc.	16	8	1	59	706	1 266	8	7 218
11	Ceramics, Glass, Musical Instruments, Toys, Jewelry, Etc.	13	5	1	71	791	1 120	5	5 561
12	Textile, Leather & Clothing	51	25	18	175	391	515	3	3 140
13	Food, Drink & Tobacco	15	7	2	147	557	1 410	5	14 820
	Total	411	145	70	2 065	1 091	5 338	1	14 9838

Ifo Investitionstest and own calculations

Figure 3.10: The Sectoral Distribution of Investment



Ifo Investitionstest and own calculations

Where RATEINV is the rate of investing to not investing firms and RATECEE is the rate of firms investing in CEE to all other firms.

Table 3.6: Correlation Coefficients

	(1)	(2)	(3)	(4)	(5)
PL in:					
(1) CEE (dum.)	1				
(2) Far-Off (dum.)	-0.26	1			
(3) W. Europe (dum.)	-0.32	0.05	1		
(4) (2) *and* (3) (dum.)	-0.16	0.69	0.54	1	
(5) Size (log of empl.)	-0.05	0.37	-0.32	0.40	1

Table 3.7: Binomial Logit Estimates of Investment in the World and in CEE

	Endogenous variable: production location (PL):			
Exogenous variables[42]	**Outside Germany**	**in CEE**	**In CEE**	**in CEE**
Size (log Employment)	0.7 (15.0)*	-0.0 (0.06)	-0.7 (-1.56)	0.24 (2.32)*
Size^2	-	-	0.1 (1.58)	-
PL in far-off locations	-	-	-	-3.4 (-7.00)*
PL in Western Europe	-	-	-	-3.3 (-7,91)*
PL in far-off and Western Europe	-	-	-	3.3 (5.90)*
Sectoral dummies:				
Chemicals	0.3 (1.00)	-0.6 (-1.03)	-0.6 (-1.14)	-0.4(-0.43)
Timber	0.2 (0.71)	0.15 (0.24)	0.1 (0.15)	-0.2 (-0.21)
Paper, Printing & Publishing	-0.7 (-1.97)*	-0.7 (-1.07)	-0.7 (-1.05)	-0.4 (-0.44)
Rubber Man Made Fibers	0.2 (0.71)	-0.1 (-0.09)	-0.1 (-0.12)	0.2 (0.30)
Metal Articles	04 (1.53)	-0.2 (-0.41)	-0.2 (-0.35)	0.0 (0.03)
Mechanical Engineering	0.7 (2.65)*	-1.7 (-3.46)*	-1.7 (-3.40)*	1.1 (-1.86)**
Motor Vehicles	0.1 (0.29)	0.3 (0.06)	-0.2 (-0.25)	0.2 (0.22)
Electrical Engineering	0.9 (3.11)*	-0.1 (-0.18)	-0.1 (-0.22)	0.5 (0.89)
Precision Engineering, Optics, Etc.	0.9 (2.37)*	0.3 (0.62)	0.2 (0.34)	1.3 (1.75)**
Ceramics, Glass, Musical Instr., Etc.	0.1 (0.22)	-0.2 (-0.30)	-0.2 (-0.32)	0.6 (0.67)
Textile, Leather & Clothing	1.24 (4.40)*	0.2 (0.49)	0.2 (0.45)	0.1 (0.14)
Food, Drink & Tobacco	-0.3 (-0.70)	0.1 (0.64)	0.2 (0.24)	0.8 (1.13)
Constant	-6.2 (-16.0)*	-0.2 (0.63)	1.9 (1.27)	0.5 (0.64)
Diagnostics:				
Number of observations	2065	411	411	411
Log L	-802.50	-248.80	-247.53	-193.88
Pseudo R2	0.22	0.07	0.07	0.27
Joined significance of sectors (at 5%)	Significant	Significant	Significant	Significant

[42] The default sector is Mining, the sector with the lowest investment rate. Test statistics are given in brackets.
* for significant at 5% level, ** for significance at 10% level.

Table 3.8: Multinomial Logit Estimates of Investment in the World and in CEE

	Endogenous variable: production location (PL):				
Exogenous variables[43]	***Only* in CEE**	**in CEE *and* elsewhere**	***Not* in CEE**	***Only* in CEE**	**In CEE *and* elsewhere**
Size (log Employment)	0.5 (4.53)*	1.0 (9.97)*	0.8 (13.1)*	0.4 (-3.39)*	0.3 (2.80)*
Sectoral Dummies:					
Chemicals	-0.5 (-0.72)	0.8 (1.04)	0.6 (1.39)	-1.0 (-1.30)	0.1 (-1.5)
Timber	0.1 (0.20)	0.1 (0.09)	0.2 (0.51)	-0.1 (-0.15)	-0.1 (-0.09)
Paper, Printing, Etc.	-1.8 (-2.28)*	-0.2 (-0.19)	-0.4 (-0.92)	-1.0 (-1.10)	-10. (-0.11)
Rubber Man Mad Fibers	-0.1 (-0.12)	0.9 (1.01)	0.3 (0.69)	-0.3 (-0.50)	0.5 (0.51)
Metal Articles	0.0 (0.01)	0.9 (1.22)	0.6 (1.58)	-0.3 (-0.60)	0.2 (0.26)
Mechanical Engineering	-1.2 (-2.04)*	0.5 (0.65)	1.2 (3.75)*	2.3 (-3.44)*	-0.8 (-1.06)
Motor Vehicles	0.0 (0.03)	0.7 (0.86)	0.1 (0.20)	-0.2 (-0.23)	-0.5 (-0.59)
Electrical Engineering	-0.5 (-0.77)	2.2 (3.22)*	1.0 (2.85)*	1.6 (-2.18)*	1.1 (1.52)
Prec. Engineering, Etc.	-0.7 (-0.70)	2.6 (3.44)*	0.9 (1.80)	-1.9 (-1.60)	1.7 (2.04)
Ceramics, Glass, Etc.	-1.3 (-1.21)	1.3 (1.59)	0.2 (0.43)	-1.6 (-1.41)	1.3 (0.88)
Textile, Leather, Etc.	1.1 (2.65)*	1.8 (2.54)*	1.2 (3.29)*	-0.1 (-0.11)	0.6 (0.82)
Food, Drink & Tobacco	-1.2 (-1.53)	1.1 (1.40)	-0.3 (-0.57)	-0.9 (0.96)	1.3 (-1.50)
Constant	-5.3 (-8.18)*	-10.6 (-10.0)*	-7.1 (-14.8)*	2.0 (2.36)*	-3.8 (-3.67)*
Diagnostics:					
Number of observations	2065			411	
Comparison group	*No* PL outside Germany			*No* PL in CEE	
Log L	-1120.95			-317.15	
Pseudo R2	0.20			0.14	
Joined sign. of sector (at 5%)	Significant			Significant	

43 The default sector is Mining, The sector with the lowest investment rate. Test statistics are given in brackets. * for significant at 5% level, ** for significance at 10% level.

Figure 3.11: The Estimated Probability of Investment in CEE with respect to Size (all Observations)

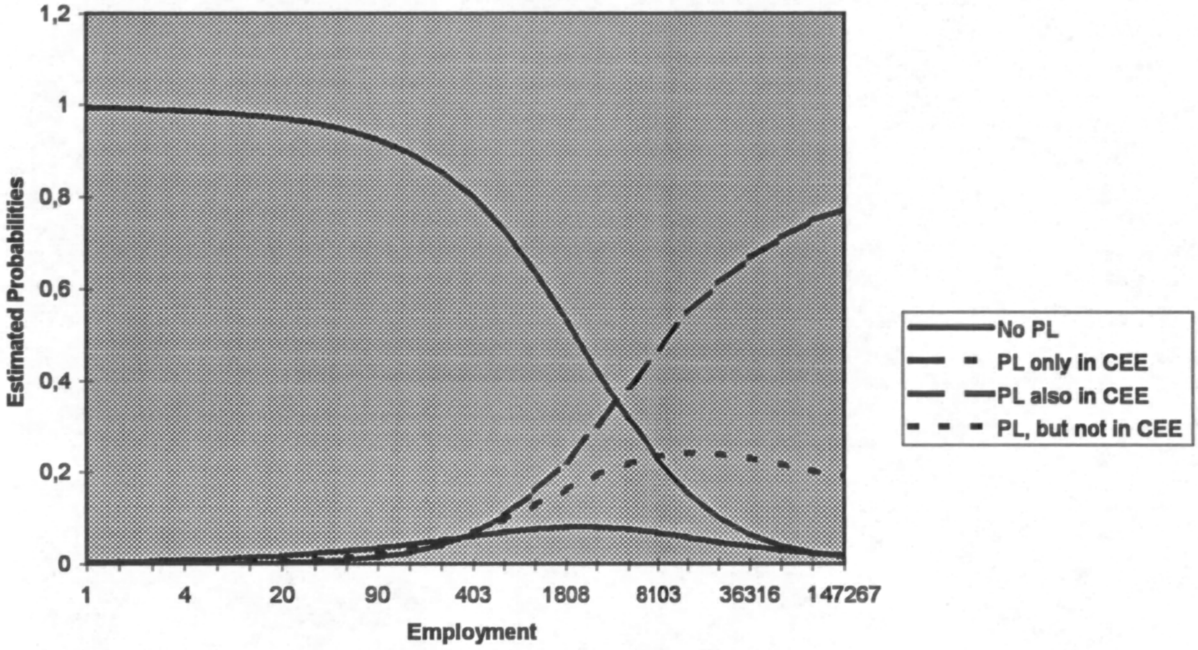
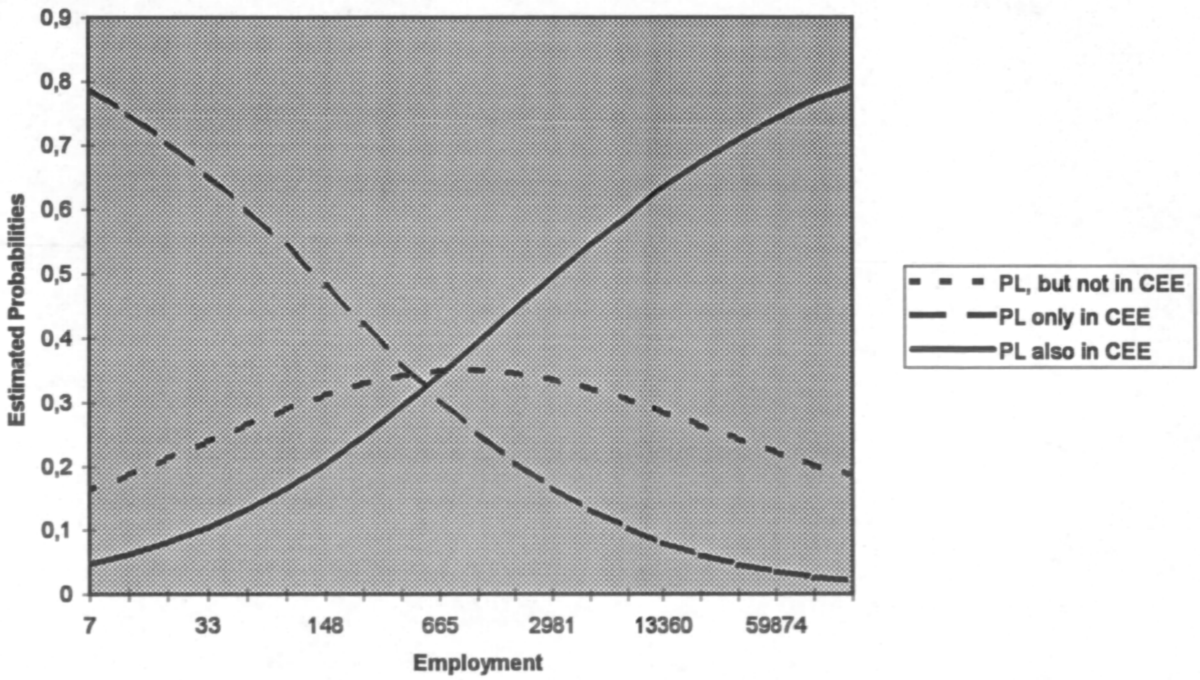


Figure 3.12: The Estimated Probability of Investment in CEE with respect to Size (Investing Firms)



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ERRATA

Chapter 1

Page 21: The example on Page 21 should be transformed to a footnote (13a). The relevant passage starts at the top of the page ("There is no brain drain...") and ends with "... with productive human capital" on that page. This case describes an example without brain drain, and is therefore not directly relevant to the paper.

Chapter 2

Pages 41 and 46: In the present form, the model only considers the profit maximization of a foreign investor who repatriates profits. The surplus of a licensor or a consultant would differ from Expression (2.8), because profits before technology transfer are not considered.

Page 51: It can easily be verified that $\frac{\delta\theta^*}{\delta t} > 0$, $\frac{\delta\theta_l}{\delta t} > 0$ and $\frac{\delta\theta^*}{\delta t} - \frac{\delta\theta_l}{\delta t} > 0$ in Expression (2.16) are positive (from Proposition 2.1 we know that $\frac{\delta\hat{s}}{\delta t} > 0$):

Given that $\theta^* = \frac{p^* + t - \hat{p}}{s^* - \hat{s}}$, $\theta_l = \frac{\hat{p}}{s} > 0$ and $\hat{p} = \frac{(p^* + t)}{2s^*} s > 0$,

$$\theta^* = \frac{(2s^* - s)(p^* + t)}{2s^*(s^* - s)}$$

$$\frac{\delta\theta^*}{\delta t} = \frac{(2s^* - s)}{2s^*(s^* - s)} + \frac{(p^* + t)}{2(s^* - s)}\frac{\delta\hat{s}}{\delta t} > 0$$

$$\theta_l = \frac{(p^* + t)}{2s^*}$$

$$\frac{\delta\theta_l}{\delta t} = \frac{1}{2s^*} > 0$$

$$\frac{\delta\theta^*}{\delta t} - \frac{\delta\theta_l}{\delta t} = \frac{s^*}{2s^*(s^* - s)} + \frac{(p^* + t)}{2(s^* - s)}\frac{\delta\hat{s}}{\delta t} > 0.$$

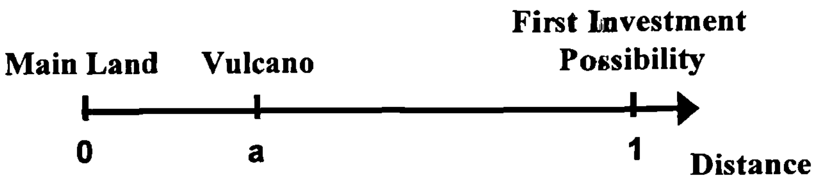
Page 64: Equation (2.35) should be

$$\frac{\delta\hat{p}}{\delta t} = \frac{(p^* + t)}{2s^*}\frac{\delta\hat{s}}{\delta t} + \frac{s}{2s^*} > 0.$$

Chapter 3

Page 67: Figure 3.1 should be

Figure 3.1: Geography



Page 69: Equation (3.2) should be

$$EI_i^k = \begin{cases} -\int_{\delta_i}^{k} (\theta - c_i - \delta t)\, d\delta & \delta_i < k \\ 0 & \text{otherwise} \end{cases}$$