Essays in Macroeconomics

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A thesis submitted to the Department of Economics of the London School of Economics and Political Science for the degree of Doctor of Philosophy

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Declaration

I certify that the thesis I have presented for examination for the PhD degree of the London School of Economics and Political Science is solely my own work other than where I have clearly indicated that it is the work of others (in which case the extent of any work carried out jointly by me and any other person is clearly identified in it).

I warrant that this authorisation does not, to the best of my belief, infringe the rights of any third party.

I declare that my thesis consists of 35067 words.

Statement of Conjoint Work

The second chapter is the result of joint work by Rigas Oikonomou and me, with equal shares in all aspects of the paper.

The third chapter draws on work that was carried out jointly by Francesco Caselli, John Coleman, and me. The work was motivated by Francesco Caselli's and John Coleman's idea to assess the role of policies in the reshuffling in relative positions between East Asian and Latin American countries. I have carried out most of the analytical and numerical analyses and written around 90% of the text; general decisions about the direction of the paper were made equally between the three authors.

Abstract

This thesis provides three essays in macroeconomics.

The first chapter analyzes trends in fertility and time allocation. Falling fertility rates have often been linked to rising female wages. However, over the last 30 years the US total fertility rate has been stable while female wages have continued to grow. Over the same period, women's hours spent on housework have declined, but men's have increased. A model with a shrinking gender wage gap is proposed capturing these trends. While rising relative wages increase women's labour supply, they also lead to a reallocation of home production from women to men, and a higher use of labour-saving inputs. Both are important in understanding why fertility did not decline further.

The second chapter presents a life-cycle model with heterogeneous households and incomplete financial markets to study the implications of a reform that eliminates capital taxation. In the economy individuals differ in terms of their gender and marital status, and decision making within the couple is modelled as a contract under limited commitment. When capital taxes are set to zero, there is a strong increase in wealth accumulation that originates in dual earner households. Moreover, the policy change has important implications for the division of resources within the family and for households' insurance possibilities.

The third chapter is motivated by the dramatic reshuffling in relative positions between East Asian and Latin American economies. It studies the dynamic response of a two-sector, manufacturing and agriculture, economy in the presence of import tariffs and export subsidies on manufacturing goods, similar to those that characterized government policy in these countries. It is shown that the response to these policies depends on the level of productivity in the agricultural sector. Quantitative work, however, finds that

differences in agricultural productivities themselves are key in explaining the differential growth experiences.

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Preface

This thesis comprises three independent chapters.

In the first chapter I analyze trends in fertility and time allocation. Increases in female employment and falling fertility rates have often been linked to rising female wages. However, over the last 30 years the US total fertility rate has been fairly stable while female wages have continued to grow. Over the same period, we observe that women's hours spent on housework have declined, but men's have increased. I propose a model with a shrinking gender wage gap that can capture these trends. While rising relative wages tend to increase women's labour supply and, due to higher opportunity cost, lower fertility, they also lead to a partial reallocation of home production from women to men and a higher use of labour-saving inputs into home production. I find that both these trends are important in understanding why fertility did not decline to even lower levels. As the gender wage gap declines, a father's time at home becomes more important for raising children. When the disutilities from working in the market and at home are imperfect substitutes, fertility can stabilize, after an initial decline, in times of increasing female market labour. That parents can acquire more market inputs into child care, is what I find important in matching the timing of fertility. In a model extension, I show that the results are robust to intrahousehold bargaining.

The second chapter, the result of joint work with Rigas Oikonomou, presents a life cycle model with heterogeneous households and incomplete financial markets, to study the implications of a reform that eliminates capital taxation. In the economy individuals differ in terms of their gender and marital status. Drawing from the sizable literature of the collective framework of household behaviour, we model decision making within the couple as a contract under limited commitment. When capital taxes are set to zero there is a strong increase in wealth accumulation that originates in dual earner households. We compare our results to the standard framework where each household is a single bread winner and find that omitting the more realistic household structure from the model can be very misleading for policy. We use the model to study how the change in policy affects the intrahousehold allocation and welfare within the household. We show that the policy change we consider has important implications for the division of resources within the family and for households' insurance possibilities.

The third chapter draws on joint work with Francesco Caselli and John Coleman and is motivated by the dramatic reshuffling in relative positions between East Asian and Latin American economies. We study the dynamic response of a two-sector, manufacturing and agriculture, economy in the presence of import tariffs and export subsidies on manufacturing goods, similar to those that characterized government policy in these countries. We show that the response to these policies depends on the level of productivity in the agricultural sector. In our quantitative work, we find however that differences in agricultural productivities themselves are key in explaining the differential growth experiences of Argentina and South Korea.

Chapter 1

Female Employment and Fertility – The Effects of Rising Female Wages

1.1 Introduction

Between the 1960s and today, we have seen enormous changes to the economic and demographic structure in all Western countries. There has been a decline in total fertility rates[1] and an increase in women's market hours (see figures 1.1 and 1.2 for US data). Many authors explain both with a rise in female wages. An apparent puzzle, however, is that while female wages and market hours have continued to grow, since the 1970s fertility[2] has stopped falling.[3] Understanding the underlying fertility decisions is important since they affect population growth, labor force composition and social security systems, and thereby economic outcomes. In this paper I argue that the common driving force behind the trends

[1]The total fertility rate (TFR) is the average number of children that would be born if all women lived to the end of their childbearing years and bore children according to the current age-specific birth rates.

[2]The total fertility rate and children ever born (CEB), a measure of completed fertility, display similar trends. Based on US data for married women born 1826–1960, Jones and Tertilt (2008) report that CEB and TFR, shifted by 27 years, are moving strongly together. Consistently, CPS data display since 1999 virtually constant CEB to women of age 40–44. Jones and Tertilt (2008) also document a strong decline in fertility over the long-run; CEB to married women fell from about 5.5 children for the cohort born in 1928 to roughly 2 for the cohort of 1958.

[3]Most of the recent rise in the official total fertility rate is driven by the effects of immigration. For US-born women the incline is much less and fertility virtually flat since the late 1970s. The details on the decomposition of TFR by mothers' birthplace are given in appendix 1.A.

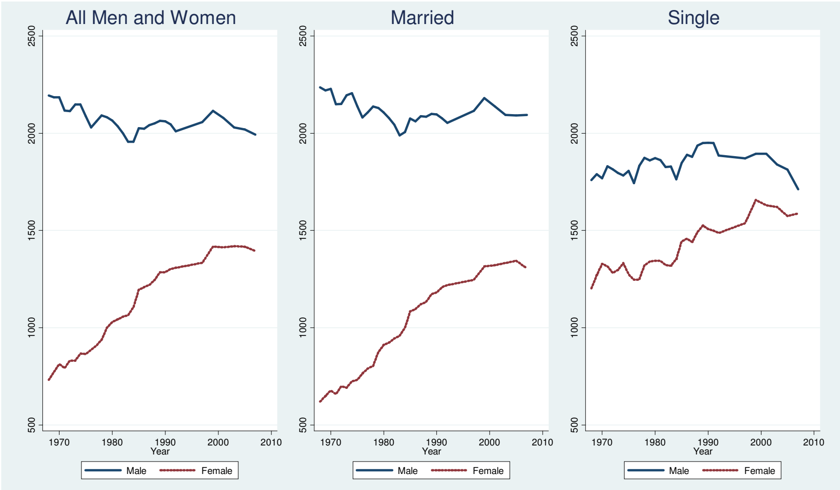

Figure 1.1: Male and female market hours

Notes: Yearly market hours worked for men and women aged 20 to 60. Source: PSID

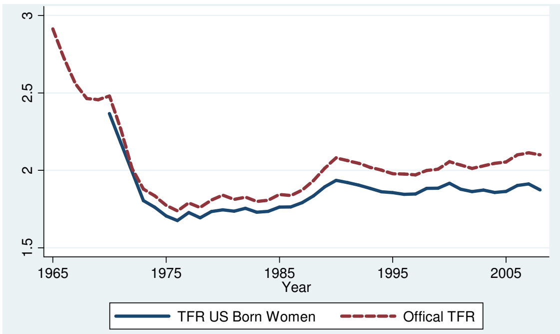

Figure 1.2: Total fertility rate

Notes: The dashed line shows the official total fertility rate (TFR) for the United States, the solid line the author's computation of TFR for US-born women; see appendix 1.A for details. Source: Vital Statistics of the United States, combined with population estimates from the US Census.

in fertility and in female employment is the narrowing of the gender wage gap (shown in figure 1.3), rather than the level of female wages per se, since it changes the division of labor within the family. Because of increasing disutilities from working at home and in the market this reallocation has a nonlinear effect.

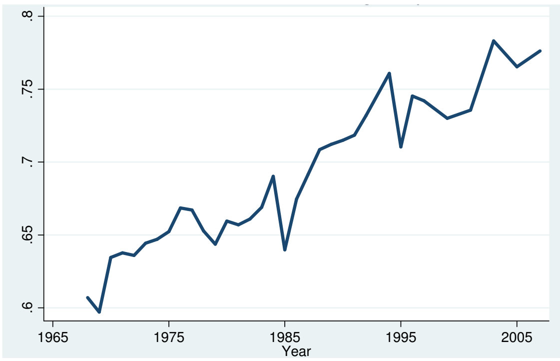

Figure 1.3: Gender wage gap

Notes: This is computed from the regression of section 1.3.1.

My explanation is based on the observation that men's home hours have increased, allowing women's home hours to fall. In the 1960s, when the wage gap was big, the catching up of females wages increases women's labor supply. The associated increase in the opportunity cost of women's time, who shoulder most of child care, lowers fertility, as argued by Becker (1960) or Galor and Weil (1996). But as relative wages become more equal over time, specialization in the household decreases. Consequently, male home hours increase, a father's time at home becomes more important for raising children, and the allocation of time between home and market work becomes more evenly balanced for men and women. If there is imperfect substitutability in the disutilities from working at home and in the market, the marginal utility cost of having an additional child can become constant, despite women working more hours in the market.

Circumstantial evidence in favor of this mechanism is provided by data on non-market hours. Using data from Aguiar and Hurst (2007), based on the American Time Use Survey since 1965, I show the trends in hours spent on home production, including time spent on child care and on obtaining goods, in figure 1.4.[4] The data displays a shift in household

[4]The measure is constructed as weekly hours spent on home production in a narrow sense, on obtaining goods, and on basic child care. Arguably, for many people child care is an activity that is more enjoyable than other forms of housework. Excluding child care from the measure of market work does not change the qualitative trends. This can be seen in the regression results of table 1.8 in the appendix.

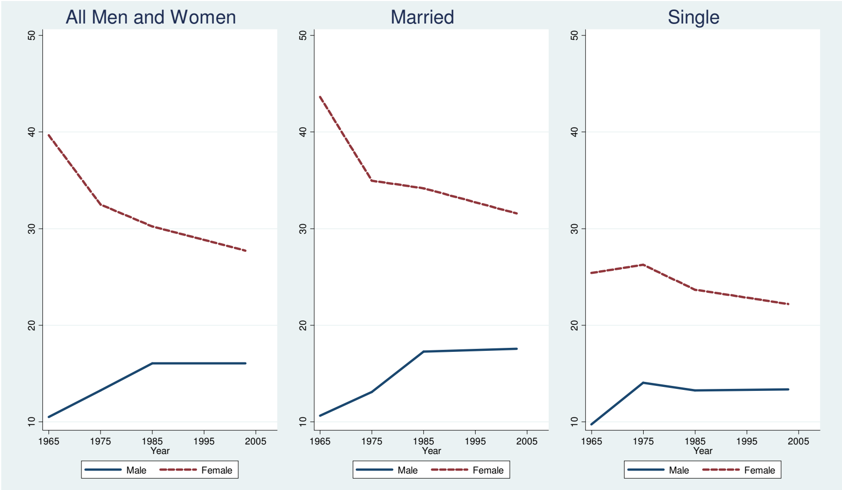

Figure 1.4: Male and female home hours

Notes: Weekly hours spent on nonmarket work and basic child care for men and women aged 20 to 80. Source: Aguiar and Hurst (2007), based on the American Time Use Survey

production from women to men, with an overall reduction of hours worked at home. My findings are consistent with the earlier work of Robinson and Godbey (2008), who find, based on time use data for 1965 to 1995, that there is convergence in activities across gender.[5]

The importance of considering intrahousehold allocations can be seen in the right panels of figure 1.4. While home hours of married men have increased over time, single men's hours of home production are constant, after an initial change between 1965 and 1975. This is consistent with the explanation I propose. Single men, without a female partner, are not affected by rising female wages, but married men spent more hours working at home –a trend in US data that has not received much attention by researchers yet, with the notable exception of Knowles (2007).[6] Single women, on the other hand, spend less time working at home, but the decline is not as pronounced as for married women, whose husbands devote more of their time to home production.[7]

[5]They also report that average parental hours spent on child-care per child has been roughly constant. Ramey and Ramey (2010), on the other hand, include time spent teaching children and document a rise since the mid 1990s, especially for college educated parents.

[6]Burda, Hamermesh, and Weil (2007) study time use data across various developed countries, and find that total work, the sum of home and market work, is virtually the same for men and women. For the US, Ramey and Francis (2009) report that total work of men and women has been constant throughout the 20th century.

[7]In the Aguiar and Hurst (2007) data marital status is defined in a legal sense, and it is not possible to disentangle cohabiting from other singles. In figure 1.18 of the appendix I show that home hours have changed more for singles with children, who are more likely to be cohabiting, than for singles without

To the best of my knowledge, the only previous paper that has noted the flattening out in total fertility rates and informally suggested an explanation in terms of increased male home production is Feyrer, Sacerdote, and Stern (2008). My paper formally models and quantifies the endogenous response of male and female hours and their implications for fertility.[8] I present a general equilibrium model matching the observed patterns of fertility and hours worked through an exogenous decrease in the gender wage gap. In the benchmark model I consider households maximizing the sum of male and female members utilities. A rise in female relative wages directly increases female labor supply and lowers female home production, whereas male time is getting devoted more to home activities and less to market work. Initially, when the gender wage gap is big, there is an overall drop in home labor and a couple devotes less time to having and raising children. However, when the gender wage gap is fairly small and shrinks further, the rise in male time spent working at home is almost big enough to keep total home labor constant. The reason for this differential reaction to improvement in female relative wages is in the increasing marginal disutility from working. Initially, specialization in the household meant a husband's labor supply was much higher than his wife's, and therefore he was less willing to spend more time on home production. But as relative wages become more equal, the spouses time allocation, and thus their disutilities from working, are getting closer to each other, and in the limit a drop in female home production is fully offset by men. To the extent that disutilities from market and home labor are imperfect substitutes, this reallocation of hours worked can be consistent with the couple's utility cost of child care remaining constant. On top of this, with the improvement in the wife's earnings, a couple can acquire more parental time saving inputs. Both the rise in male home labor and the higher use of parental time-saving inputs into home production is what I find key in explaining the flattening out of the total fertility rate.

In a model extension I show that these results are robust to intrahousehold bargaining. Calibrated against US data, my model suggests that for the trends in fertility changing relative wages per se are much more important than their bargaining-induced shifts in

children.

[8]Feyrer, Sacerdote, and Stern (2008) explain the increase in male home hours with intrahousehold bargaining. I show that bargaining is not necessary; a change in relative wages per se implies not only a reallocation of work in the market, but also at home. However, I also explore a version with intrahousehold bargaining.

intrahousehold allocations.

Other papers that have studied the implications of the decline in the gender wage gap for both male and female hours are Jones, Manuelli, and McGrattan (2003) and Knowles (2007), but none of these papers has explored the implications for fertility. Galor and Weil (1996) present a unified framework to explain the rise in female employment and the fall in fertility that we observed until the mid 1970s. Since their mechanism links fertility decisions to the market value of women's disposable time[9], it cannot explain why fertility stopped falling when female wages continued improving. My work therefore highlights that the existing literature that assumes perfect specialization within families, such that women shoulder all of home production or child care, has overlooked important implications of intrahousehold allocations.

1.2 The Model

1.2.1 Assumptions

I build a general equilibrium model of overlapping generations. Agents enter the economy as young adults at age 20 and can have children in the first period of their lives, before they turn 30. At age 60, agents retire, and they die deterministically at age 80. The advantage of this modeling approach is that it incorporates an explicit age structure and has implications for the demographic pyramid. Fertility leads to population growth and thereby affects future labor markets and factor prices, and also social security benefits. A complication is, I need to keep track of when children are born, as this implies when they turn adults and leave their parent's household. Thus, I assume for tractability that each cohort can be represented by one representative household, formed by a representative male and female, which can have a continuous number of children. Also the length of the model period is motivated by tractability; a model period corresponds to 10 years.

[9]Other papers linking fertility decisions to the market value of women's disposable time include Greenwood, Seshadri, and Vandenbroucke (2005) and Doepke, Hazan, and Maoz (2007).

Agents and Households

All agents, men and women, derive utility from consumption of a market good (c) and from having children (b), but derive disutility from working in the labor market (n) and at home (h). They discount the future with factor β. Agents differ in terms of their gender ($g \in \{m, f\}$) and their age (j). I assume that all economic active men and women live in couple households, formed by one man ('husband') and one woman ('wife'). Children live with their parents. In other words, when children move out of their mother's and father's household, they find a spouse right away and form a new couple household. To keep things simple I assume that both spouses are of the same age and have the same deterministic life-span, which I denote by T_l. For computational tractability, I assume that women, and hence couples, can have children only in the first period of their (adult) life. I denote a couple's total number of children by b and the number of children living in their household by b_h. I assume that children leave the parental household after T_a periods. While parents derive utility from having a child as long as they are alive themselves, households do not leave bequests, abstracting from any further intergenerational altruism. Therefore agents start their economic-active life (at age $j = 1$) with zero assets and leave no assets when they die (at age $j = T_l$). Couples retire at age T_r, stop working in the market and receive social security benefits $\mathcal{T}_{ss}$ each period.

Let the absolute size of the cohort of couples of age j in period t be $S_t(j)$. In period t, the population share of the cohort aged j is then

$$\mu_t(j) = \frac{S_t(j)}{\sum_{k=1}^{T_l} S_t(k)} \tag{1.1}$$

I apply a model of collective household behavior, as introduced by Chiappori (1988). The male and the female partner have their own preferences, and derive felicity u_m and u_f respectively. Since they hold wealth jointly and have children together, they solve a joint maximization problem. In particular, the couple household solves a Pareto program with relative weight θ attached to the husband's and $1 - \theta$ to the wife's utility. In the *benchmark model*, the household behaves as a *unitary* agent and $\theta = 0.5$ throughout.

For the model with *intrahousehold bargaining*, I assume that the Pareto weight is determined through Nash bargaining under full commitment over the surplus generated by marriage, where the threat point of a spouse is not entering the marriage. Since life-time utilities of single men and women differ to the extent that they face different wages, the outcome of the bargaining depends on relative wages.

Fertility

Childbearing imposes a time-cost on the mother (τ_b), whereas child-care requires more home production (x), which could be done by the father, the mother, or both.[10] A further input to home production are goods acquired in the market (e). Although I refer to this home-labor saving input as home appliances, in a broader sense this could include paid domestic help, such as hiring nannies. I assume that the amount of the home good needed is

$$\bar{x} = \bar{x}(b_h) \text{ with } \bar{x}'(b_h) > 0 \tag{1.2}$$

Couples can have children only in the first period of their lives. Bearing a child reduces the mother's disposable time by τ_b in that period.

Household Production

Following Olivetti (2006) and Knowles (2007), I assume that the home good is produced using a technology that is consistent with substitution among household member's time and home appliances according to

$$x_h = e^{\gamma} H^{1-\gamma} \tag{1.3}$$

where home labor input is $H = z_m h_m + z_f h_f$, and z_m and z_f the male and female home labor productivities. This technology allows, to some degree, for a marketization of inputs to home production.[11] Rising market wages could lead to increases in market hours and decreases in home hours –such as we have observed in the data for married females–, without a drop in home production, as the household can acquire more home appliances.

[10] The former assumption is similar to Erosa, Fuster, and Restuccia (2010), the latter is as in Knowles (2007) and similar to Greenwood and Seshadri (2005)

[11] In a structural transformation framework, Ngai and Pissarides (2008) study substitutions between home and market production, but do not distinguish between male and female labor.

The home good is nonstorable and is a public good within the household.

Market Technology

Assume there is a final goods technology of the form

$$Y_t = K_t^{\alpha} N_t^{1-\alpha} \tag{1.4}$$

aggregating total market labor (N) and capital (K) into a final good which can be used for consumption (c), investment in future capital stock, and for home appliances (e), which I model as a flow to simplify matters. Capital depreciates at a rate δ each period. The final goods sector is competitive. Factor prices are therefore equated to marginal products, implying for the rental rate of capital (r) and wage rate per efficiency unit of labor (w)

$$r_t = \alpha K_t^{\alpha-1} N_t^{1-\alpha} - \delta \tag{1.5}$$

$$w_t = (1-\alpha) K_t^{\alpha} N_t^{-\alpha} \tag{1.6}$$

Endowments and Markets

Each individual is endowed with one unit of time that they can use for working in the market (n) and at home (h); the remainder is leisure. Since childbearing lowers a woman's effective time endowment (by τ_b), the male and female time constraints are

$$n_m(j) + h_m(j) \leq 1 \text{ for } j = 1, \ldots, T_l$$

$$n_f(j) + h_f(j) \leq \begin{cases} 1 & \text{for} \quad j = 2, \ldots, T_l \\ 1 - \tau_b b & \text{for} \quad j = 1 \end{cases}$$

Since in the data there is an age-profile in wages, I assume an age-dependent endowment of efficiency units of labor for men $p_m(j)$ and for women $p_f(j)$. The model implies for the wage of a woman of age j relative to a man of the same age that $\frac{w_f(j)}{w_m(j)} = \frac{p_f(j)}{p_m(j)}$. A gender wage gap corresponds in the model therefore to different labor productivities across gender. In reality, of course, differences in pay may be the result of discrimination. One way of rationalizing the simplifying modeling assumption of differential productivities is, because of discrimination, women, with same abilities as men, have sorted into less productive occupations. I will take women's relative earnings, after controlling for observables such as education, in year t from the data, which I denote by χ_t, and impose $p_{f,t}(j) = \chi_t p_m(j)$.

Once agents have passed the retirement age T_r they can no longer generate labor income, which corresponds to $p_m(j) = p_f(j) = 0$ for $j \geq T_r$, but the couple receives social security benefits $\mathcal{T}_{ss}$. There is no uncertainty and agents' income is not subject to shocks. Agents can trade an asset with return r_t. The economy is closed.

Government

The government provides a pay-as-you go social security system. Similar to the US system, it levies a constant social security tax τ_{ss} on labor income and redistributes the proceeds as benefits $\mathcal{T}_{ss}$ to retired households. Hence

$$\mathcal{T}_{ss,t} = \frac{\tau_{ss} \cdot w_t N_t}{\sum_{j=T_r}^{T_l} \mu(j)} \tag{1.7}$$

Preferences

Agents derive utility from consumption of the market good and enjoy having children, but have disutility from working in the market or at home. In particular, assume that preferences are additively separable and given by[12]

$$u = \frac{c^{1-\sigma} - 1}{1 - \sigma} - \left(\phi_n \left(\frac{n^{1+\eta}}{1+\eta} \right)^{\frac{s-1}{s}} + \phi_h \left(\frac{h^{1+\varepsilon}}{1+\varepsilon} \right)^{\frac{s-1}{s}} \right)^{\frac{s}{s-1}} + \phi_b \frac{b^{1-\sigma_b} - 1}{1 - \sigma_b} \tag{1.8}$$

where c, n, and h are specific to a spouse, but the number of children b is common to the couple.

These preferences feature imperfect substitutability of disutilities of working in the market or at home. I view it as realistic to allow the utility cost of these two very different activities to differ. Nonetheless, there is a relationship between the two: The marginal disutility of supplying an additional hour of market work is increasing in the time worked

[12]Adding utility from children in this additive form is generalizing Galor and Weil (1996) and Greenwood and Seshadri (2005), who assume $ln(b)$.

at home, and vice versa. These preferences allow for time allocations, consistent with the data, such that both men and women work in the labor market and in the household –even when male and female time are perfect substitutes.

I assume that there is a subsistence level in consumption of the home produced good, which is increasing in the number of children living in the household (b_h). As a simplifying assumption, following Knowles (2007), agents do not derive any further utility from home production, and this constraint will be binding, $x = \bar{x}(b_h)$.

1.2.2 Couple Household's Optimization

In the benchmark model I consider households in which spouses have equal Pareto weights ($\theta = 0.5$), such that the household behaves like a unitary agent. Since I assume for the bargaining model full commitment to the sharing rule determined when both partners meet (see section 1.5.1), in both scenarios the Pareto weight θ is constant over the couple's lifetime. Consider the optimization problem of a couple household of age j with current wealth a, total number of children b, of which b_h are still living at home. Let $u_g(c_g, n_g, h_g, b)$ denote the own utility function of the member of gender $g \in \{m, f\}$. The household's resources from financial assets are $a(1+r)$. Households before retirement can earn a labor income net of taxes of $\tilde{w}_m(j)n_m + \tilde{w}_f(j)n_f$, where $\tilde{w}_m(j) = (1-\tau_{ss})p_m(j)w$ is the net male wage and $\tilde{w}_f(j) = \chi\tilde{w}_m(j)$ the net female wage. After reaching the retirement age (T_r) households receive social security benefits $\mathcal{T}_{ss}$.

After having decided at the beginning of their lives on the number of children (b), for age $j \geq 2$ the value functions of the representative couple household solves[13]

$$V_C(a; b, j) = \max_{\substack{a', e, c_m, c_f \\ n_m, n_f, h_m, h_f}} \theta u_m(c_m, n_m, h_m, b) + (1-\theta)u_f(c_f, n_f, h_f, b) + \beta V_C(a'; b, j+1) \tag{1.9}$$

[13]To economize on notation, I do not index variables by time, but it should be understood that age (j) takes on this intertemporal role.

subject to the constraint set:

$$a' = \begin{cases} (1+r)a + \tilde{w}_m(j)n_m + \tilde{w}_f(j)n_f - c_m - c_f - e \text{ for } j < T_r \\ (1+r)a + \mathcal{T}_{ss} - c_m - c_f - e \text{ for } j \geq T_r \end{cases} \tag{1.10}$$

$$\bar{x}(b_h) = e^{\gamma}\left(z_m h_m + z_f h_f\right)^{1-\gamma} \tag{1.11}$$

$$b_h(j) = \begin{cases} b \text{ for } 1 \leq j < T_a \\ 0 \text{ for } j > T_a \end{cases} \tag{1.12}$$

$$n_m + h_m \leq 1 \text{ and } n_f + h_f \leq 1 \tag{1.13}$$

$$V_C(\cdot; T_l + 1) = 0 \text{ and } a_{T_l+1} \geq 0 \tag{1.14}$$

$$\{w_m(k), w_f(k), r(k)\}_{k=j}^{T_l} \text{ known} \tag{1.15}$$

In the first period of a household's life, the value function is different. Then the couple decides on the number of children (b), from which the parents will derive utility throughout their lifetime. Since I am focusing on a representative couple, the household can choose any nonnegative continuous quantity. At model age $j = 1$, when the household starts out and is without any assets ($a = 0$), the value function solves

$$V_C(0; b; 1) = \max_{\substack{b, a', e, c_m, c_f \\ n_m, n_f, h_m, h_f}} \theta u_m(c_m, n_m, h_m, b) + (1-\theta) u_f(c_f, n_f, h_f, b) + \beta V_C(a'; b; 2) \tag{1.16}$$

subject to the constraints (1.10) to (1.15), with the time constraints (1.13) modified to

$$n_m + h_m \leq 1 \text{ and } n_f + h_f \leq 1 - \tau_b b \tag{1.17}$$

since having children lowers the mother's disposable time.

There is no closed form solution to this optimization problem, but the usual Euler equations hold. Numerically, I solve a couple's deterministic finite life-time optimization problem (1.9) conditional on a fertility history backwards, making use of the intratemporal first-order conditions, which I show in the appendix. Then I choose the number of children that maximizes the couple's life-time value function in the first period of their lives (1.16). When choosing a fertility plan the couple is outweighing benefits and costs from having children.[14] The marginal benefit of having this extra child arises from higher felicity for the rest of couple's lifetime. The marginal cost of having more children lies in the need for more home production, for as long as the child lives with the parents (T_a periods). To increase home production, the couple devotes more time to home labor and uses more home appliances. Both adjustments reduce consumption of the parents. As male and female home labor rises, the parents find it more costly to supply as much labor to the market, and therefore generate less income. Since home appliances are acquired in the market, disposable income for goods consumption drops further.

1.2.3 Equilibrium

In equilibrium all households maximize their life-time utility, firms maximize profits, the government budget is balanced, all markets clear, and population growth is determined by fertility decisions. In particular, couples of all ages solve their optimization problem (1.9) and (1.16), factor prices are determined competitively by (1.5), social security benefit

[14]At an interior solution, the optimal number of children satisfies

$$\begin{aligned}
\phi_b b^{-\sigma_b} \sum_{j=1}^{T_l} \beta^{j-1} &= \frac{\theta}{\gamma} \sum_{j=1}^{T_a} \beta^{j-1} c_m(j;b)^{-\sigma} \left(\frac{\bar{x}(b)}{z_m h_m(j;b) + z_f h_f(j;b)} \right)^{\frac{1-\gamma}{\gamma}} \bar{x}'(b) \\
&= \frac{\theta}{z_m} \sum_{j=1}^{T_a} \beta^{j-1} \left(\phi_n \left(\frac{n_m(j;b)^{1+\eta}}{1+\eta} \right)^{\frac{s-1}{s}} + \phi_h \left(\frac{h_m(j;b)^{1+\varepsilon}}{1+\varepsilon} \right)^{\frac{s-1}{s}} \right)^{\frac{1}{s-1}} \tilde{\phi}_h h_m(j;b)^{\zeta} \bar{x}'(b) \\
&= \frac{1-\theta}{z_f} \sum_{j=1}^{T_a} \beta^{j-1} \left(\phi_n \left(\frac{n_f(j;b)^{1+\eta}}{1+\eta} \right)^{\frac{s-1}{s}} + \phi_h \left(\frac{h_f(j;b)^{1+\varepsilon}}{1+\varepsilon} \right)^{\frac{s-1}{s}} \right)^{\frac{1}{s-1}} \tilde{\phi}_h h_f(j;b)^{\zeta} \bar{x}'(b)
\end{aligned}$$

where $\tilde{\phi}_h = \phi_h(1+\varepsilon)^{1/s}$ and $\zeta = \frac{(s-1)\varepsilon-1}{s}$. The left-hand side is the marginal benefit of having an additional child, which at the optimum has to equal the marginal cost, the right-hand side. If a mother's time constraint was binding, the time cost of having the baby would have a further effect of lowering consumption, since she would have less time to divide between market work and home production and loses earnings potential ($\tau_b w_f$).

satisfy (1.7), and factor markets clear according to[15]

$$N_t = \sum_{j=1}^{T_r} S_t(j)\left(p_m n_{m,t}(j) + p_f(j) n_{f,t}(j)\right) \tag{1.18}$$

$$K_t = \sum_{j=1}^{T_l} S_t(j) a_t(j) \tag{1.19}$$

and the size of cohorts of *adult couples* is given by[16]

$$S_t(j) = \begin{cases} \frac{1}{2} S_{t-T_a}(1) b_{t-T_a} & \text{for} \quad j = 1 \\ S_{t-1}(j-1) & \text{for} \quad 2 \leq j \leq T_l \\ 0 & \text{for} \quad j > T_k \end{cases} \tag{1.20}$$

Notice that the population growth rate changes over time, which in turn affects the capital-labor ratio. The model implies a working-age average male and female labor supply of $N_{g,t} = \sum_{j=1}^{T_R-1} \tilde{\mu}_t(j) n_{g,t}(j)$ for $g \in \{m, f\}$, where $\tilde{\mu}_t(j) = \mu_t(j)/(\sum_{k=1}^{T_R-1} \mu_t(k))$ is the mass of the aged j cohort relative to the working-age population. Similarly, average (over all ages) home hours for $g \in \{m, f\}$ are $H_{g,t} = \sum_{j=1}^{T_l} \mu_t(j) h_{g,t}(j)$ and appliances $E_t = \sum_{j=1}^{T_l} \mu_t(j) e_t(j)$. Since couples have children only at the beginning of their adult lives, the total fertility rate is simply given by the number of children the representative household of model age $j = 1$ has in that period, $TFR_t = b_t$.

1.3 Calibration

I choose parameters such that the model replicates in a base year the total fertility rate and married male and married female hours worked, both at home and in the market. I calibrate all parameters as time-invariant, and the only exogenous change over time is in

[15] I solve for the equilibrium using a Auerbach and Koltikoff (1987) type algorithm. This entails 1. guessing time-paths for aggregate state variables and thereby of factor prices, 2. solving the optimization problems of all households given the guesses, 3. aggregating over all generations alive and computing the deviations from the guessed paths, 4. If the deviations are sufficiently small, the equilibrium has been found; if not, update the guesses and iterate until consistent.

[16] On the right hand side of (1.20) the shift of T_a periods appears since children turn adult after T_a periods and have been born when their parents where of age $j = 1$. The factor 1/2 in front reflects the fact that children born are half boys and half girls, and a couple household consist of a man and a woman (of the same age).

the gender wage gap. A model period is set to 10 years. I calibrate the model parameters against data for 1965, taking the demographic structure of that year, the size of cohorts and the population growth rate, as given. For the required amount of home production, I make use of the variation of married men's and women's home hours against the number of children in the household. Table 1.1 lists all model parameters, along with a value taken from the literature[17], or whether it is to be set in a calibration exercise.

Table 1.1: Model parameters

	Description	**Value/Moment to Match**
σ	elasticity of consumption	1 (log-utility)
σ_b	elasticity of demand for children	calibration
η	related to elasticity of market hours	2 (Domeij and Floden (2006))
ε	related to elasticity of home hours	calibration
s	substitutability of disutilities to work	calibration
ϕ_n	weight on disutility from market labor	calibration
ϕ_h	weight on disutility from home labor	calibration
ϕ_b	weight on utility from children	calibration
β	discount factor	0.580 (Cooley and Prescott (1995))
δ	depreciation of capital	0.382 (Cooley and Prescott (1995))
α	capital share in market output	0.36 (Hansen (1985))
$p_m(j)$	male wage profile	estimated, see section 1.3.1
τ_{ss}	social security tax rate	0.11 (Heer and Maußner (2009))
γ	share of market inputs in home	0.2 (and robustness checks)
z_m	male home labor productivity	1 (normalization)
z_f	female home labor productivity	1 (assuming $z_m = z_f$)
τ_b	time cost on mother per child	$\frac{1}{2}\frac{1}{10}$ (6 month)
$\bar{x}(b_h)$	amount of home good needed	cross-sectional variation
χ_t	gender wage gap	estimated, see section 1.3.1

Notes: Since the model is calibrated to a ten years frequency, the discount rates and depreciation rates are converted as $\beta = 0.947^{10}$ and $\delta = 1 - (1 - 0.047)^{10}$.

In the literature the range of estimates of the labor share in home production is very wide. Studies that include housing as capital or equipment used for home production typically find a relatively low value, close to the one of market production, e.g. Greenwood, Rogerson, and Wright (1995), while Benhabib, Rogerson, and Wright (1991), who exclude housing, estimate a very high value of 0.92. In my model, the need for home production is at the margin arising from having children living in the household, and does not correspond

[17] As an approximation to the first order, the Frisch elasticity of market labor supply –when time-constraints are slack– is $\frac{1}{\eta}$.

closely to either study. Since parents can acquire home production inputs in the market, such as hiring nannies or paid domestic help, the share of time-saving inputs acquired in the market, γ, should be higher than the Benhabib, Rogerson, and Wright (1991) value. As a benchmark I consider an intermediate value of $\gamma = 0.2$, but I conduct a series of robustness checks in section 1.F.

1.3.1 The Gender Wage Gap as Ratio of Residual Wages

To construct a series of the gender wage gap to feed into the model, I use data from the Panel Study of Income Dynamics (PSID) for the United States from 1968 to 2007.[18] First I regress for individuals aged 20 to 59 the logarithm of real wages on a set of observables, including most importantly education. In particular I estimate by OLS

$$\log w_{i,t} = \beta_{0,t} + \beta_{1,t} Dfemale_{i,t} + L(j) + X_{i,t}\gamma + \epsilon_{i,t} \tag{1.21}$$

where $Dfemale_{i,t} = 1$ if i is female and 0 if male. $L(j)$ is a polynomial in age and $X_{i,t}$ a vector of other observables, including a polynomial in years of education and race dummies. The estimated gender wage gap for year t, defined as the ratio of women's to men's relative earnings not explained by $X_{i,t}$, is then given by $e^{\beta_{1,t}}$. I give the full regression results in table 1.9 of the appendix, and plot the implied series in figure 1.3. To construct the series of χ_t to feed into the model, where a period has a length of 10 years, I take the simple averages. For the final steady state I assume that the gender wage gap is closed. I impose for the transition periods between the last available data point and the steady state, that χ_t grows at the same rate as over 1968–2007 until it reaches 1 and then remains at 1.

The estimates of equation 1.21 imply an age profile in wages, for male wages $p_m(j) = \exp(L(j))$, which I illustrate in figure 1.5. Then I impose for females

$$p_{f,t}(j) = \chi_t p_m(j) \tag{1.22}$$

where I obtained χ_t as described above.

[18] In section 1.B of the appendix, I discuss the advantages of using data from the PSID, rather than from the CPS, and compare the data and results from these two surveys.

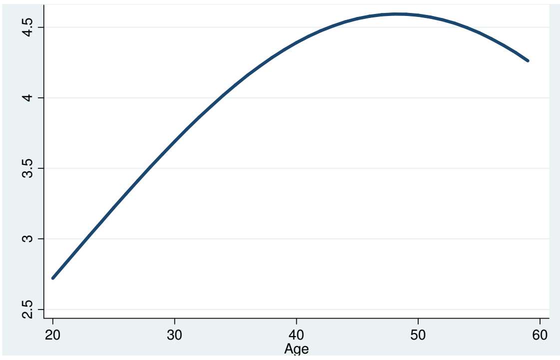

Figure 1.5: Age profile of wages

1.3.2 Home Production

To calibrate the required amount of home goods $\bar{x}(b_h)$, notice that male and female home and market hours depend on a couple's Pareto weights, consumptions and the required amount of home good $\bar{x}(b_h)$. In particular, at an interior solution a household's first order condition imply

$$\bar{x}(b_h) = \left(\frac{\phi_h}{\phi_n} \left(\frac{1+\varepsilon}{1+\eta} \right)^{1/s} \frac{h_m^{\frac{(s-1)\varepsilon-1}{s}}}{n_m^{\frac{(s-1)\eta-1}{s}}} \frac{\tilde{w}_m}{z_m} \frac{\gamma}{1-\gamma} (z_m h_m + z_f h_f) \right)^{\gamma} \tag{1.23}$$

Conditional on all other parameters, this relationship can be used to infer $\bar{x}(b_h)$ from the Aguiar and Hurst (2007) data. As a functional form I assume

$$\bar{x}(b_h) = \kappa_0 + \kappa_1 \cdot b_h^{\kappa_2} \tag{1.24}$$

and expect to find $\kappa_0 > 0$, $\kappa_1 > 0$ and $0 < \kappa_2 < 1$, which would mean home production is always positive and increasing in number of children, but at a decreasing rate. I choose the parameters $\kappa_0, \kappa_1, \kappa_2$ to replicate the observed variation of married men's and women's average home hours against the number of children in the household, according to (1.23). The details are given in appendix 1.D.

1.3.3 Remaining Parameters

Six parameters are left to be chosen, but I have only the five targets of table 1.2 to match in 1965, the base year. Four parameters $(\phi_n, \phi_h, \varepsilon, s)$ correspond to the targets for male

Table 1.2: Calibration targets of the benchmark model

1965-Moments to be Matched	**Data**	**Fictive S.S.**	**in Transition**
Number of children (TFR)	2.913	2.9726	2.8493
Market hours of men	0.3886	0.3890	0.3907
Market hours of women	0.1120	0.1111	0.1139
Home hours of men	0.0950	0.0950	0.0953
Home hours of women	0.3896	0.3909	0.3893
Additional Target to be Matched			
Long-run TFR	2 (assumed)		2.0312

Notes: For the 1965 moments, the first column shows the value of the statistics in the data. The second column shows the model analogues, taking the demographics as given, when agents believe the gender wage gap to remain constant forever. The third column shows the model implied outcomes, when in 1965 agents learn the true future path of the gender wage gap. To discipline the calibration a restriction on the long-run number of children is added. For the long-run TFR, the last column shows the model's final steady state TFR.

and female hours worked at home and in the market, and two parameters (ϕ_b, σ_b) are key for the fertility choice.

These parameters are, of course, calibrated jointly, but it is insightful to think of them as being chosen to match particular moments in the data. Notice that the optimality conditions for a household before retirement imply $\left(\frac{h_m(j)}{h_f(j)}\right)^{\frac{(s-1)\varepsilon-1}{s}} = \frac{z_m}{z_f}\chi(j)\left(\frac{n_m(j)}{n_f(j)}\right)^{\frac{(s-1)\eta-1}{s}}$. Intuitively, given the gender wage gap and relative home productivities, s is chosen to replicate the ratio of female to male labor supply. Then ε is set to match relative home hours. Then ϕ_n and ϕ_h are chosen so that absolute male and female market and home hours, respectively, equal the observed ones. Given these parameters, the cross-sectional variation in hours worked against the number of children gives, according to (1.23), the parameters $\kappa_0, \kappa_1, \kappa_2$, describing the required amount of home production $\bar{x}(b_h)$. Finally, the two parameters governing fertility have to be chosen. While ϕ_b captures the relative weight the household attaches to having children (compared to consumption), σ_b essentially captures the curvature. I restrict the calibration by choosing σ_b such that in the final steady state, the total fertility rate is approximately 2. A value of 2 seems natural, as the number of children born is just replacing previous generations. Moreover, it is close to most recent values for the US. Conditional on a value for σ_b, I calibrate the remaining five parameters to the data of 1965 under the fiction that households believed gender wage gap to remain constant forever. Then I solve the model for the final steady state, in which the gender wage is closed. If the implied long-run fertility rate differs from 2, I update the guess for σ_b until consistent.[19] Table 1.3 shows the values found through this calibration exercise. They imply for the required amount of home production $\bar{x}(b_h) = 0.1813 + 0.0279(b_h)^{0.8845}$.

Table 1.3: Calibrated parameters of the benchmark model

	Description	**Value**
σ_b	elasticity of demand for children	0.3950
ε	related to elasticity of home hours	3.5740
s	substitutability of disutilities to work	1.4041
ϕ_n	weight on disutility from market labor	2.6712
ϕ_h	weight on disutility from home labor	1.8398
ϕ_b	weight on utility from children	0.0515

1.4 Results of the Benchmark Model

To obtain the transition path of the calibrated model, I feed the series of the observed gender-wage gap into the model. For the first period I need initial conditions. I take the demographic structure from the data. Since I do not have age-specific data on household asset holdings for 1965, I initialize household asset holdings with the values of a fictive steady state in which agents believed the gender wage gap to remain constant forever.[20] It should be stressed that in the model young couples, who are the ones deciding on how many children to have, start out with zero assets. The initialization of asset holdings applies to older households only, and could affect fertility only through general equilibrium effects on wages or interest rates, which are likely to be small.

I assume that the economy will eventually reach a steady state in which male and female wages are equalized. Since fertility is a choice in the model, the age distribution evolves endogenously over time. Like Auerbach and Koltikoff (1987), I select the long-run equilibrium such that in the final steady state the growth rate of the population is constant. A constant number of children per couple is not enough to ensure this outcome, as an infinite echoing series of baby booms or busts might occur. Since a balanced growth path

[19]I perform a series of robustness checks, including alternative values for σ_b (and therefore of ϕ_b), and report the model results under alternative parameters in section 1.F in the appendix.

[20]This is the fictive steady state used for calibrating the model against the data. The age-distribution of 1965 is, however, not the stationary distribution, which would be implied by the population growth rate of this year.

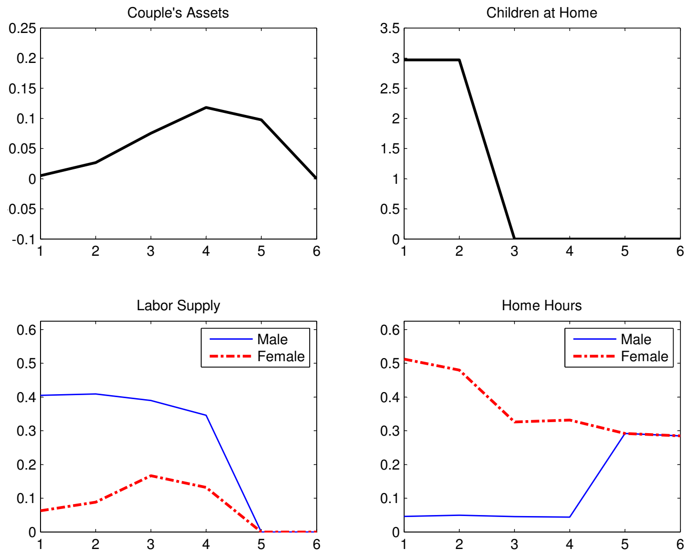

Figure 1.6: Life-time choices in the initial steady state

Notes: This graphs plots the representative couple household's policy functions for assets, male and female market and home hours, as well as number of children living at home, over the life-cycle, from age $j = 1$ (20–29) to $j = T_l = 6$ (70–79).

requires constant population growth to ensure a constant capital-labor ratio, I solve for the final steady state by solving a fixed-point problem for the population growth rate.[21]

1.4.1 Comparing the Steady States

Figures 1.6 and 1.7 show the policy functions of the representative couple in the fictive initial and in the final steady state. In the initial steady state a couple has more than two children and there is population growth. Therefore, there are relatively more young households in the economy, who start out without any assets. As a consequence, the equilibrium interest rate is such that $\beta(1+r) > 1$, and consumption, both male and female, is increasing over the household's life-cycle. As consumption rises, an agent prefers to work less at a given wage. However, holding consumption and home production constant, labor supply increases in the wage rate. Since there is the age premium in wages (figure 1.5), these two effects work against each other, resulting in the labor supply plotted in the graph.

In the initial steady state, the gender wage gap implies gains from specialization in the

[21]First I guess a population growth rate, which implies a stationary age distribution. Then I compute the steady state and the population growth rate implied by (1.20). I iterate to find the fixed point.

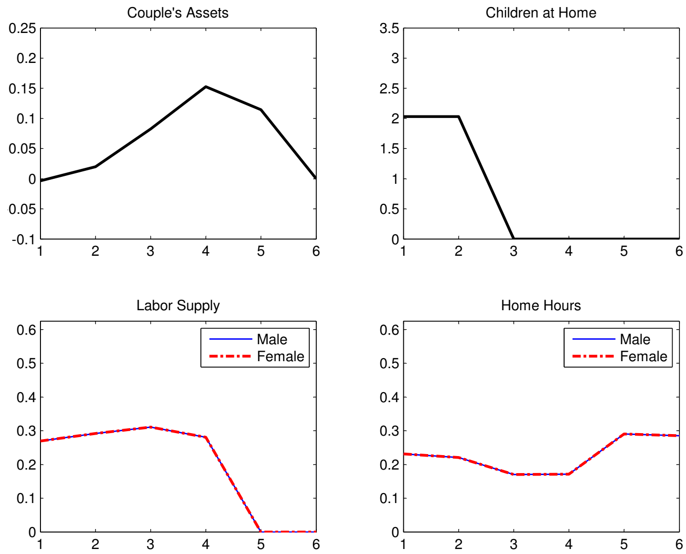

Figure 1.7: Life-time choices in the final steady state

Notes: This graphs plots the representative couple household's life-cycle policy functions for assets, male and female market and home hours, as well as number of children living at home, under the prices of the final steady state. Since the gender wage gap is closed, hours worked of men and women coincide.

couple household. Consequently, a wife shoulders most of the housework, and most of a couple's labor supply is coming from the husband. In the final steady state, on the other hand, the gender wage gap is closed, and there are no gains from specialization anymore.[22] Hours worked of men and women are therefore equalized, both in the market and at home.

Comparing the policy functions of the final and the initial steady state shows, most of the increase in female labor supply comes from young women, which is consistent with the empirical findings by Buttet and Schoonbroodt (2006) and Olivetti (2006).

1.4.2 The Transition in the Benchmark Model

Figure 1.8 shows the transitional dynamics of the economy[23], starting from an initial situation ($t < 0$), in which wages were expected to remain constant at their 1965 values. Then at $t = 0$, corresponding to the year 1965, the true path of the gender wage gap gets known, but relative wages do not start changing before $t = 1$, year 1975. The economy

[22]By assumption male and female home productivities are equal throughout. Advances in technologies over the last century, such as infant formula, have brought male and female productivities closer together. Albanesi and Olivetti (2007) argue that this allowed female labor force participation to rise. In my framework, it also implies a rise in male participation at home.

[23]The transitional graphs in the main text show the behavior of aggregate variables. Figure 1.21 of the appendix shows the disaggregation by age.

starts to converge to a new steady state in which relative wages are equalized. During the transition the gender wage gap, shown in the upper-left panel, closes gradually. As a consequence, women work more hours in the market and less at home, whereas for men the opposite happens. Initially, fertility is declining as raising children becomes more costly to the parents.

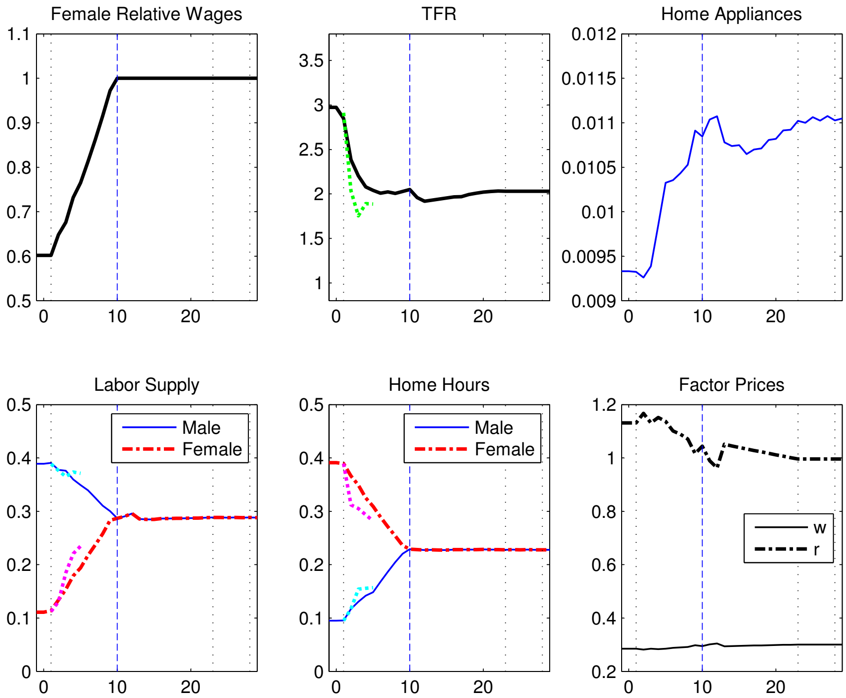

Figure 1.8: Transition path of the unitary model ($\theta = 0.5$)

Notes: This graphs shows the benchmark model's transition over time, that is implied by the narrowing of the gender wage gap (upper-left panel). The dotted lines show the data.

What is striking in the transition process is that fertility flattens out *before* the gender wage gap is closed (at the blue dashed line). While the gender wage gap is closing, the model implies a reallocation of labor across gender. When female wages rise, a household finds it optimal to increase the wife's labor supply and to decrease her time working at home. However, since relative wages have changed, but not relative productivities at home, this reallocation entails an increase in men's home production. In all periods, the couple also acquires more home appliances to substitute for the overall drop of their time working at home. The link between higher female relative wages and lower fertility breaks at some point.

The change in relative wages alters the environment in which the couple makes its economic decisions. Initially, when the gender wage gap is big, there is a great degree of specialization in the household, resulting in a husband working substantially more in the labor market than his wife, but much less at home. In this situation, due to increasing marginal disutility from working, a husband is not prepared to put in much more time at home when his wife works more hours in the market. A rise in female relative wages directly increases female labor supply, and lowers female, as well as total, time spent on home production. As the couple devotes less time to having children, fertility falls sharply, despite the rise in home appliances. However, in later periods when the gender wage gap is fairly small, the spouses time allocation and, thus, their disutilities from working are very similar. When then the wage gap shrinks further, the rise in male home hours is, at a given level of home production almost big enough to keep total home labor constant; in the limit of equalized wages, a drop in female home production is fully offset by men. On top of this, with the improvement in the wife's earnings, the couple can acquire more parental time saving inputs.

For the optimal choice on how many children to have, the couple outweighs the benefits from having an additional child with the utility cost of child care. The reallocation of a man's time from market to home, which comes with the change in relative wages, might actually reduce his marginal cost of having an additional child, although his share of child care rises, since the disutilities are imperfect substitutes and his initial time allocation was very unbalanced. Similarly, a mother's marginal cost might increase, fall, or not be affected at all. The model results clearly suggest that for the first part of the transition, as female relative wages improve, the parents' marginal utility cost is increasing, and therefore they prefer to have fewer children. But when the gender wage gap is sufficiently small and shrinks further, their marginal cost is not affected, resulting in a constant fertility rate.

I will show in the next two sections that key in understanding why fertility did not fall further is the rise in male home labor, that we have observed in the data. The higher use of parental time-saving inputs into home production is important in matching the timing, but it alone is insufficient to explain the data.

1.4.3 Counterfactual: The Absence of Male Home Labor

In this part I am shutting down the rise of male home labor. In the existing literature on fertility it is commonly assumed that child-care is a function of female time only. By setting male home productivity to zero, my model nests this as a special case. Notice that in this counterfactual exercise, men and women do not become 'identical' in the final steady state. Although their wages will eventually be equalized, specialization in the household persists because of the different home productivities.

Not to confound changes in technology with changes in preferences, I keep all preference parameters at their baseline values, but set $z_m = 0$ and adjust z_f such that the household still chooses in 1965 the same number of children as in the data.[24] Figure 1.9 shows the transition of the model, when men cannot counteract the fall in women's home hours.

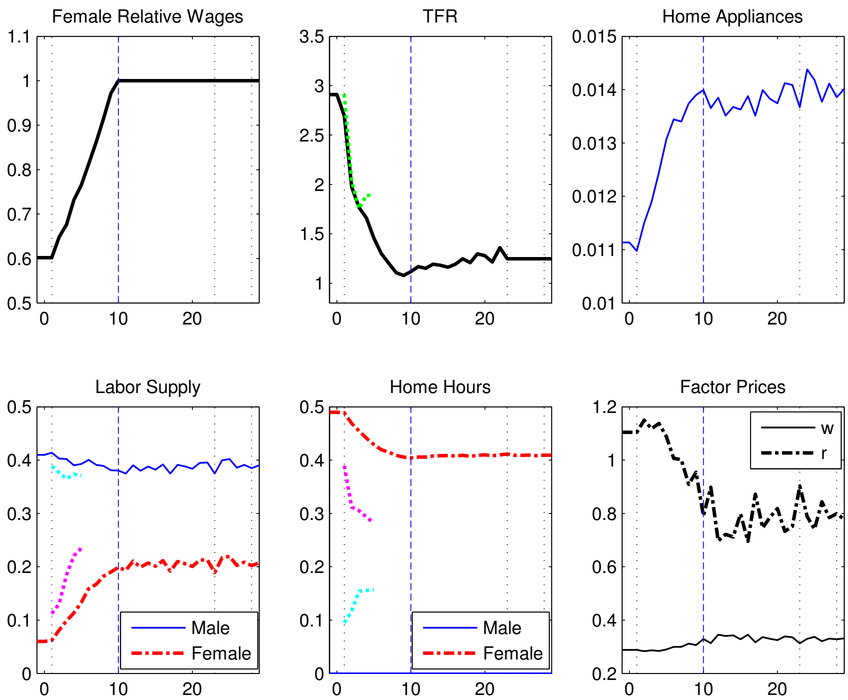

Figure 1.9: Transition of the unitary model ($\theta = 0.5$) with $z_m = 0$

Notes: For the model without male home production, this graphs plots the transition implied by the narrowing of the gender wage gap (upper-left panel) over time. The dotted lines show the data.

It implies a monotone drop in fertility as long as female wages catch up– which is

[24]Since by assumption of $z_m = 0$ this model variant is doomed to fail along the dimension of male home hours, notice that I could not apply the calibration strategy of the benchmark model, which has H_m as one of the targets.

inconsistent with the data. Throughout the transition, parents are having fewer and fewer children, since child-care hours continue to fall, when women's market labor supply rises. As women's income increase, couples also acquire more home appliances, but this marketization of home production is not strong enough to prevent fertility from falling. Only once the gender wage gap has closed, the optimal number of children stabilizes.

Alternative Calibration of No Male Home Production

As an alternative calibration for the $z_m = 0$-model, I adjust the parameters capturing the choice of number of children, such that also this model variant has a total fertility rate of 2 in the final steady state. More specifically, I take the benchmark calibration, with $z_m = 0$ and $z_f = 1$, and adjust (ϕ_b, σ_b) to target a long-run TFR of 2, but keeping 1965's TFR at the observed value. Given all other parameters from the benchmark, this adjustment yields $\phi_b = 0.0872$ and $\sigma_b = 0.9625$. Then I solve for the transition of the model under this alternative calibration and show the results in figure 1.10. Also under these alternative

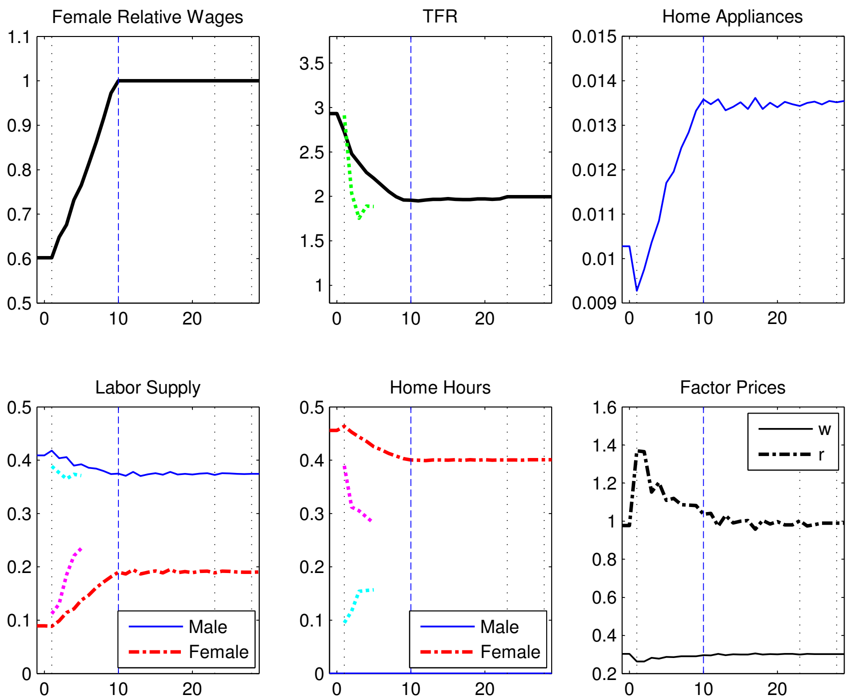

Figure 1.10: Transition of the unitary model ($\theta = 0.5$) with $z_m = 0$, alternative calibration

Notes: For model without male home production under the alternative calibration, this graphs plots the transition implied by the narrowing of the gender wage gap (upper-left panel) over time. The dotted lines show the data.

parameters, the model without male home production predicts that the total fertility rate falls as long as the gender wage gap shrinks. That parents use more market inputs into home production is not sufficient for generating a flattening out of the fertility rate before the gender wage gap has closed.

To conclude, in the benchmark model of above, it is the rise in male home labor, which counteracts the fall of female time inputs into child raising, that is key in understanding why the fertility decline ended.

1.4.4 No Marketization of Home Production

In this section I show, that parents can use more time-saving inputs at home when female wages rise, is not crucial for generating a flattening out of the total fertility rate. However, it is important in matching the timing.

To rule out marketization of home production, consider a simpler version of the model in which home production is a function of male and female home hours only. This is the special case of $\gamma = 0$. I use the same calibration strategy as for the benchmark model, in order to give both models equal chances in matching the data.[25] Figure 1.11 shows the transition of this model variant. Also the model without marketization predicts that fertility stops falling before the gender wage gap is closed (in $t = 10$, at the dashed line). This shows that the reallocation of men's time from market to home, and of women's time from home to the labor market is, in principle, sufficient in breaking the direct link between higher female wages and fewer children. However, this version of the model predicts that fertility does not flatten out before the year 2025 ($t = 7$), but in the data the fertility rate has been constant already since the late 1970s. The benchmark model featuring marketization of home production, on the other hand, gets closer and predicts, as shown

[25] The same calibration strategy as for the benchmark model gives the following parameters: $\sigma_b = 0.750$, $\varepsilon = 3.4935$, $s = 1.4073$, $\phi_n = 2.6281$, $\phi_h = 1.8434$, $\phi_b = 0.0524$ implying $\bar{x}(b_h) = 0.3762 + 0.0515(b_h)^{0.9254}$. They imply for the targets:

1965-Moments to be Matched	**Data**	**Fictive S.S.**	**in Transition**
Number of children (TFR)	2.913	2.9134	2.7982
Market hours of men	0.3886	0.3890	0.3949
Market hours of women	0.1120	0.1104	0.1159
Home hours of men	0.0950	0.0711	0.0715
Home hours of women	0.3896	0.3630	0.3616
Additional Target to be Matched			
Long-run TFR	2 (assumed)		2.0279

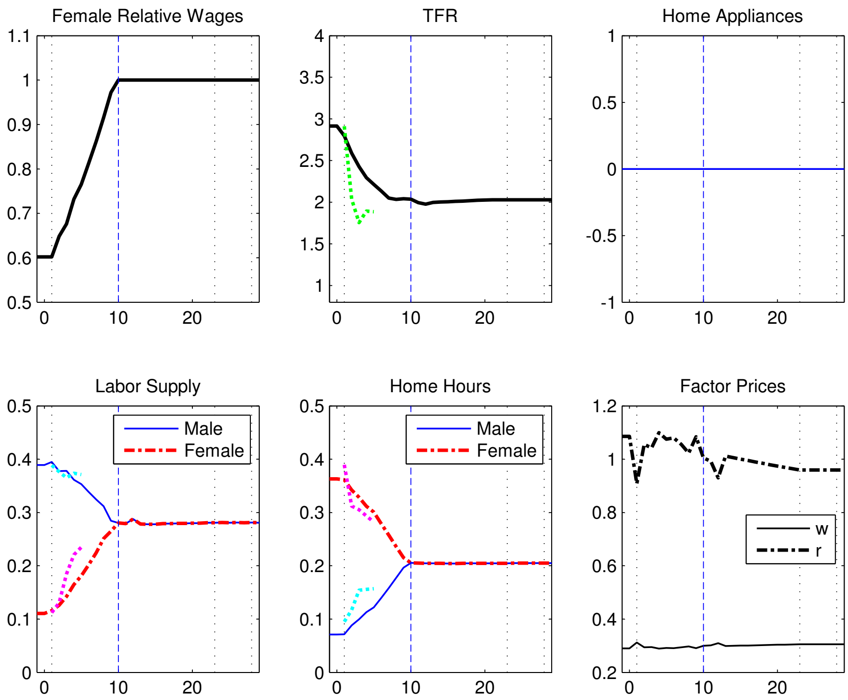

Figure 1.11: Transition path of the unitary model ($\theta = 0.5$) with $\gamma = 0$

Notes: For the model without marketization, this graphs plots the transition implied by the narrowing of the gender wage gap (upper-left panel) over time. The dotted lines show the data.

in figure 1.8, a flat fertility rate since 1995 ($t = 4$). In section 1.6, below, I compare the different versions of the model and the data in greater detail.

1.5 The Bargaining Model

Since Feyrer, Sacerdote, and Stern (2008) have argued that changes in women's household status is important in explaining the time series in total fertility, I introduce next household bargaining. The only modification to the benchmark model is that now the Pareto weights in the household's optimization program are determined endogenously.

Here, rising relative wages also improve women's say in household decision making, which corresponds in my model to a higher weight on women's utility in a couple's optimization program. I assume that this weight is the result of a Nash bargaining over the surplus generated by marriage. The wife's bigger say reduces her share of housework, relative to her husband, by more than what a change in relative wages per se would imply.

1.5.1 Determination of Intrahousehold Weights

The solution to the couple's optimization program at a given Pareto weight θ defines a sequence of life-time utilities $\{V_{C,m}(j|\chi,\theta),\, V_{C,f}(j|\chi,\theta)\}_{j=1}^{T_l}$ for the man and the woman who form the household. I follow McElroy and Horney (1981) and assume that the sharing rule θ is the result of Nash Bargaining. When both partners meet at the beginning of their adult lives, they bargain under full commitment over the surplus generated from marriage. The threat point of each partner is staying single, rather than entering the match. In equilibrium, the weights are then the solution to

$$\theta = \arg\max_{\tilde{\theta}}[V_{C,m}(1|\chi,\tilde{\theta}) - V_{S,m}(1|\chi)][V_{C,f}(1|\chi,\tilde{\theta}) - V_{S,f}(1|\chi)] \tag{1.25}$$

where $V_{C,m}(1|\chi,\tilde{\theta})$ and $V_{C,f}(1|\chi,\tilde{\theta})$ are the husband's and wife's lifetime utilities at age $j = 1$ that are implied by the joint optimization program, and $V_{m,S}(1|\chi)$ and $V_{f,S}(1|\chi)$ are the life-time utilities if the man or the women stayed single (at age $j = 1$), given the series of the gender pay gap that they face over their lives ($\chi = \{\chi_j\}_{j=1}^{T_l} = \{\frac{w_f(j)}{w_m(j)}\}_{j=1}^{T_l}$).

To find the value of the threat points, consider the optimization problem of male and female singles. Since they cannot have children, the value function of a single agent of gender $g \in \{m, f\}$ solves

$$V_{S,g}(a;j) = \max_{c,,n,h,e,a'} u(c,n,h,0) + \beta V_{S,g}(a';j+1) \text{ for } j \geq 1 \tag{1.26}$$

subject to

$$a' = \begin{cases} (1+r)a + \tilde{w}_g(j)n - c - e & \text{for} \quad j < T_r \\ (1+r)a + \frac{T_{ss}}{2} - c - e & \text{for} \quad j \geq T_r \end{cases} \tag{1.27}$$

$$\bar{x}(0) = e^{\gamma}H^{1-\gamma} \text{ with } H = z_g h \tag{1.28}$$

$$n + h \leq 1 \tag{1.29}$$

$$V_{S,g}(\cdot;T_l+1) = 0 \text{ and } a_1 = T_{l+1} = 0 \tag{1.30}$$

$$\{w_g(k), r(k)\}_{k=j}^{T_l} \text{ known} \tag{1.31}$$

I find the singles' value function at age $j = 1$ numerically. Then I solve the Nash bargaining problem (1.25) to find a household's Pareto weight. The resulting sharing rule depends on the life-time series of the gender wage gap, since it changes the outside option of females relative to males. In other words, the spouse's bargaining position depends on their relative wages.

1.5.2 Dependence on the Weights

A rise in wives' Pareto weights, relative to their husbands, –a drop in θ– makes them better off through a intrahousehold reallocation of consumption and hours worked. One optimality condition that is particular useful in illustrating the mechanism of the model is the ratio of male to female home hours. When both time constraints (1.13) are slack, the optimal division of home labor for retired couples is given by[26]

$$\frac{h_m}{h_f} = \left(\frac{1-\theta}{\theta}\frac{z_m}{z_f}\right)^{1/\varepsilon} \quad \text{for } j \geq T_r \tag{1.32}$$

Increase in women's relative Pareto weight imply an increase in the share of men's home hours. Numerically I find that this also the case for working-age couples. An improvement in a woman's bargaining position therefore decreases her share of home hours and lowers *her* opportunity cost of having children. However, as her partner then has to contribute more to home production, *his* preferred number of children is falling.

1.5.3 Calibration

As for the benchmark model in section 1.3, I calibrate the model with intrahousehold bargaining against data for 1965. I report the obtained parameter values in table 1.4, and the targets and their counterparts in the model table 1.5. They imply for the required amount of home production $\bar{x}(b_h) = 0.1923 + 0.0299(b_h)^{0.8793}$.

1.5.4 Steady State Comparison

Table 1.6 shows the model implied variables for the 1965-steady state, taking the age distribution as given, and the final steady state with endogenous distribution across age.

[26]One can show that as $s \to \infty$, making the choice of home and market hours separable, the optimality condition (1.32) also holds for working-age couples.

Table 1.4: Calibrated parameters for the bargaining model

	Description	**Value**
σ_b	elasticity of demand for children	0.4800
ε	related to elasticity of home hours	4.1041
s	substitutability of disutilities to work	1.3673
ϕ_n	weight on disutility from market labor	2.3727
ϕ_h	weight on disutility from home labor	2.4044
ϕ_b	weight on utility from children	0.0764

Table 1.5: Calibration targets for the bargaining model

1965-Moments to be Matched	**Data**	**Fictive S.S.**	**in Transition**
Number of children (TFR)	2.913	2.8371	3.0463
Market hours of men	0.3886	0.3889	0.3941
Market hours of women	0.1120	0.1111	0.1008
Home hours of men	0.0950	0.0948	0.0902
Home hours of women	0.3896	0.3885	0.4001
Additional Target to be Matched			
Long-run TFR	2 (assumed)		2.0205

Notes: For the 1965 moments, the first column shows the value of the statistics in the data. The second column shows the model analogues, taking the demographics as given, when agents believe the gender wage gap to remain constant forever. The third column shows the model implied outcomes, when in 1965 agents learn the true future path of the gender wage gap. To discipline the calibration a restriction on the long-run number of children is added. For the long-run TFR, the last column shows the model's final steady state TFR.

The steady state results of the bargaining model, rows 1 and 2, confirm, improvement in women's relative wages lead to a reduction in men's Pareto weight in household decision making. In the final steady state, in which the gender wage gap is assumed to have disappeared, both spouses have an equal weight in the household optimization ($\theta = 0.5$), whereas initially, when men earned relatively more, husbands accrued a bigger weight.

Not surprisingly, in response to higher wages, female labor supply increases and women's share of home production decreases. Fertility is lower in the long-run, when the gender wag gap has closed. In the bargaining model there are three forces driving fertility decisions. Firstly, higher wages exert a positive income effect increasing a couple's desire to have children. Secondly, higher relative earnings to women affect the division of market and home labor between men and women. In particular, men have to contribute more to home production, leaving women with more disposable time, which tends to boost fertility. Thirdly, however, the bargaining effect has differential effects on men and women. While a

Table 1.6: Steady states comparisons

χ	θ	TFR	N_m	N_f	H_m	H_f
0.602	endogenous 0.612	2.8371	0.3889	0.1111	0.0948	0.3885
1	endogenous 0.500	2.0205	0.2972	0.2972	0.2254	0.2254
1	fixed at 0.612	2.0884	0.2407	0.3600	0.2351	0.2158

Notes: This table shows the bargaining model's steady state predictions, taking the gender wage gap (χ) as given. The first row corresponds to the year 1965, for which the age distribution $\mu(j)$ is taken from the data. The second row shows the prediction for the final steady state, in which, because of equal wages, the spouses' Pareto weights are equalized ($\theta = 0.5$). The last row shows the counterfactual steady state that would occur if the Pareto weights remained constant at their 1965 value.

higher Pareto weight on females increases the number of children a mother wants to have, it reduces the optimal number for men, who will need to provide more input to child care.

To disentangle the effects, I conduct a counterfactual exercise. I vary women's relative wages, but keep the Pareto weights constant. The last row of table 1.6 shows the steady state results under a fixed weight of $\theta = 0.612$, which was found to be optimal under $\chi = 0.602$. Comparing them with the row above highlights the role of household bargaining: household bargaining reduces fertility in the final steady state. While the improvement in women's say in the household, which comes along with the shrinking of the gender wage gap, increases their preferred number of children, it reduces the optimal number of children for fathers, who need to work more and more at home due the mothers' bigger say. The number of children the couple chooses is in between the optimal numbers for both spouses. Overall I find that when female relative wages are high and women's Pareto weights increase, fertility drops. The intuition is that higher relative female wages per se imply that, optimally, a husband provides more home hours. When in addition the husband's relative weight falls, he needs to supply yet more home hours, which reduces his utility substantially. Consequently, the higher female relative wages are, the faster the male preferred number of children drops; they prefer reducing home production over having more children. Wives do prefer to have more children in this case, but the increase in their weight in the household optimization is not strong enough to overcome the drop in husbands' optimal number of children.

1.5.5 The Transition Path of the Bargaining Model

Figure 1.12 shows the transitional dynamics of the economy in the presence of intrahousehold bargaining. As the gender wage gap closes, the husband's relative weight in household

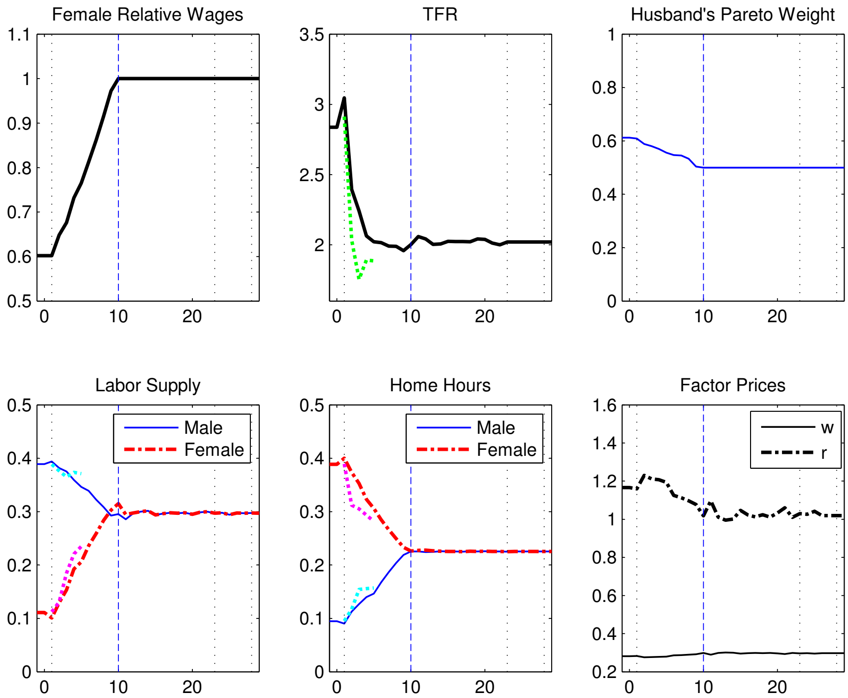

Figure 1.12: Transition path of the bargaining model

Notes: This graphs plots the transition of the model with intrahousehold bargaining. The gender wage gap (upper-left panel) closes exogenously over time. As a consequence the husband's relative Pareto weight, shown for newly matched households (age $j = 1$), falls (upper-right panel). The dotted lines show the data.

decision declines, until in the final steady state with equalized wages both spouses have equal say and $\theta = 0.5$. Notice that at $t = 0$ households learn the true future path of the gender wage gap, but relative wages do not start changing before $t = 1$. Since Pareto weights depend on life-time relative wages, the improvement in the wife's relative wages reduces the newly-matched husband's Pareto weight, already in $t = 0$. This bargaining effect increases female relative consumption, and *ceteris paribus* reduces her hours worked. The reallocation of home hours from women to men is therefore stronger than what is explained by changes in relative wages per se.

To further investigate how bargaining affects the transition, I take the bargaining model under the same calibration, but keep the Pareto weights artificially at their initial level. The transition path implied by this counterfactual is shown in figure 1.13. The same

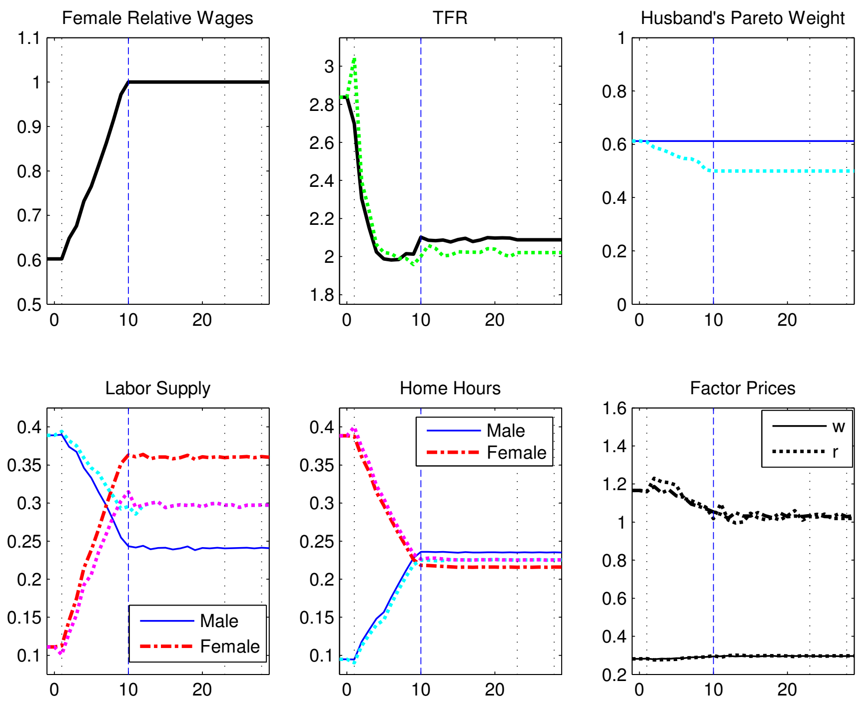

Figure 1.13: Counterfactual transition: holding Pareto weight constant

Notes: This graphs plots the hypothetical transition if men's Pareto weight remained at their initial level. The gender wage gap (upper-left panel) closes exogenously over time. The dotted lines reproduce the transition path of the model with bargaining-determined Pareto weights.

income and substitution effects are at work, but only in figure 1.12, here reproduced by the dotted lines, the bargaining effect is present. With household bargaining, in response to higher relative wages, women get a bigger say in decision making, and their husbands' relative weights decline. As a consequence, men's share of housework rises by more than what is explained by relative wages alone. Since initially home hours differ a lot by gender, men's disutility from putting in more time at home is relatively small, but the marginal gain to women is big. The couple finds it, therefore, optimal to have more children when bargaining shifts the burden of housework towards men. Thus, when the gender wage gap is big and consequently home hours very unequal, intrahousehold bargaining tends to boost fertility. However, when home hours are already rather equal because the gender wage gap is fairly small, bargaining has the opposite effect on fertility. Rising relative female wages per se imply that, optimally, a husband provides more home hours. When in addition the husband's relative weight falls, he needs to supply yet more home hours, which reduces his utility substantially. Consequently, the higher female relative wages are, the faster drops the male preferred number of children; they prefer reducing home production over having more children. Wives do prefer to have more children in this case, but the increase in their weight in the household optimization is not strong enough to overcome the drop in husband's optimal number of children.

While initially, when the gender wage gap is big, the bargaining effect leads to higher fertility, in the longer run it lowers fertility. Overall, however, the effect of intrahousehold bargaining on fertility is rather small, and the behavior of fertility over time is, qualitatively, as in the unitary model.

1.6 Confronting the Models and the Data

In this section, I compare the predictions of the different versions of the model to each other and to the observed variation in the data. Table 1.7, lists the relative changes from 1965 to 2005, and figure 1.14 shows the transition paths of the various models and the data for married men and women. The benchmark model performs better than the model

Table 1.7: Relative changes (in percent) over 1965–2005

	Data		**Model**			
	Married only	All Individuals	Benchmark	$z_m = 0$	$\gamma = 0$	Bargaining
TFR	−35.3 (US-born mothers)		−28.4	−45.9	−20.9	−33.6
N_m	−5.6	−7.3	−10.7	−5.1	−10.6	−12.1
N_f	+109	+87.5	+70.3	+114.3	+56.4	+104.3
H_m	+70.8	+61.2	+55.7	0	+70.8	+62.3
H_f	−24.5	−27.6	−20.6	−12.2	−16.8	−23.6
'RSS', $\frac{1}{5}\sum_{i=1}^{5}(m_i^{model} - m_i^{data})^2$, against						
		data for married only	0.0355	0.0923	0.0647	0.0023
		data for all individuals	0.0087	0.0962	0.0280	0.0065
'Normalized RSS', $\frac{1}{5}\sum_{i=1}^{5}(\frac{m_i^{model} - m_i^{data}}{m_i^{data}})^2$, against						
		data for married only	0.4240	0.2843	0.4788	0.5805
		data for all individuals	0.0735	0.3166	0.1361	0.1022

Notes: H_m and H_f correspond to the Aguiar and Hurst (2007) data for 2003. TFR in 2005 is based on my calculations for TFR of US-born women only, but for 1965 it is for the entire US population. The error due to data limitations is likely to be small, as in the 1970s US-born TFR was closely following the aggregate. I also do not have enough information to decompose fertility into wedlock and out-of-wedlock births. The m_i in the success measures are the relative changes from 1965 to 2005 in TFR, N_m, N_f, H_m, H_f.

version ruling out male participation at home ($z_m = 0$), and than the version not allowing

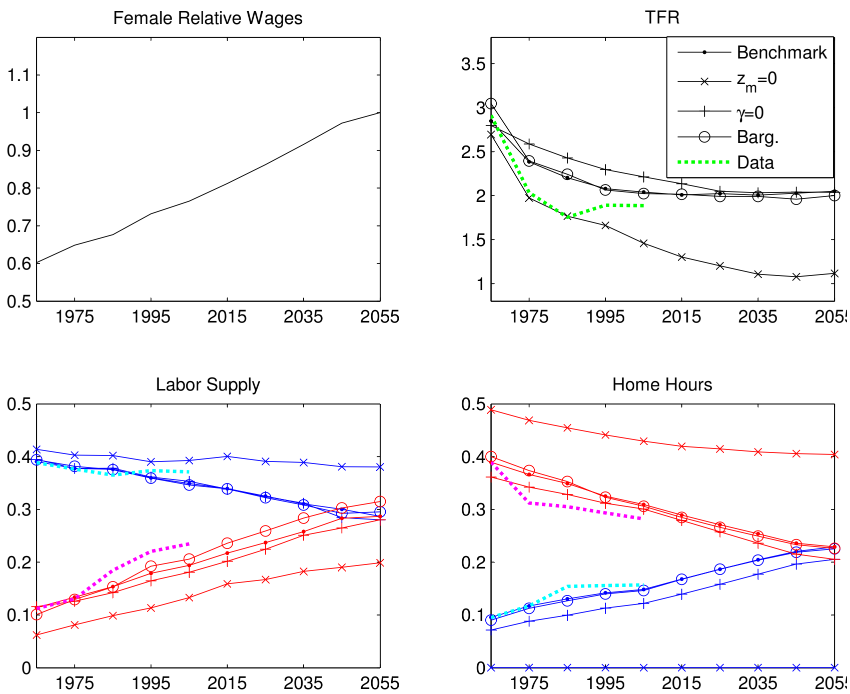

Figure 1.14: Comparing the models and the data

for marketization of home production ($\gamma = 0$). But qualitatively all models with male home production are quite successful. They imply (i) that the fertility rate should stabilize before the gender wage gap is closed, and (ii) a secular rise in men's time devoted to home production. The $z_m = 0$-model, on the other hand, fails in generating a flattening-out of fertility before the gender wage gap has closed. This suggests that key in understanding why fertility did not fall further, despite female wages kept improving, is the rise of male home labor.

However, all models predict that fertility would flatten out much later than observed in the data. In the benchmark model, the optimal number of children per couple stabilizes in 1995, but in the data the total fertility rate is virtually flat since the late 1970s. In the model with $\gamma = 0$, which does not allow for marketization of home production or child care, fertility stabilizes even later. It also understates the rise in female labor supply, but overstates the number of children per couple.

Thus, quantitatively, both the rise of male time and the acquisition of time-saving inputs into home production are important in understanding why the fertility decline came to halt. Comparing the $\gamma = 0-$model to the benchmark, which uses $\gamma = 0.2$, also suggests, that the higher the share of market inputs into child care, the earlier fertility flattens out. In the appendix I show a series of robustness checks, including this parameter, which confirm this.

1.7 Conclusion

In this paper I argue that the common force behind the observed trends in fertility and hours worked is the narrowing of the gender wage gap. I present a general equilibrium model in which having children increases the need for home production, and in which rising female relative wages have not only direct effects on employment, but also reallocate hours worked at home from women to men. Initially, because of the gender wage gap, women shoulder most of home production. When the wage gap shrinks, women's labor supply increases and total home production falls. Men, whose labor supply is much higher than their wives, are because of increasing disutility from working not willing to fully offset the drop in women's time working at home. As a consequence fertility falls. However, the smaller the gender wage gap is, the less of an effect there is on total home production, as the scope for specialization in the household decreases. Because of imperfect substitutability between the disutilities from working at home and in the market, the marginal utility cost of having an additional child can become constant when female relative wages are still improving, despite the change in hours worked, and fertility can remain flat.

Qualitatively the model predictions are consistent with the data: after an initial steep decline, fertility stabilizes before the gender wage gap has fully closed. The model also implies the secular rise of male home production and a fall in female time spent working at home. However, the model generates the flattening out of the total fertility rate later than observed in the data. While qualitatively the rise in male participation in home production can yield a flattening out of the fertility rate, I find that a higher use of parental time-saving inputs into home production helps in matching the timing. However, a marketization of home production alone is not sufficient. Both the rise in male home production and marketization are key in explaining why fertility did not decline to even lower levels.

Appendix to Chapter 1

1.A Total Fertility Rate by Mothers' Birthplace

The US total fertility rate exhibits a U-shape with an incline since the late 1970s. Since immigrant women have more children than the native population (in recent years)[27], at least some parts of this recovery in the aggregate data are the result of immigration. Thus, I construct a series of total fertility rate for US-born women only. I take data from the

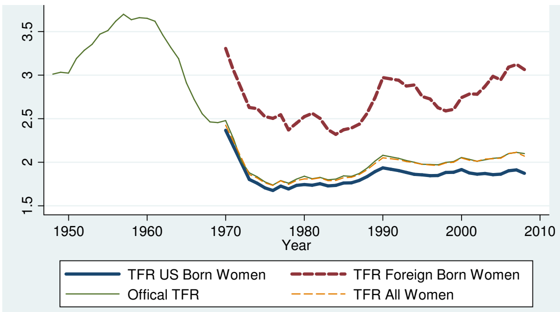

Figure 1.15: Total fertility rate: decomposition by mother's birthplace

Notes: Source: Author's computation based on Vital Statistics of the United States, combined with population estimates from the US Census.

US Vital Statistics, which, since 1970 (but not in 1972) lists live births by the mother's birthplace and five-year age brackets. To obtain age-specific birthrates by immigration status, I then divide the number of live births by the corresponding number of women in the population, for which I use IPUMS data (Census and American Community Survey) with linear interpolation between collection years. Finally I calculate the total fertility rates by adding up the age-specific birthrates and multiplying by 5, as the age brackets are

[27] Over the last decades there has been a dramatic rise in the fraction of births to immigrant mothers. While in 1970 foreign-born mothers accounted for 7.2 percent of all births, in 2008 they account for 24.4 percent, see Vital Statistics of the United States.

of five years width.[28] Figure 1.15 shows the resulting breakdown: fertility of the native population has shown only a very modest incline after the 1970s.

1.B Data Appendix

1.B.1 Fertility in Europe

Fertility trends in most European countries have been very similar to the US: after a decline, fertility rates have stabilized. In figure 1.16 I show the total fertility rate for 20 European countries. These are the official numbers as published by Eurostat; for these countries, due to lacking data, I cannot construct a measure for fertility of native women only.

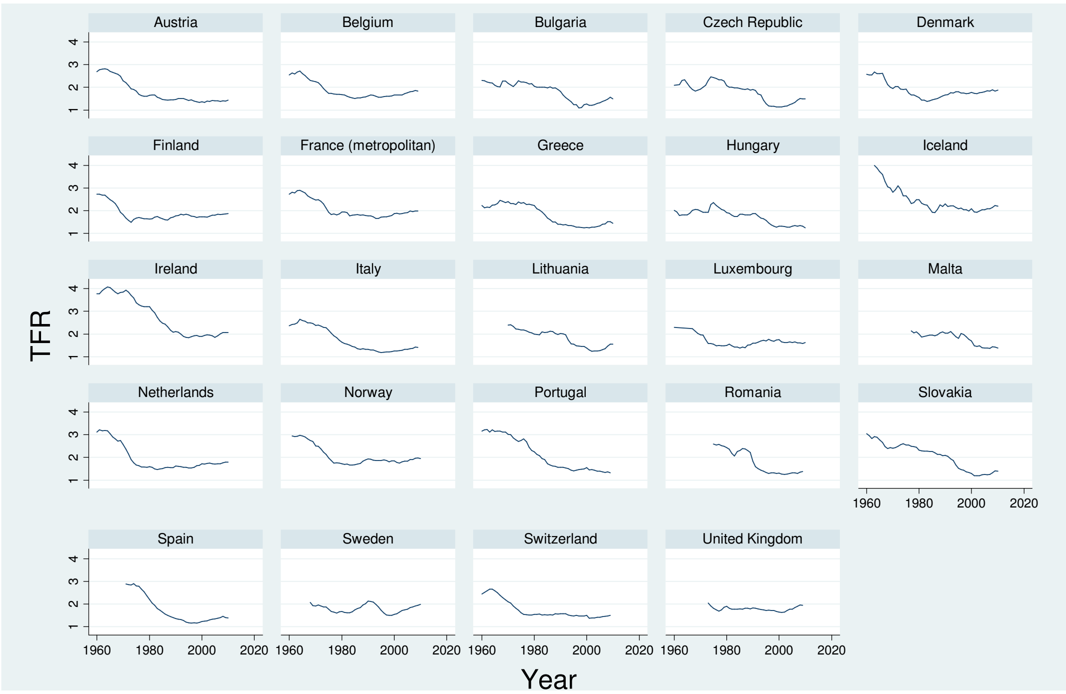

Figure 1.16: Total fertility rates in Europe

Notes: Source: Eurostat

[28]As a consistency check, I do the same calculations for all women in the population, i.e. independent of their immigration status, and compare the constructed series to the official total fertility data. The two series align almost perfectly.

1.B.2 Time Spent on Home Production

To highlight trends in home production, I use data from Aguiar and Hurst (2007), based on the American Time Use Survey (ATUS). Unfortunately the survey questionnaire in 1993 did not ask for the family structure of respondents, such as marital status or number of children. Hence I drop 1993 from my analysis. Next, I need to define what activities asked from ATUS to include as home hours. I start with the definitions of activities Aguiar and Hurst (2007) made:

1. 'Basic Child Care' (what Aguiar and Hurst call child care basic). This excludes time spent on teaching (in a broad sense) and playing with a child.

2. 'Full Child Care' (what Aguiar and Hurst call child care full) includes also teaching and playing with children.

3. 'Home Production', which is sum of time spent on preparing meals, housework, home and car maintenance, gardening and pet care and other domestic duties.

4. 'Non-Market Work' defined as 'Home Production' plus time spent on obtaining goods.

5. My own and *preferred* indicator 'Non-Market Work including Basic Child Care', which I construct as 'Non-Market Work' plus 'Basic Child Care'.

In all statistics and regressions with the dataset I make use of the adjusted weights that Aguiar and Hurst (2007) provide. While the ATUS was designed to be nationally representative when started in 1965, in subsequent years the survey provides weights for respondents. Aguiar and Hurst (2007) adjust these weights for the number of working days within the interview periods, as the survey asks for activities undertaken within a given week.

All five measures of home hours show the same trend as in figure 1.4 over time: a secular decline for women and a rise for men. This robustness across the different measures is confirmed in OLS regressions for data on married respondents in 1965, 1975, 1985 and 2003. The results are shown in table 1.8.

The coefficients of the year dummies indicate the time-trend for female home hours. The trend in male hours is given by the sum of coefficients of the year dummies and

Table 1.8: Regressions of different measures of home hours for married men and women

VARIABLES	(1) Basic Child Care	(2) Full Child Care	(3) Home Production	(4) Non-Market Work	(5) Non-Market +Basic Child Care
Dummy Year 1975	-1.691***	-1.629***	-5.533***	-6.386***	-8.077***
	(0.353)	(0.405)	(0.888)	(0.985)	(1.065)
Dummy Year 1985	-0.252	0.290	-7.293***	-7.215***	-7.467***
	(0.334)	(0.394)	(0.727)	(0.828)	(0.914)
Dummy Year 2003	0.797***	2.302***	-10.68***	-11.40***	-10.60***
	(0.304)	(0.355)	(0.644)	(0.729)	(0.801)
Dummy 1975× Male	2.887***	2.580***	8.158***	8.700***	11.59***
	(0.429)	(0.492)	(1.062)	(1.227)	(1.324)
Dummy 1985× Male	1.934***	1.671***	14.06***	14.22***	16.15***
	(0.378)	(0.455)	(0.897)	(1.050)	(1.140)
Dummy 2003× Male	1.916***	1.456***	16.53***	17.11***	19.02***
	(0.350)	(0.417)	(0.758)	(0.889)	(0.973)
Dummy Male	-5.111***	-5.436***	-25.52***	-28.11***	-33.22***
	(0.296)	(0.348)	(0.658)	(0.782)	(0.857)
Number of Kids in Hh	2.323***	3.111***	2.306***	2.422***	4.745***
	(0.140)	(0.168)	(0.302)	(0.346)	(0.378)
(Number of Kids in Hh)^2	-0.182***	-0.274***	-0.168***	-0.192***	-0.374***
	(0.0319)	(0.0378)	(0.0571)	(0.0649)	(0.0742)
Age	-0.919***	-0.864***	-0.396	-0.463	-1.382***
	(0.134)	(0.157)	(0.341)	(0.383)	(0.417)
Age^2	0.0160***	0.0141***	0.0108	0.0129	0.0289***
	(0.00270)	(0.00317)	(0.00732)	(0.00819)	(0.00885)
Age^3	-8.86e-05***	-7.41e-05***	-6.27e-05	-8.06e-05	-0.000169***
	(1.69e-05)	(2.00e-05)	(4.90e-05)	(5.47e-05)	(5.88e-05)
Constant	19.36***	19.62***	29.32***	37.03***	56.39***
	(2.095)	(2.418)	(4.837)	(5.420)	(5.975)
Observations	17199	17199	17199	17199	17199
R^2	0.198	0.209	0.270	0.259	0.295

Robust standard errors in parentheses
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

their corresponding interaction with the male dummy. Across the five measures, the only coefficients differing in signs are on the year 1985 and the year 2003 dummy for child care. For all other measures of home hours they are significantly negative, indicating a downward trend in female hours. The coefficient on the dummy for male respondents is significantly negative and substantially big (in absolute values). Moreover, the coefficients on the interaction of year dummies and the dummy for males is significantly positive and exceed the overall year effect. This indicates that in 1965 married men worked fewer hours at home than married women, and that over time male hours have been rising and female hours falling.

My preferred measure is 'Non-Market Work including Basic Child Care'. Although most parents might enjoy child care more than other domestic chores, I do include basic care, as it is a necessary task to be done. The change in home hours over time is similar across households with and without children (living at home), as shown in figure 1.17. While these two household types have different levels of home hours, both display the decline in women's and the rise in men's hours.

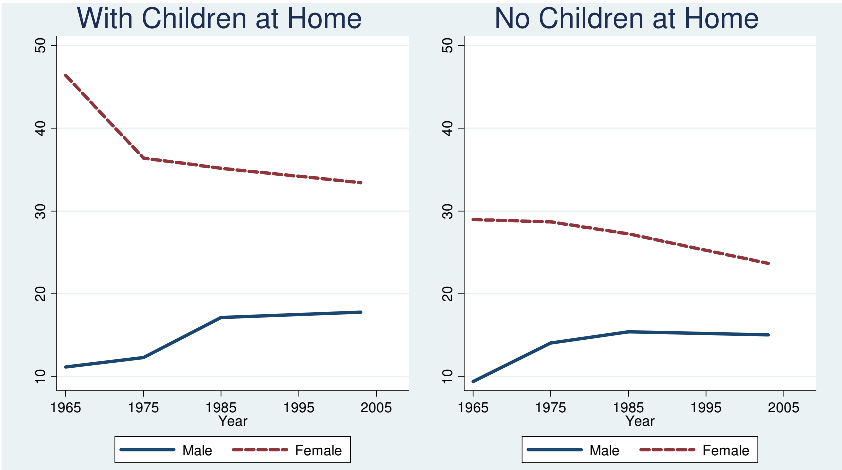

Figure 1.17: Home hours for men and women, with and without children

Notes: Weekly hours spent on nonmarket work and basic child care for men and women aged 20 to 80.
Source: Aguiar and Hurst (2007), based on the American Time Use Survey

One final comment is in order. Since marital status in the Aguiar and Hurst (2007) data is defined in a legal sense, it is not possible to disentangle cohabiting from other singles. But since it is more likely that men and women who are not married, but have children together, are cohabiting, the current number of children can be employed as a proxy. Since changes in cohabitation affect mainly younger people, I plot in figure 1.18 non-market hours worked for men and women aged 20-40. Over time, as relative female wages rise, women spend less time working at home, whereas men devote more time to non-market work. These effects are strongest for married men and women, followed by singles with children. This evidence supports that single men with no children, who are more likely to be without a female partner, are not affected by female relative wages. For single women, however, the trends in home hours of those with and without children are very similar, and virtually flat. Notice that in the dataset time spent on activities is measured in hours per week. In the model, agents have each period a time endowment of 1 that they can split

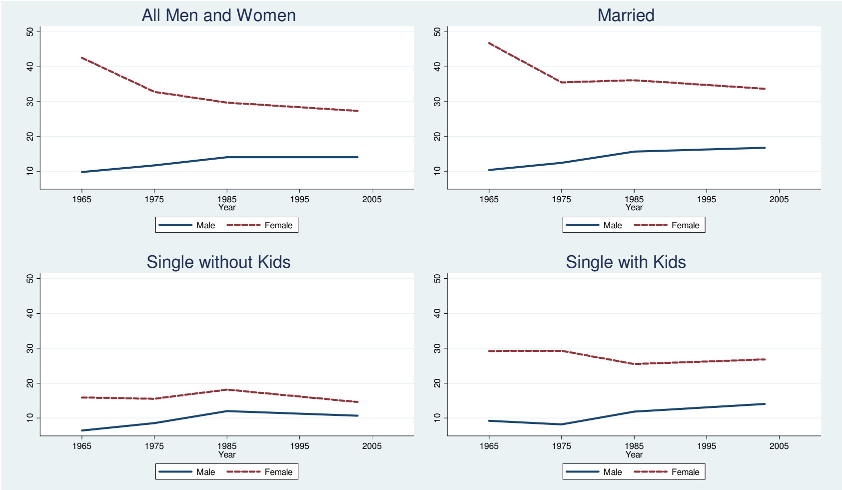

Figure 1.18: Home hours of 20 to 40 year old, married, and singles with and without children
Notes: Weekly hours spent on nonmarket work and basic child care for men and women aged 20 to 40.
Source: Aguiar and Hurst (2007), based on the American Time Use Survey

between market work, home work, and leisure time. Assuming that people need 8 hours of rest every day, the principal total of 168 hours a week leaves 112 discretionary hours over which people can decide. Hence to map data from Aguiar and Hurst (2007) into my model, I divide all hours by 112.

1.B.3 Market Hours: PSID versus CPS Data

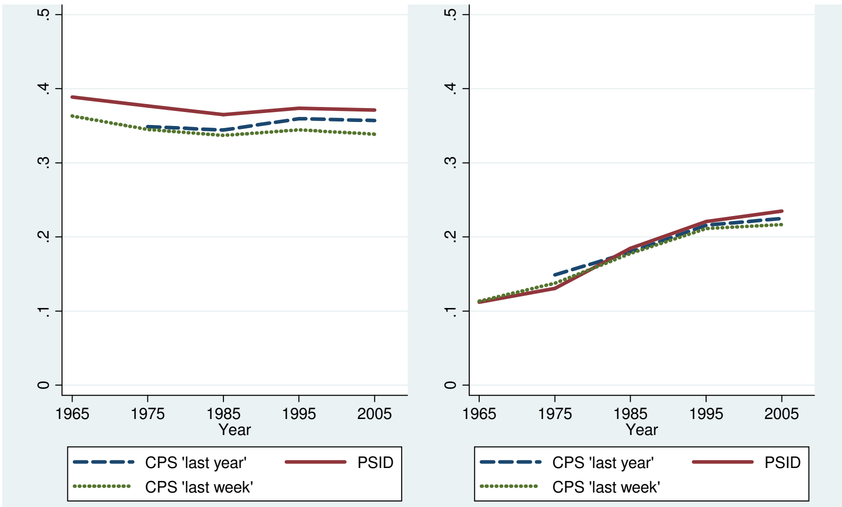

Figure 1.19: Hours worked: PSID versus CPS

Notes: Market hours of married men and women aged 20 to 60 in the PSID and in the CPS, mapped into a time endowment of 1.

The sample size of the PSID is small compared to the Current Population Survey (CPS), which I retrieve from IPUMS, provided by King, Ruggles, Alexander, Flood, Genadek, Schroeder, Trampe, and Vick (2010). However, there are advantages of using the PSID data. Prior to 1975, the CPS did not ask respondents for the exact number of weeks worked last year (but only for a bracketing), and did not ask at all for the usual hours worked per week. Therefore one cannot construct a reliable measure of yearly hours worked before 1975. In all years since its launch in 1962, however, the CPS asked for hours worked in the previous week. I can map this too into my model. In particular, under my assumption that 2/3 of time is disposable, I divide 'hours worked last week' by $(2/3 \times 24 \times 7)$ to obtain a yearly analogue of male and female labor supply out of a time endowment of 1. Then I take averages over nonoverlapping windows of 10 years, which is the length of one period in my calibrated model. In figure 1.19 I compare male and female market labor as indicated by the CPS and the PSID data. The data is very similar. Albeit the CPS suggests a slightly higher level for married men's labor supply, the two surveys show the same trends over time. Also hourly wages, calculated as last year's wage and salary income divided by last year's hours worked, in the CPS are not available before 1975. Therefore I can only obtain the gender wage gap from the regression specified in 1.21 from 1975 onward. In figure 1.20

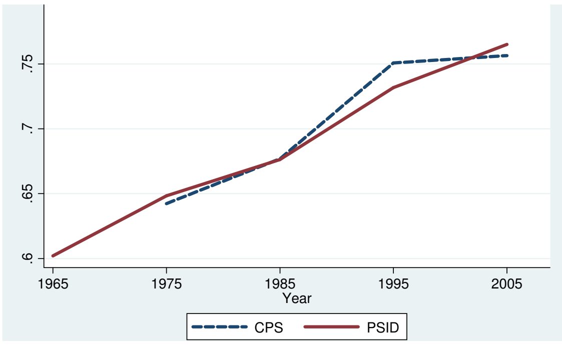

Figure 1.20: Gender wage gap: PSID versus CPS

Notes: Estimated gender wage gap based on PSID or CPS data.

I show the estimated gender wage gap based on PSID and on CPS data. For the available years, they are very similar. Calibrating the model against the smaller PSID sample, seems therefore unproblematic for the purpose of this paper.

1.C Mathematical Appendix

1.C.1 Couple's Optimization Problem

To derive the intratemporal optimality conditions of the couple's optimization program, substitute out c_m and e in 1.9 from the constraints (1.10) and (1.11). Denote the multiplier on the male and female time constraints (1.13) by λ_m and λ_f respectively. To ease notation, let $I_b = b$ for $j = 1$ and $I_b = 0$ otherwise. Then under the assumed preferences (1.8), conditional on fertility choices and aggregate variables, the set of intratemporal first-order conditions (Karush-Kuhn-Tucker) conditions are:

$$c_f = \left(\frac{1-\theta}{\theta}\right)^{1/\sigma_c} c_m \tag{1.33}$$

$$\left(\phi_n\left(\frac{n_m^{1+\eta}}{1+\eta}\right)^{\frac{s-1}{s}} + \phi_h\left(\frac{h_m^{1+\varepsilon}}{1+\varepsilon}\right)^{\frac{s-1}{s}}\right)^{\frac{1}{s-1}} \tilde{\phi}_n n_m^{\frac{(s-1)\eta-1}{s}} = \frac{\tilde{w}_m}{c_m^\sigma} - \frac{\lambda_m}{\theta}$$

$$\left(\phi_n\left(\frac{n_f^{1+\eta}}{1+\eta}\right)^{\frac{s-1}{s}} + \phi_h\left(\frac{h_f^{1+\varepsilon}}{1+\varepsilon}\right)^{\frac{s-1}{s}}\right)^{\frac{1}{s-1}} \tilde{\phi}_n n_f^{\frac{(s-1)\eta-1}{s}} = \frac{\theta}{1-\theta}\frac{\tilde{w}_f}{c_m^\sigma} - \frac{\lambda_f}{1-\theta}$$

$$\left(\phi_n\left(\frac{n_m^{1+\eta}}{1+\eta}\right)^{\frac{s-1}{s}} + \phi_h\left(\frac{h_m^{1+\varepsilon}}{1+\varepsilon}\right)^{\frac{s-1}{s}}\right)^{\frac{1}{s-1}} \tilde{\phi}_h h_m^{\frac{(s-1)\varepsilon-1}{s}} = \frac{1}{c_m^\sigma}\frac{1-\gamma}{\gamma}\left(\frac{\bar{x}(b_h)}{H}\right)^{\frac{1}{\gamma}} z_m - \frac{\lambda_m}{\theta}$$

$$\left(\phi_n\left(\frac{n_f^{1+\eta}}{1+\eta}\right)^{\frac{s-1}{s}} + \phi_h\left(\frac{h_f^{1+\varepsilon}}{1+\varepsilon}\right)^{\frac{s-1}{s}}\right)^{\frac{1}{s-1}} \tilde{\phi}_h h_f^{\frac{(s-1)\varepsilon-1}{s}} = \frac{\theta}{1-\theta}\frac{1}{c_m^\sigma}\frac{1-\gamma}{\gamma}\left(\frac{\bar{x}(b_h)}{H}\right)^{\frac{1}{\gamma}} z_f - \frac{\lambda_f}{1-\theta}$$

$$\lambda_m(n_m + h_m - 1) = 0 \text{ and } \lambda_f(n_f + h_f + \tau_b I_b - 1) = 0$$

$$\text{where } \tilde{\phi}_n = \phi_n(1+\eta)^{1/s} \text{ and } \tilde{\phi}_h = \phi_h(1+\varepsilon)^{1/s}$$

$$\text{and } H = z_m h_m + z_f h_f$$

The Envelope Condition is $\frac{\partial V(a;b,j)}{\partial a} = \theta \frac{\partial u_m}{\partial c_m}(1+r)$, implying $\frac{\partial V(a';b,j+1)}{\partial a'} = \theta \frac{\partial u_m}{\partial c'_m}(1+r')$, such that the usual Euler equation $\frac{\partial u_m}{\partial c_m} = \beta(1+r')\frac{\partial u_m}{\partial c'_m}$ follows. There is no closed-form solution for these equations. Hence I solve the set of nonlinear intratemporal first-order conditions (1.33) numerically, conditional on the individual state variables (assets and number of children), and the aggregate state variables (gender wage gap and aggregate capital stock, which imply the interest rate, male and female wages).

For retired households (of age $j \geq T_r$) with slack time constraints, i.e. with $\lambda_m = \lambda_f = 0$, one can characterize the optimal choices as a function of consumption further. Since $\tilde{w}_m(j) = \tilde{w}_f(j) = 0$ and thus $n_m(j) = n_f(j) = 0$, the optimality conditions (1.33) imply

$$\frac{h_m(j)}{h_f(j)} = \left(\frac{1-\theta}{\theta}\frac{z_m}{z_f}\right)^{1/\varepsilon} \quad \text{for } j \geq T_r$$

which is equation (1.32) in the main text.

1.D Calibration Appendix

1.D.1 Gender Wage Gap as Ratio of Residual Wages

I use data from the Panel Study of Income Dynamics from 1968 to 2007. First I estimate for men and women between of age 20 to 59 equation (1.21) by OLS. The obtained estimates are shown in table 1.9. Since $E[\log w_{i,t}|Dfemale_{i,t} = 1] - E[\log w_{i,t}|Dfemale_{i,t} = 0] = \beta_{1,t}$, the gender wage gap for year t is given by $e^{\beta_{1,t}}$, which I plot in figure 1.3 of the main text. To feed χ_t into the model, where a period is 10 years, I take the averages over the appropriate (nonoverlapping) windows.

1.D.2 Required Amount of Home Production

I aim at finding the parameters of $\bar{x}(b_h) = \kappa_0 + \kappa_1 b_h^{\kappa_2}$ by exploiting the observed cross-sectional variation in a base year of male and female hours against the number of children in the household. Off-corners the intratemporal first-order conditions (1.33) for n_m and h_m imply

$$\bar{x}(b_h) = \left(\frac{\phi_h}{\phi_n} \left(\frac{1+\varepsilon}{1+\eta} \right)^{1/s} \frac{h_m^{\frac{(s-1)\varepsilon-1}{s}}}{n_m^{\frac{(s-1)\eta-1}{s}}} \frac{\tilde{w}_m}{z_m} \frac{\gamma}{1-\gamma} (z_m h_m + z_f h_f) \right)^{\gamma} \tag{1.34}$$

In the model, hours worked at home and in the market[29] depend on the amount of home goods needed. The dataset provided by Aguiar and Hurst (2007) includes respondents' wages and number of children in the household for some years. Thus, equation (1.23) can be used to back out the parameters of $\bar{x}(b_h)$, conditional on all other parameters. I map Aguiar and Hurst's data for 1985 into my model, by scaling hours worked such that the total time endowment is one, as explained above. Then I take averages by the number of children in the household. Finally I scale male wages from the collapsed data such that their mean equals the model's (cohort-size weighted mean) equilibrium wage. Since

[29] The use of home appliances changes with the required amount, and this has –through the budget constraint (1.10)– an effect on consumption, which affects labor supply, by (1.33).

Table 1.9: Regression of log wages

VARIABLES	$\log w_{i,t}$	continued		continued		continued	
Dummy 1968	0.805***	Dummy 1987	0.773***	Dummy Fem.× 1972	-0.453***	Dummy Fem.× 1991	-0.331***
	(0.0266)		(0.0255)		(0.0184)		(0.0126)
Dummy 1969	0.848***	Dummy 1988	0.761***	Dummy Fem.× 1973	-0.440***	Dummy Fem.× 1992	-0.312***
	(0.0265)		(0.0256)		(0.0178)		(0.0124)
Dummy 1970	0.849***	Dummy 1989	0.754***	Dummy Fem.× 1974	-0.435***	Dummy Fem.× 1994	-0.273***
	(0.0263)		(0.0256)		(0.0170)		(0.0138)
Dummy 1971	0.878***	Dummy 1990	0.718***	Dummy Fem.× 1975	-0.427***	Dummy Fem.× 1995	-0.342***
	(0.0261)		(0.0251)		(0.0163)		(0.0139)
Dummy 1972	0.908***	Dummy 1991	0.713***	Dummy Fem.× 1976	-0.403***	Dummy Fem.× 1996	-0.294***
	(0.0258)		(0.0251)		(0.0161)		(0.0139)
Dummy 1973	0.914***	Dummy 1992	0.695***	Dummy Fem.× 1977	-0.405***	Dummy Fem.× 1997	-0.298***
	(0.0256)		(0.0250)		(0.0159)		(0.0153)
Dummy 1974	0.881***	Dummy 1994	0.760***	Dummy Fem.× 1978	-0.427***	Dummy Fem.× 1999	-0.315***
	(0.0254)		(0.0257)		(0.0156)		(0.0150)
Dummy 1975	0.893***	Dummy 1995	0.765***	Dummy Fem.× 1979	-0.441***	Dummy Fem.× 2001	-0.307***
	(0.0252)		(0.0258)		(0.0151)		(0.0143)
Dummy 1976	0.883***	Dummy 1996	0.738***	Dummy Fem.× 1980	-0.416***	Dummy Fem.× 2003	-0.245***
	(0.0253)		(0.0258)		(0.0148)		(0.0137)
Dummy 1977	0.891***	Dummy 1997	0.738***	Dummy Fem.× 1981	-0.420***	Dummy Fem.× 2005	-0.267***
	(0.0252)		(0.0260)		(0.0148)		(0.0136)
Dummy 1978	0.895***	Dummy 1999	0.800***	Dummy Fem.× 1982	-0.414***	Dummy Fem.× 2007	-0.253***
	(0.0252)		(0.0259)		(0.0147)		(0.0134)
Dummy 1979	0.866***	Dummy 2001	0.828***	Dummy Fem.× 1983	-0.402***	Dummy Black	-0.157***
	(0.0252)		(0.0258)		(0.0146)		(0.00290)
Dummy 1980	0.825***	Dummy 2003	0.781***	Dummy Fem.× 1984	-0.371***	Dummy Other Race	-0.0727***
	(0.0252)		(0.0256)		(0.0145)		(0.00680)
Dummy 1981	0.801***	Dummy 2005	0.772***	Dummy Fem.× 1985	-0.447***	Years of Educ.	0.0150***
	(0.0253)		(0.0255)		(0.0144)		(0.00240)
Dummy 1982	0.798***	Dummy 2007	0.780***	Dummy Fem.× 1986	-0.394***	(Years of Educ.)^2	0.00313***
	(0.0253)		(0.0254)		(0.0145)		(9.98e-05)
Dummy 1983	0.791***	Dummy Fem.× 1968	-0.499***	Dummy Fem.× 1987	-0.369***	Age	0.0631***
	(0.0253)		(0.0213)		(0.0145)		(0.000972)
Dummy 1984	0.779***	Dummy Fem.× 1969	-0.516***	Dummy Fem.× 1988	-0.345***	(Age)^2	-0.000653***
	(0.0254)		(0.0206)		(0.0144)		(1.25e-05)
Dummy 1985	0.797***	Dummy Fem.× 1970	-0.455***	Dummy Fem.× 1989	-0.340***		
	(0.0254)		(0.0195)		(0.0143)		
Dummy 1986	0.797***	Dummy Fem.× 1971	-0.450***	Dummy Fem.× 1990	-0.335***	Observations	235629
	(0.0255)		(0.0191)		(0.0128)	R^2	0.949
	ctd. in next column		ctd. in next column		ctd. in next column		

Standard errors in parentheses
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

$\bar{x}(b_h) = \kappa_0 + \kappa_1 b_h^{\kappa_2}$, it follows

$$\kappa_0 + \kappa_1 b_h^{\kappa_2} = \left(\frac{\phi_h}{\phi_n} \left(\frac{1+\varepsilon}{1+\eta} \right)^{1/s} \frac{(h_m(b_h))^{\frac{(s-1)\varepsilon-1}{s}}}{(n_m(b_h))^{\frac{(s-1)\eta-1}{s}}} \frac{\tilde{w}_m}{z_m} \frac{\gamma}{1-\gamma} (z_m h_m(b_h) + z_f h_f(b_h)) \right)^{\gamma}$$

I solve this set of equations for $b_h = 0, 1, 2$ in the three unknowns $\kappa_0, \kappa_1, \kappa_2$, conditional on all other parameters.

1.D.3 Remaining Parameters

Where parameters could not be backed out from model's equilibrium conditions in combination with the data and could not be taken from the literature, I choose them to match features of the 1965 data. I take the demographic structure of 1965 as a given, and compute the cohort densities $\{\mu(j)\}_{j=1}^{T_l}$ from the United Nations World Population Prospects: The 2008 Revision.

Conditional on a guess for σ_b, I choose the remaining parameters to match the moments shown in table 1.2, under the fiction that agents assumed prices to remain constant. $\{\phi_n, \phi_h, \varepsilon, s\}$ are set to match N_m, H_m, N_f, H_f, while ϕ_b is set to match the total fertility rate in 1965. Next, I solve for the final steady state of the model under these parameters. If the final TFR is close to 2, I keep the values as calibrated parameters. If not, I guess a new σ_b and return to choosing $\{\phi_n, \phi_h, \varepsilon, s\}$. To note is that changing one of the parameters in $\{\phi_n, \phi_h, \varepsilon, s\}$ triggers changes in $\kappa_0, \kappa_1, \kappa_2$ (see the previous section).

1.E Additional Results

Figure 1.8 of the main text shows the model-implied behavior of aggregate variables, averaging over all households alive. Figure 1.21 also shows the disaggregated transition paths for the different age groups in the benchmark model ($\theta = 0.5; \gamma = 0.2$).

1.F Robustness Checks

First, I perform a series of robustness checks on σ_b, which relates to the elasticity of utility with respect to children. For the benchmark model I chose σ_b to target a long-run total

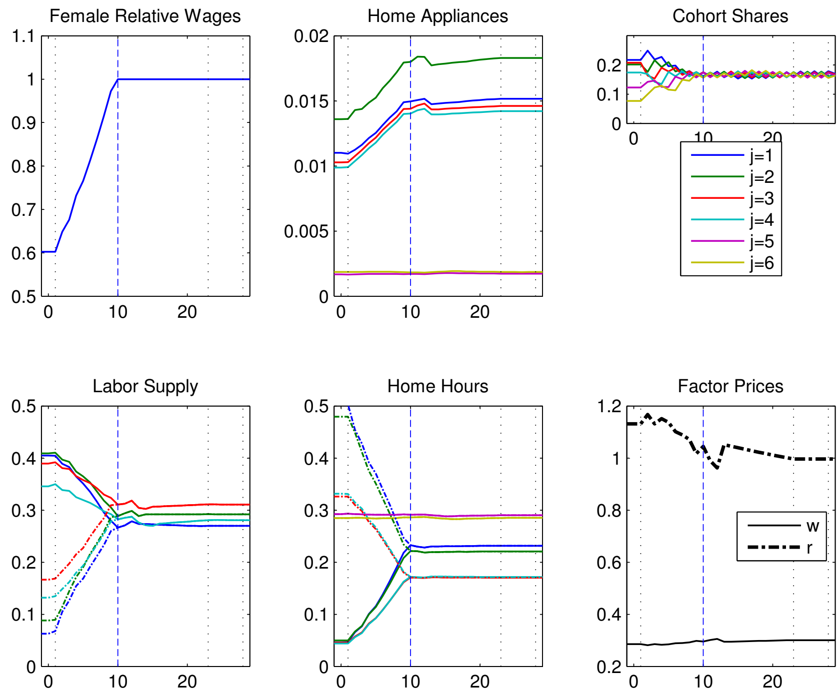

Figure 1.21: Transition of the benchmark model – disaggregation by age

fertility rate of 2. Now I am lifting this restriction, and use various ad-hoc values for σ_b. All other parameters are chosen under the calibration strategy of section 1.3, using $\gamma = 0.2$ as in the benchmark. Table 1.10 shows the resulting final steady states. The higher σ_b,

Table 1.10: Sensitivity analysis: steady state effect of σ_b

	$\sigma_b = 0.25$	$\sigma_b = 0.3$	$\sigma_b = 0.395$	$\sigma_b = 0.6$
TFR	1.80	1.902	2.031	2.227
N_m	0.292	0.290	0.288	0.285
N_f	0.292	0.290	0.288	0.285
H_m	0.229	0.229	0.228	0.228
H_f	0.229	0.229	0.228	0.228

Notes: This table shows the final steady states of the different versions of the model, that are calibrated individually. The calibration follows section 1.3, but uses ad-hoc values for σ_b, rather than targeting a long-run TFR. The benchmark model is the one with $\sigma_b = 0.395$.

the higher is fertility in the final steady state, and the less fertility declines during the transition. To replicate the steep decline in TFR of the 1960s, however, the model needs a value for σ_b that is not too high. A very low value of σ_b, on the other hand, would imply a lower TFR than observed most recently. All values, however, do imply a flattening out of fertility before the gender wage gap is closed.

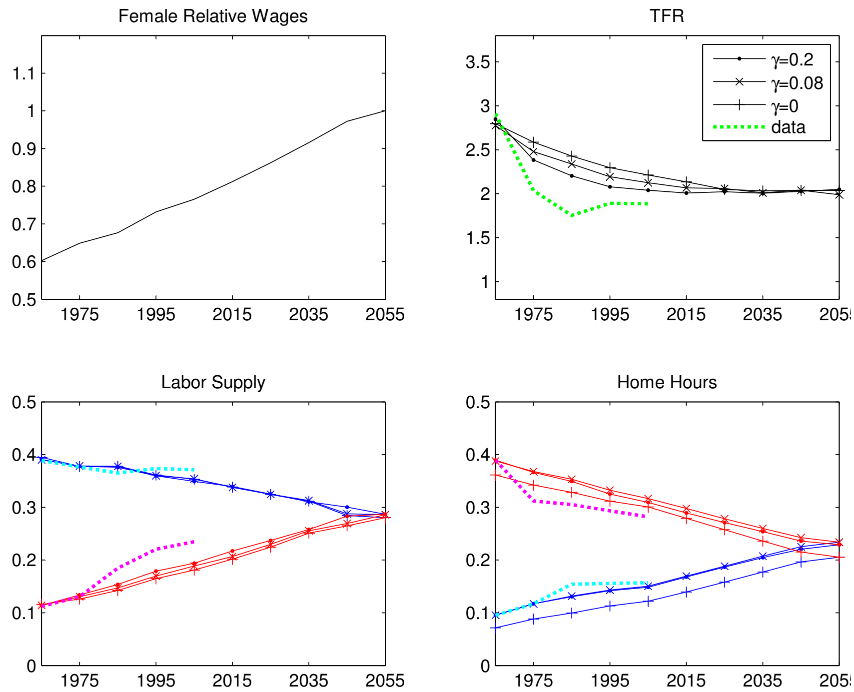

Figure 1.22: Sensitity analysis: varying γ

Next, I conduct a sensitivity analysis for the share of market inputs into home production, γ, since in the literature the range of estimates is wide, and in my model the interpretation of γ should include all market inputs into home production, not only appliances. In the benchmark model I set $\gamma = 0.2$, which is much bigger than the estimate of 0.08 by Benhabib, Rogerson, and Wright (1991) to allow for a greater marketization of child care, but below the upper-end value of Greenwood, Rogerson, and Wright (1995), who include housing capital and conclude that market inputs' share into home production does not differ from the capital share in market output ($\gamma = \alpha$). Since in my model home production is at the margin varying only with child care, which requires mainly human time, I work with a ($\gamma < \alpha$). In section 1.4.4, I have already shown the transition of the model with $\gamma = 0$. As a further sensitivity analysis, I also calibrate models based different values for γ, and solve their transition to steady state. Figure 1.22 and table 1.11 summarize the findings. The higher γ, the earlier the fertility rate stabilizes, bringing the model closer to the data.

Table 1.11: Sensitivity analysis: varying γ

	$\gamma = 0$	$\gamma = 0.08$	$\gamma = 0.2$
Final Steady State			
TFR	2.027	1.99	2.031
N_m	0.281	0.285	0.288
N_f	0.281	0.285	0.288
H_m	0.205	0.235	0.228
H_f	0.205	0.235	0.228
Relative Changes (in percent) over 1965–2005			
TFR	−20.9	−23.4	−28.4
N_m	−10.6	−9.2	−10.7
N_f	+56.4	+65.2	+70.3
H_m	+70.8	57.7	+55.7
H_f	−16.8	−18.37	−20.6

Notes: This table shows the calibrated models' final steady states and the implied changes over 1965–2005. The models are calibrated individually, using the strategy outlined in section 1.3. The baseline model has $\gamma = 0.2$.

Chapter 2

Capital Taxes, Labor Taxes and the Household[1]

2.1 Introduction

There is considerable literature that investigates the effect of changes in the tax code on the economic behavior of individuals. First, using the collective model of household behavior, Apps and Rees (1988; 1999) and Donni (2003), among others, present a formal investigation of the impact of taxes on hours worked and welfare within the household. A second strand is the dynamic macro literature of optimal taxation. Domeij and Heathcote (2004), Conesa and Krueger (2006) and Conesa, Kitao, and Krueger (2009), among others, have used the so called model of heterogeneous agents and wealth accumulation to analyze the impact of changes in tax code.

Both bodies of work have undoubtedly highlighted important issues that governments need to be aware of when changing their policies. We proffer that unless these influential frameworks are combined into one, they offer only a partial view of the effects that changes in the tax scheme have. To understand our objections, consider first the literature on heterogeneous agents in incomplete financial markets. In this framework the household is most often represented by a single individual, typically a male. This individual has an uncertain labor income stream and accumulates wealth in order to buffer shocks to his

[1]This chapter is the result of joint work by Rigas Oikonomou and me, with equal shares in all aspects of the paper.

labor income. A considerable effort is made to match various cross sectional facts that make this model a suitable representation of the economy to study the *between* household distributional effects of changes in the tax policy. When the policy changes, however, little is known of what happens *within* the household; especially, whether the new policy affects the intrahousehold allocation and welfare.

In the collective framework the family is formed by more members than just one individual, typically two spouses, a male and a female. The couple allocates resources between its members according to a sharing rule, and changes in tax rates affect the sharing rule and the division of the surplus within the family. One limitation of this literature is that the models are usually *static* and therefore not suitable to analyze how different tax schedules affect capital accumulation and, more generally, the *intertemporal* behavior of families.

In this paper, we combine the two approaches. We set up a quantitative dynamic model in which individuals live for several periods, some as singles and some married, as part of a couple. Marital status is determined at the initial period of the life-cycle and is assumed not to change over time. There is uncertainty about the labor income of individuals and there are incomplete financial markets. As in the dynamic optimal taxation literature, single individuals supply labor and accumulate precautionary savings in order to self-insure against income risks. Couple households also save and allocate hours to the market, but as in the collective model these decisions are made according to a sharing rule which reflects the bargaining position of the male and the female spouse. This rule is initiated in the first period of the life-cycle, whereby it solves a Nash bargaining problem. For every subsequent model period the rule is updated to ensure that both spouses are better off in the marriage than as singles. By considering different model variants, we thoroughly investigate the impact of the household contract on the aggregate economy and the effects of policy on the intrahousehold allocation. Our approach offers the possibility to study the welfare effects of changes in the tax code between households as well as at the individual level, within the household.

Taking US institutions as given, we consider a simple change in policy. We assume that the government eliminates capital taxation and instead finances its spending through higher distortive labor taxes.[2] We use the model to answer the question: which individuals and household types benefit from this reform in the long-run, and which gain in the transition? In dynamic models with single agents and precautionary savings, this type of policy change has been shown to confer large welfare losses to the population. For example Domeij and Heathcote (2004) illustrate that on the transition path only a small fraction of individuals benefit from the reform, and Conesa, Kitao, and Krueger (2009) suggest that taxing capital at a high rate in this environment may not be a bad idea. The intuition is as follows: Since precautionary savings make the demand for capital less elastic to the rate of return and thereby to capital taxes, positive capital taxation does not have a large distortive effect on the economy.

When we look at this effect from the perspective of our model that includes dual earner and single earner households, we find that it is no longer of primary importance. We trace this difference to the following empirical fact: Changes in labor income are not perfectly correlated within families, and therefore couple households can reduce overall risks considerably. Strong empirical evidence for this is given in the recent work of Blundell, Pistaferri, and Saporta-Eksten (2012). Since family labor supply acts as an insurance mechanism, it weakens the incentive to accumulate savings for precautionary purposes. In effect the demand for capital, in the aggregate, becomes more elastic with respect to taxes. Capital taxes have a large distortive effect on the economy and when our reform eliminates them, individuals benefit both in the long-run and in the transition.

In our model the sharing rule, which divides resources, depends on the outside options of the male and female spouse. As such, there is a limited commitment problem within the household. For example when the labor income of one spouse increases, the sharing rule must allocate more resources to her. This implies that the couple has to give up some risk sharing to satisfy a participation constraint. Since our theory assigns an important role to the savings behavior of couples, we need investigate the impact of this limited commitment problem on household savings. We explore whether limited commitment means that household members behave more like single individuals, thus restoring a strong demand for precautionary savings in the household. In a simplified analytical version of the

[2]Following the works of Chamley (1986) and Judd (1985), many authors have studied the effects of eliminating capital taxation in a wide range of models and contexts but without investigating the effects on intrahousehold allocations.

model in section 2.3, we show that it is virtually impossible to sign the impact of limited commitment on the couples demand for savings. In our quantitative model we find that less commitment has only a mild effect on wealth accumulation.

In our model, changes in the mixture of capital and labor taxes have a big impact on the intrahousehold sharing rule. We show that increasing labor taxes has two opposing effects: First, it decreases intrahousehold inequality in income and thus improves the households' commitment and insurance possibilities. But through a second channel it may tighten the participation constraints, as it impoverishes the household and thus makes it more tempting to renege on past commitments. Lowering capital taxes, on the other hand, is shown to always enhance commitment. This result derives from our treatment of wealth as a state variable in the model. In line with empirical evidence for the US economy, we assume that assets are commonly held within the couple. Therefore, as a household's financial income increases, a larger fraction of consumption is financed through wealth, relaxing the participation constraints.

When the change in policy takes place, we look at how these channels translate quantitatively to an impact on the sharing rule. We find that the incidence of rebargaining on the intrahousehold allocation rises sharply, by nearly 35% compared to the original steady state with high capital taxes. Younger families experience the largest drop in intrahousehold insurance, meaning that the participation constraints become tighter for these groups, since their assets are too low. In contrast, in the final steady state all age cohorts build up a higher stock of wealth, and we show that the new policy regime may ultimately improve the households' insurance possibilities.

Even though intrahousehold commitment is less when the policy changes, there is a reduction in consumption inequality within the household. Eliminating capital taxation in our model means that more of individual consumption is financed through wealth, which is a common resource in the family. But for the same reason between household consumption inequality increases considerably under the new policy since wealth is more dispersed than labor income across households. Overall in the cross section of individuals the second effect dominates over the first.

Our paper is related to several strands of the literature. First as discussed previously, there is a sizable literature on the optimality of the US tax code in models of heterogeneous and wealth accumulation. Early contributions in this literature include the work of Aiyagari (1995) and Imrohoroglu (1998) and more recent ones include the models of Domeij and Heathcote (2004), Conesa, Kitao, and Krueger (2009) and Conesa and Krueger (2006). In terms of our parametrization of individual uncertainty in the labor market, the framework that we setup shares many features with the work by Conesa, Kitao, and Krueger. Whereas they focus on the progressivity of the tax code and its welfare implications between households, we look at the effects of changing linear taxes and investigate also intrahousehold allocations.

More recently Guner, Kaygusuz, and Ventura (2012a;b) set up a model where families are formed by a husband and a wife and use it to investigate the aggregate effects on hours and output of allowing couples to file separately for taxes. Their work exploits the fact that female labor supply is more elastic because women in their model decide whether or not to participate in the labor market. We take a different stand in our paper. We look at families as an insurance device against idiosyncratic labor productivity shocks, whereas in Guner, Kaygusuz, and Ventura (2012a) there are no unpredictable changes in labor income over the life-cycle.

Fuster, Imrohoroglu, and Imrohoroglu (2008) take a model with idiosyncratic labor income risks and linear taxes and study the welfare effects of reforms that eliminate capital taxation. In their model, they have extended families which consist of a parent and her children, to observe the link between generations. They show that, because of double altruism, setting the capital tax to zero and replacing it with labor income taxes, their economy can generate support for the reform. Our analysis reaches a similar conclusion but from a very different perspective. Rather than allowing for intergenerational transfers, we present a model with transfers between spouses.

Our paper is also related to the considerable literature of the collective model of intrahousehold decisions.[3] To the best of our knowledge, we are the first to investigate the impact of changes in the tax code on the intertemporal behavior of families and the scope of intrahousehold risk sharing. Existing work in the collective framework uses static models to investigate whether men and women should be taxed separately or face

[3] See for example Chiappori (1988; 1992), Blundell and Etheridge (2010)) and especially to the recent work of Mazzocco, Ruiz, and Yamaguchi (2007) and Gallipoli and Turner (2011) who present a dynamic extension of this model.

different tax schedules in light of the differences in the elasticity male and female labor supplies. For example Apps and Rees (1999) investigate revenue neutral reforms that increase the marginal tax rates of men and lower the tax rates of women in a model with home production. Apps and Rees (2011) ask whether the optimal Ramsey policy calls for lower marginal tax rates for women (see also Alesina, Ichino, and Karabarbounis (2011)). Here, we do not attempt to address these issues. Our approach is to abstract from the complexities of the tax code and to summarize the institutions in a simple linear tax system. But since our model is dynamic, we add to the literature by formalizing how changes in linear taxes can affect the welfare and the risk sharing possibilities of families.

2.2 The Model

We consider an economy populated by a continuum of individuals, equally many males and females. Gender is indexed by $g \in \{m, f\}$ and age by $j \in \{1, 2, ..., J\}$. Individuals survive from age j to $j+1$ with probability ψ_j. At each date a new cohort of individuals enters the economy; we assume that population grows exogenously at rate θ. Since population growth and the survival probabilities are time-invariant, the model age distribution is stationary.

The life-cycle of individuals comprises of the following three stages: Marriage (matching), work and retirement. Since our model does not endogenize family formation, we simplify the first stage by letting matching take place in a pre-labor-market period of life labeled age zero. A fraction μ of individuals will find partners at this stage and form households as couples, and the remaining agents will remain bachelors. Marital status does not change over time. After date zero individuals work for $j_R - 1$ periods –conditional on survival– and then retire at date j_R. At age J, they die with probability one.

Agents are risk averse and derive utility from consumption c and leisure l. Per-period utility is denoted by $u(c, l)$. We follow the convention in the literature of representing male and female preferences by the same utility function. Finally individuals and households discount future utility flows at a constant factor β.

2.2.1 Endowments

Agents in the economy differ in terms of their labor productivity along three dimensions: a deterministic (life-cycle) component $L_g(j)$, a fixed effect $\alpha_{i,g}$ and an idiosyncratic labor productivity shock $\epsilon_{i,g}$. When entering the labor market, each agent draws a realization of $\alpha_{i,g}$, the value of which remains constant throughout her working life. We assume that there are N possible realizations $\{\alpha_{1,g}, \alpha_{2,g}, ...\alpha_{N,g}\}$ for each gender. We also assume that the assignment of an agent to a realization is made according to some probabilities $p^S_{i,g}$ when the agent is single, and according to probabilities $p^M_{i,k}$ when the individual is married. Notice that $p^M_{i,k}$ is the joint distribution of the two spouses across all possible values of $\alpha_{i,m}$ and $\alpha_{k,f}$. In our model, we allow the productivity endowments to be correlated within the couple.

Idiosyncratic productivity ϵ_g changes stochastically over time according to a first order Markov process. We let $\pi_g(\epsilon'_g|\epsilon_g)$ be the conditional pdf for this process. The analogous object for couples is denoted by $\pi(\epsilon'|\epsilon)$, where ϵ in the case of a couple household is the vector of productivities of its members. We also allow for an arbitrary correlation of labor income shocks within the family.

2.2.2 Markets and Technology

We assume that the production technology can be represented with a Cobb-Douglas function of the form:

$$Y = K^\alpha (AN)^{1-\alpha} \tag{2.1}$$

where K denotes the economy's aggregate capital stock, and N is the aggregate labor input, and A is the level of labor-augmenting technology. The resource constraint is given by

$$K' = (1-\delta)K + Y - G - C \tag{2.2}$$

where by convention, primes denote the next model period. C is aggregate consumption in the economy, G is government spending and δ is the depreciation rate of the aggregate capital stock. Factor prices are determined in competitive markets. Wages, measured in efficiency units, are equal to the marginal product of labor, and the return to capital is its marginal product net of depreciation. We denote these objects by w and r respectively.

Financial markets are incomplete. There are no state contingent securities. By trading claims on the aggregate capital stock, agents can self insure. In keeping with the literature, we assume that these trades are subject to an ad hoc borrowing constraint $\overline{a}$. The value for the constraint is set to zero, such that our economy rules out borrowing altogether. Moreover, there are no annuity markets and households leave accidental bequests which we denote by B. Bequests are distributed uniformly across individuals in the economy.

2.2.3 Government

The government engages in two activities. First, it levies taxes on consumption τ_C, on financial income τ_K, and on labor income τ_N to finance a level of expenditures G. We rule out government debt so that the government runs a balanced budget each period.

Second, it runs a Pay-as-you-Go social security system, which is financed through a proportional tax on the earnings of the working population. We denote by τ_{SS} the social security tax, and by $SS(g, \alpha_{i,g})$ the transfer that retired individual i receives from the government. Notice that transfers depend on gender g, and the wage fixed effect $\alpha_{i,g}$. Our aim is to capture the current US social security system in a parsimonious way. $SS(g, \alpha_{i,g})$ depends on gender because life-cycle productivity $L_g(j)$ differs across men and women in the economy.

2.2.4 Value Functions

Bachelor Households. We first consider the program of a bachelor of gender g and age j. We let $S_g(a, X, j)$ be the lifetime utility for this agent when her (his) stock of wealth is a, her permanent productivity is $\alpha_{i,g}$, her idiosyncratic time varying productivity is ϵ_g. To save on notation, we summarize the fixed effect and the time varying component of productivity in a vector X. This agent must choose consumption c and hours worked n (if not retired, i. e. $j < j_R$) to maximize her utility subject to the budget and the borrowing constraints. She solves the following functional equation:

$$S_g(a, X, j) = \max_{a' \geq \overline{a}, l} u(c, l) + \beta\psi_j \int S_g(a', X', j+1) d\pi_g(X'|X) \tag{2.3}$$

Subject to:

$$l + n \leq 1$$

$$\begin{aligned} a' + (1+\tau_C)c &= (a+B)(1+r(1-\tau_K)) + w\epsilon_g \alpha_{i,g} L_g(j)(1-\tau_N-\tau_{SS})n \quad \text{if } j < j_R \\ a' + (1+\tau_C)c &= (a+B)(1+r(1-\tau_K)) + SS(g,\alpha_{i,g}) \quad \text{if } j \geq j_R \end{aligned}$$

Couple Households. In this paragraph, we describe the program of the couple. As discussed previously, we model decision making within the household as a contract under limited commitment. By that we mean that there is a sharing rule on the basis of which resources are divided between the male and the female spouse, and that this rule is affected by the bargaining position of the household members. To be more specific, we assume, as in Mazzocco, Ruiz, and Yamaguchi (2007), Gallipoli and Turner (2011) and Voena (2012), that the household contract is such that both partners must at any point in time be better off in the marriage than as singles. As in the limited commitment literature (see for example Ligon, Thomas, and Worrall (2000)), the household needs to give up some efficiency and risk sharing to ensure that participation is satisfied for both of its members. We introduce an additional state variable to the value function that represents the male spouse's share on household resources. We call this share λ. Equivalently, $1-\lambda$ represents the female spouse's share. As we explain below, the shares λ and $(1-\lambda)$ will change over time to satisfy the participation constraints. Moreover, they will be initiated at the matching stage, whereby the household will solve a Nash bargaining game.

As in Cubeddu and Ríos-Rull (1997), Regalia and Ríos-Rull (2001) and Mazzocco (2007), among others, we assume that wealth is a commonly held resource in the family. This assumption is a considerable simplification of the households program because it reduces the number of state variables (we only have to keep track of the households total wealth), and it implies that individual Euler equations do not have to be introduced as additional constraints to the household's program. Moreover, it seems that it is a reasonable assumption to make for the behavior of US households. According to Mazzocco (2007), in all US states, with the exception of the state of Mississippi, all income earned in the marriage and wealth acquired with those earnings are considered common marital property.

We take this to mean that only aggregate family wealth matters for the households decision making.

In order to determine the outside options for the male and the female spouse, we assume as Mazzocco (2007) that divorce leads to an equal division of assets. This assumption also appears to be empirically relevant; in those states that have a 'common property law' assets are indeed divided equally between the spouses after a divorce. Moreover, in the so called equitable property states assets after a divorce are divided 'fairly', meaning that courts take into account a variety of factors, including the contributions of each party, but also future earnings and living standards. Overall, in the US data an equal division of household assets is the average (see Mazzocco). Because individuals are born with zero assets in our model, couples are born married and stay married forever. Our assumptions of common property and equitable division are therefore in line with the US data.[4]

Let $M(a, X, \lambda, j)$ be the value function of a household of age j (in our economy households are formed by agents of the same cohort), where X summarizes the productive endowments of its members, and as before a is the level of wealth of the household. Moreover we let ξ be a constant benefit that accrues to each spouse in the marriage. The program of the couple can be written as:

$$\begin{aligned} M(a, X, \lambda, j) = & \max \lambda u(c_m, l_m) + (1-\lambda)u(c_f, l_f)) + \xi \\ & + \beta\psi_j \int M(a', X', \lambda', j+1) d\pi(X'|X) \end{aligned} \tag{2.4}$$

Subject to:

$$l_g + n_g \leq 1 \quad \text{for} \quad g \in \{m, f\}$$

[4]We assume that there are no legal costs associated with separation. In contrast, Cubeddu and Ríos-Rull (1997) assume that divorces lead to a large destruction of household net worth (40% in their model). In our case, because divorce never occurs in equilibrium even if we assume no legal costs, it is innocuous in terms of the wealth distribution. Of course the saving behavior would be affected, because the outside options of the male and the female spouse determine the rebargining of the marital contract. For example, if households lose a percentage of their wealth in the process of divorce, as they do in Cubeddu and Ríos-Rull (1997), then higher wealth means that the incentive to stay together will probably be stronger. But if costs are fixed then poorer households will have more commitment. In reality, we believe that the proper way to introduce wealth destruction during separations is to use both types of costs. For wealthier households legal fees are more likely to be higher as the incentive to hire more qualified lawyers is obviously greater.

$$
\begin{aligned}
a' + (1+\tau_C)(c_m + c_f) &= (a+2B)(1+r(1-\tau_K)) \\
&\quad + w(\sum_g L_g(j)\alpha_i \epsilon_{i,g} n_g (1-\tau_N-\tau_{SS})) \quad \text{if } j < j_R \\
a' + (1+\tau_C)(c_m + c_f) &= (a+2B)(1+r(1-\tau_K)) + \sum_g SS(g,\alpha_{i,g}) \quad \text{if } j \geq j_R
\end{aligned}
$$

Notice that in 2.4, the couple draws a new value λ' in the next period. We assume that this updating occurs if there is a violation of participation. If, for example, under a new realization of the state vector X' the husband is better off as a single than under the contract λ, his share in household resources must increase to reflect his improved bargaining position. Analogously, λ decreases if the female spouse has to be made better off. Formally, let $V_g(a, X, \lambda, j)$ be the expected lifetime utility of the household member of gender g under the optimal policies that solve equation 2.4. It is determined by the following functional equation:

$$
V_g(a, X, \lambda, j) = u_g(c_g, l_g) + \xi + \beta\psi_j \int V_g(a', X', \lambda, j+1) d\pi(X'|X) \tag{2.5}
$$

The updating rule for λ is as follows:

$$
\begin{aligned}
\lambda' \in \arg\min_{\lambda^*} |\lambda^* &- \lambda| \text{ such that} \\
V_g(a', X', \lambda^*, j+1) &\geq S_g(\frac{a'}{2}, X'_g, j+1)
\end{aligned} \tag{2.6}
$$

where X_g is a vector formed by elements of X that are relevant to household member g if he or she were to be single. Equation 2.6 says that the value of λ is updated in those states where the participation constraint is violated, and is otherwise constant. Whenever there is a change in λ, this change is the minimum required to satisfy participation for both spouses.

The value of λ is initiated at the matching stage of the life-cycle, as a solution to the following Nash bargaining problem:

$$
\lambda_1 \in \arg\max_{\lambda} [\, V_m(a, X, \lambda, 1) - S_m(\frac{a}{2}, X, \lambda, 1) + \overline{\xi}_m] \, [\, V_f(a, X, \lambda, 1) - S_f(\frac{a}{2}, X, \lambda, 1) + \overline{\xi}_f]
$$

Two final comments are in order. First, notice that the Nash sharing rule determines the initial intrahousehold allocation under the influence of two additional gender specific utility gains $\bar{\xi}_g$ for $g \in \{m, f\}$. These gains at the matching stage determine the magnitude of income transfers from one spouse to the other. For example, if $\bar{\xi}_m > \bar{\xi}_f$ then the household contract will give an initial allocation with large transfers from the male to the female spouse thus leading to a big inequality in hours within the family. We will choose values for $\bar{\xi}_m$ and $\bar{\xi}_f$ to target the division of hours in the family as in the US data.

Second, although the marriage gain ξ is constant over the life-cycle and, therefore, has no direct effect on the optimality conditions in 2.4, it does affect the extent to which the two spouses can commit to the allocation that they bargain in period 1. For instance, if ξ is sufficiently large, the household surplus is sufficiently large such that updating of the weight λ never occurs. In this case, there exists an initial weight λ_1 such that the household can commit to never update the sharing rule, and perfect risk sharing within the household will obtain. For smaller values of the utility gain the household contract is one of limited commitment, meaning that the participation constraints will occasionally bind (see Ligon, Thomas, and Worrall (2000); Attanasio and Ríos-Rull (2000)). In our numerical analysis, we investigate how different values of this parameter affect the household contract and the welfare gains from the tax reform.

We characterize the competitive equilibrium in section 2.C in the Appendix.

2.3 A Two Period Version of the Model

In this section we present a simplified version of the model. We assume that individuals live for two periods and face labor income uncertainty only in period 2 of the life-cycle. There are no fixed effects or gender differences in the price of labor. Idiosyncratic labor productivity in period 1 is normalized to unity. We denote the period two endowment of the individual of gender g by ϵ_g. The mean productivity is equal across the two agents. Furthermore the utility gains at the matching stage $\bar{\xi}_m$ and $\bar{\xi}_f$ are set to zero. The Nash sharing rule thus specifies an initial share $\lambda_1 = \frac{1}{2}$ as the two family members are effectively identical in period one.

This version of the model buys us considerable tractability. In period two, given the idiosyncratic productivities ϵ_m and ϵ_f, we can solve analytically for the intrahousehold allocation. Moreover, given preferences, the utility gain ξ and the endowments of the two agents, we can determine how the sharing rule λ_2 evolves. We use the model first to determine the impact of the tax schedule on the intrahousehold allocation and, second, to investigate how the degree of commitment affects optimal household savings.

2.3.1 The Effect of Taxes on Household Decision Making

We first illustrate how capital and labor taxes affect the properties of the sharing rule in period two. Our starting point is to assume that $u(c_g, l_g) = \eta \log\ c_g + (1-\eta)\log l_g$. With this parametrization of preferences a share of one half translates into equal consumption between male and female spouses. If, on the other hand, $\lambda_2 \neq \frac{1}{2}$, then under limited commitment the consumption levels diverge, giving rise to within household inequality. Our goal here is to trace the effect of different policies on risk sharing in that sense.

We solve the model backwards. Assume that we are in period 2, and that given the sharing rule, the household decides how to split consumption and hours in the family. Let $A_c = (1 + r(1-\tau_K))a_1$ be the level of wealth of the household brought forward from period one. It is trivial to show that the optimal consumption is $c_m = \lambda_2 \eta (A_c + \sum_g w(1-\tau_N)\epsilon_g)$ and $c_f = (1-\lambda_2)\eta(A_c + \sum_g w(1-\tau_N)\epsilon_g)$. Similarly, the optimal choice of leisure for male and female spouses is given by: $l_m = \lambda_2(1-\eta)\frac{A_c + \sum_g w(1-\tau_N)\epsilon_g}{\epsilon_m w(1-\tau_N)}$ and $l_f = (1-\lambda_2)(1-\eta)\frac{A_c + \sum_g w(1-\tau_N)\epsilon_g}{\epsilon_f w(1-\tau_N)}$.

Participation Constraints. To respect the participation constraint of each household member, the allocation rule λ_2 must satisfy the following conditions:

$$\begin{aligned} \eta \log \lambda_2\, \eta\, (A_c + \sum_g w(1-\tau_N)\epsilon_g) \quad + \quad (1-\eta)\log \lambda_2\, \eta\, \frac{(A_c + \sum_g w(1-\tau_N)\epsilon_g)}{\epsilon_m w(1-\tau_N)} + \xi \geq \\ \eta \log\ \eta\, (\frac{A_c}{2} + w(1-\tau_N)\epsilon_m) \quad + \quad (1-\eta)\log\ \eta\, \frac{(\frac{A_c}{2} + w(1-\tau_N)\epsilon_m)}{\epsilon_m w(1-\tau_N)} \end{aligned} \tag{2.7}$$

which guarantees that the male spouse is better off in the marriage than as a single and,

$$\begin{aligned} \eta \log (1-\lambda_2)\, \eta\, (A_c + \sum_g w(1-\tau_N)\epsilon_g) \quad + \quad (1-\eta)\log \lambda_2\, \eta\, \frac{(A_c + \sum_g w(1-\tau_N)\epsilon_g)}{\epsilon_f w(1-\tau_N)} + \xi \geq \\ \eta \log\ \eta\, (\frac{A_c}{2} + w(1-\tau_N)\epsilon_f) \quad + \quad (1-\eta)\log\ \eta\, \frac{(\frac{A_c}{2} + w(1-\tau_N)\epsilon_f)}{\epsilon_f w(1-\tau_N)} \end{aligned} \tag{2.8}$$

which represents the analogous condition for the female spouse.

Solving equations 2.7 and 2.8 for λ_2 defines the following bounds:

$$\lambda_2 \in \{ \; e^{-\xi} \; \frac{\frac{A_c}{2} + \epsilon_m \; w \; (1-\tau_N)}{A_c + \sum_g \epsilon_g \; w \; (1-\tau_N)}, \;\; 1 - e^{-\xi} \frac{\frac{A_c}{2} + \epsilon_f w (1-\tau_N)}{A_c + \sum_g \epsilon_g w (1-\tau_N)} \;\; \} \tag{2.9}$$

Notice that with $\xi = 0$ the level of utility for each household member is identical to what they would get as singles. In this case, the spouses cannot commit to any allocation other than the one that divides the assets equally and gives to each of them their own labor income. Being together is no different than being a single when $\xi = 0$.

However, if $\xi > 0$, expression 2.9 gives a region where the initial allocation is not rebargained. For instance, for each value of ϵ_f and financial income A_c, there is a unique threshold $\underline{\epsilon}_m(A_c, \epsilon_f)$ such that if $\epsilon_m < \underline{\epsilon}_m(A_c, \epsilon_f)$, the contract updates λ_2 to be equal to the upper bound of 2.9. In words, if male productivity in period 2 is low, the sharing rule has to be rebargained. The new weight λ_2 is equal to the upper bound of 2.9 because the upper bound is lower than a half, thus making the participation constraint of the female spouse bind. Similarly, there is an analogous $\overline{\epsilon}_m(A_c, \epsilon_f)$ such that for an ϵ_m above this threshold the new contract gives λ_2 equal to the lower bound of 2.9. Henceforth, we refer to the lower bound in 2.9 as λ_2^L and to the upper bound as λ_2^U.

Labor Taxes. Given the intrahousehold allocation, we can derive the effect of changes in the level of labor taxes τ_N and capital taxes τ_K. First consider that labor taxes fall, i.e. $(1-\tau_N)$ increases. Abstracting for the moment from general equilibrium effects (movements in wages and interest rates), we can write:

$$\frac{d\lambda_2^L}{d\,(1-\tau_N)} = e^{-\xi} A_c \frac{\epsilon_m w - \frac{\sum_g \epsilon_g w}{2}}{(A_c + \sum_g \epsilon_g (1-\tau_N) w)^2} \tag{2.10}$$

$$\frac{d\lambda_2^U}{d\,(1-\tau_N)} = e^{-\xi} A_c \frac{\frac{\sum_g \epsilon_g w}{2} - \epsilon_f w}{(A_c + \sum_g \epsilon_g (1-\tau_N) w)^2} \tag{2.11}$$

Consider first the case where $\epsilon_m > \overline{\epsilon}_m(A_c, \epsilon_f)$. In this case, it must be that $\lambda_2 = \lambda_2^L > \frac{1}{2}$, i.e. the male spouse's weight needs to increase (the lower bound in 2.9 binds). The partial derivative 2.10 will be positive; meaning that a reduction in the level of labor taxes increases

λ_2^L and, therefore, makes the change in λ_2 relative to λ_1 even greater. A fall in the tax rate reduces risk sharing within the household because in those states where the male labor income is high, the husbands consumption share increases even more relative to an economy where tax rates on labor income are high. The intuition is that changes in labor income are the root of the limited commitment problem. Lower tax rates exacerbate intrahousehold income inequality and also exacerbate the limited commitment problem. Note that if $\epsilon_f >> \epsilon_m$ the upper bound λ_2^U will bind. In that case, the female spouse must be made better off and a reduction in τ_N will decrease λ_2^U hence making the fall in the male share larger.[5] We summarize the result in the following proposition:

Proposition 1. *Holding wages and interest rates constant, a reduction of labor income taxes reduces insurance within the household under log-log separable preferences. The household sharing rule and thus intrahousehold allocation become more responsive to changes in the idiosyncratic labor productivity of the male and the female spouse.*

General equilibrium effects that are left out from 2.10 and 2.11 operate in the opposite direction. To see this, note that in the short-run, with the economy's capital being fixed, a fall in labor taxes will affect wages and interest rates through hours worked. Since hours will increase in response to the fall in distortionary taxation, the wage rate w will decrease and the interest rate r will rise. Consequently, the above expressions have to be multiplied by $1 + \frac{dw}{d(1-\tau_N)} \frac{(1-\tau_N)}{w}$, and also an additional term that reflects the effect of higher financial income on the constraint set has to be included.[6] This term is given by $\frac{d\, r(1-\tau_K)a_1}{d\,(1-\tau_N)} > 0$ times the partial derivatives of λ_2^L or λ_2^U with respect to A_c.

$$\frac{d\lambda_2^L}{d\,A_c} = e^{-\xi}(1-\tau_N)\frac{\frac{\sum_g \epsilon_g w}{2} - \epsilon_m w}{(A_c + \sum_g \epsilon_g(1-\tau_N)w)^2} \tag{2.12}$$

[5]Obviously from 2.10 and 2.11, these effects go through if the household has positive wealth at the beginning of period 2. If A_c equals zero, then the derivatives are zero and changes in the tax schedule have no impact on the intrahousehold allocation.

[6]Notice that the magnitude of the term $\frac{dw}{d(1-\tau_N)} \frac{(1-\tau_N)}{w}$ has to be implausible to invalidate proposition 1. For example, assume that the technology is off the form $K^\alpha N^{1-\alpha}$; that gives a wage rate $w = (1-\alpha)K^\alpha N^{-\alpha}$. Moreover, note that we can write the term $\frac{dw}{d(1-\tau_N)} \frac{(1-\tau_N)}{w}$ as $\frac{dw}{dN} \frac{dN}{d(1-\tau_N)} \frac{(1-\tau_N)}{w}$ Let e_N be the elasticity of N with respect to $(1-\tau_N)$, it follows that $\frac{dw}{dN} \frac{dN}{d(1-\tau_N)} \frac{(1-\tau_N)}{w} = -\alpha e_N$. If we assume that α (the capital share in value added) is roughly one third, the elasticity has to be above three to reverse the sign of the term $1 + \frac{dw}{d(1-\tau_N)} \frac{(1-\tau_N)}{w}$. This seems to be implausibly high given that most empirical estimates place the elasticity of labor supply below unity.

$$\frac{d\lambda_2^U}{d\,A_c} = e^{-\xi}(1-\tau_N)\frac{\epsilon_f w - \frac{\sum_g \epsilon_g w}{2}}{(A_c + \sum_g \epsilon_g(1-\tau_N)w)^2} \tag{2.13}$$

By a similar reasoning to the one above, we can show that $\frac{d\lambda_2^L}{d\,A_c} < 0$ and $\frac{d\lambda_2^U}{d\,A_c} > 0$. In other words, when labor taxes fall, the rise in the interest rate will increase the importance of financial income to the households budget and will relax the limited commitment constraints. This effect, however, will grow weaker as the economy builds up a higher capital stock after the fall in the labor income tax rate.

Capital Taxes. Notice that expressions 2.12 and 2.13 imply that a rise in asset income from any source, capital taxes, interest rates or savings, has a beneficial effect on household risk sharing. More risk sharing comes from two sources. First, the household will enjoy a higher return given the stock of assets (in the short-run), and second the level of wealth will increase as the household is induced to save more in response to the higher return (in the longer term). As more of the households consumption is financed through wealth, changes in labor income have a smaller impact on individual welfare and, therefore, on the participation constraints. The next proposition summarizes the effect of lower capital taxation on household insurance:

Proposition 2. *Lower capital taxes improve insurance under log-log preferences. The household sharing rule and thus intrahousehold allocation are less responsive to changes in labor income.*

Again, the result in proposition 2 holds unless there are powerful general equilibrium effects in the short-run after the change in policy takes place. In our quantitative model in section 2.5, we will comment on how the change in the tax scheme affects household commitment and risk sharing when general equilibrium effects are present.

Non-Separable Preferences. We derive the impact of changes in taxation assuming that individual utility is given by $u(c_g, l_g) = \frac{(c_g^\eta l_g^{1-\eta})^{1-\gamma}}{1-\gamma}$ with $\gamma > 1$. Using simple algebra, we can write the participation constraints for male and female spouses as follows:

$$\left(\frac{A_c + \sum_g w(1-\tau_N)\epsilon_g}{(1+f(\lambda_2,\epsilon))((w(1-\tau_N)\epsilon_m))^{1-\eta}}\right)^{1-\gamma}\frac{\chi}{1-\gamma} + \xi \geq \left(\frac{\frac{A_c}{2} + w(1-\tau_N)\epsilon_m}{(w(1-\tau_N)\epsilon_m)^{1-\eta}}\right)^{1-\gamma}\frac{\chi}{1-\gamma}$$

$$\left(\frac{f(\lambda_2,\epsilon)}{1+f(\lambda_2,\epsilon)}\frac{A_c+\sum_g w(1-\tau_N)\epsilon_g}{(w(1-\tau_N)\epsilon_f)^{1-\eta}}\right)^{1-\gamma}\frac{\chi}{1-\gamma}+\xi\geq\left(\frac{\frac{A_c}{2}+w(1-\tau_N)\epsilon_f}{(w(1-\tau_N)\epsilon_f)^{1-\eta}}\right)^{1-\gamma}\frac{\chi}{1-\gamma}$$

where $\chi = (\eta^\eta(1-\eta)^{1-\eta})^{1-\gamma}$ and $f(\lambda_2,\epsilon) = (\frac{\lambda_2}{1-\lambda_2}(\frac{\epsilon_f}{\epsilon_m})^{(1-\eta)(1-\gamma)})^{-1/\gamma}$ determines the shares of resources that accrues to the male and the female spouses. Notice that with nonseparable utility, the family member that works the most must be compensated with a higher consumption share, and thus the sharing rule depends on the relative endowments (the term $\frac{\epsilon_f}{\epsilon_m}$). We show in the appendix that the effect of a rise in $1-\tau_N$ on λ_2^L is determined by the sign of the following expression:

$$(1-\gamma)\left[(\tilde{\xi}\,(\frac{A_c\,(1-\eta)}{1-\tau_N}-\eta\sum_g w\,\epsilon_g)\,\kappa_1(A_c,\epsilon)+(A_c\,w\,(\epsilon_m-\frac{\sum_g\epsilon_g}{2}))\kappa_2(A_c,\epsilon))\right] \quad (2.14)$$

where $\kappa_1 = \frac{(w(1-\tau_N)\epsilon_m)^{(1-\eta)(1-\gamma)}}{(A_c+\sum_g w(1-\tau_N)\epsilon_g)^{2-\gamma}} > 0$, $\kappa_2 = \frac{(\frac{A_c}{2}+w(1-\tau_w)\epsilon_m)^{-\gamma}}{(A_c+\sum_g w(1-\tau_w)\epsilon_g)^{2-\gamma}} > 0$ and $\tilde{\xi} = \frac{-\xi(1-\gamma)}{\eta^\eta(1-\eta)^{1-\eta}} > 0$.

In 2.14, if $A_c = 0$ then only the leading term is different from zero and in fact it is positive. In this case, we can show that an increase in $1-\tau_N$ will increase intrahousehold risk sharing against uncertain labor income, or to put it differently, it will reduce the response of the sharing rule to variations in income. When $A_c > 0$, the second term is added and also the first term in 2.14 eventually switches sign. When the overall partial derivative is negative, the fall in labor taxation exacerbates inequality within the family and reduces welfare by reducing insurance. This is the result we established under log-log separable utility. What non-separability brings to the equation is the leading term in 2.14 that yields the non-monotonicity of the sharing rule in labor taxes and makes the effect of changes in labor income taxation ambiguous.

To understand what this term captures, note that when wealth is low, a rise in the tax rate reduces inequality in terms of labor incomes, but it also impoverishes the household. When utility is curved, the reduction in household income translates into a huge increase in the marginal utility of consumption. Given ϵ_m and ϵ_f the participation constraints tighten. There is, therefore, a powerful income effect that in the case of log utility was balanced by the larger equity in household resources. In the appendix, we show that a similar result applies to the upper bound λ_2^U. We also establish that the effect of lower capital taxation is unambiguous; it always improves the household's insurance possibilities.

Proposition 3. *Assume that utility is nonseparable in consumption and leisure. Lowering labor income taxes reduces intrahousehold inequality when household wealth is low. In contrast, when the household is wealthy, reducing labor taxation has a detrimental effect on intrahousehold insurance. Lower capital taxes always improve the households insurance.*

Proof: See Appendix.

In our quantitative analysis in section 2.5, we deal only with the case of nonseparable utility. As the results of this section suggest, because the new policy will replace capital taxes with labor taxes it is not clear whether it will ultimately relax the households' limited commitment problem or not. To the extent that the policy change does not affect overall household resources by much, shifting the burden of taxation from wealth to labor income will probably enhance commitment, because under the new policy more of the households consumption will be financed through wealth. Older households are wealthier and more likely to fit this requirement. According to proposition 3, younger individuals are poorer and less likely to satisfy this condition. In section 2.5, we will show that the results from the quantitative model are in line with this intuition.

2.3.2 Optimal Savings

In this section, we illustrate what determines a couple household's savings. Consider a couple that starts the first period of the life-cycle with a weight $\lambda_1 = \frac{1}{2}$. Note that an increase in savings in the first period entails a cost in terms of marginal utility. If utility is log-log separable, this cost is given by the expression $\frac{1}{-a_1+2w(1-\tau_N)}$, and if $\gamma > 1$ it is given by $\frac{(-a_1+2w(1-\tau_N))^{-\gamma}}{(w(1-\tau_N))^{(1-\eta)(1-\gamma)}}\chi$ where $\chi = \eta^{\eta(1-\gamma)}(1-\eta)^{(1-\eta)(1-\gamma)}$.[7] The second period benefit from higher savings is given by:

$$\beta(1+r(1-\tau_K))E_1\left[\lambda_2\frac{du_m}{dA_c} + (1-\lambda_2)\frac{du_f}{dA_c} + \frac{d\lambda_2}{dA_c}(u_m-u_f)\right] \tag{2.15}$$

The leading two bracketed terms in 2.15 represent the marginal benefit, keeping the household sharing rule constant, whereas the last term measures the effect of higher savings

[7]Notice that the period one idiosyncratic productivity endowments are normalized to unity for both spouses.

on the sharing rule. If the couple was able to commit to the first period contract, setting $\lambda_2 = \frac{1}{2}$ everywhere on the state space, the derivative $\frac{d\lambda_2}{dA_c}$ would equal zero. It follows that the marginal utility terms would be the only ones that would count for the marginal benefit of household savings.

Under log separable utility, we can show that

$$E_1 \left[\lambda_2 \frac{du_m}{dA_c} \; + \; (1 - \lambda_2) \, \frac{du_f}{dA_c} \right] = \frac{1}{\sum_g \epsilon_g w (1 - \tau_N) + A_c} \tag{2.16}$$

Notice that the right hand side of 2.16 is independent of the weight λ_2. In fact, this expression is the same as the one we would get if we were to solve for the full commitment allocation that sets $\lambda_2 = \frac{1}{2}$ regardless of the productivity levels of the male and female spouse. Under log utility, therefore, it is the last terms in 2.15 ($\frac{d\lambda_2}{dA_c}(u_m - u_f)$) that describes how household bargaining affects the expected marginal benefit from savings. In order to assess whether limited commitment leads to a higher demand for savings, we have to focus on that term.

We consider separately each relevant region in the state space where the term $\frac{d\lambda_2}{dA_c}(u_m - u_f)$ is different from zero, that is every region where the marital contract is rebargained. As discussed previously, for male productivity ϵ_m less than a lower bound $\underline{\epsilon_m}(A_c, \epsilon_f)$ the weight λ_2 will fall to λ_2^U (there is an increase in the female spouse's share). Conversely, if $\epsilon_m > \overline{\epsilon_m}(A_c, \epsilon_f)$ (upper bound) then $\lambda_2 = \lambda_2^L$. In any other region there is no rebargaining of the households allocation and, therefore, $\lambda_2 = \frac{1}{2}$. Thus we can write the conditional expectation of $\frac{d\lambda_2}{dA_c}(u_m - u_f)$ as:

$$\begin{aligned} E_1 \frac{d\lambda_2}{dA_c}(u_m - u_f) \;\; &= \;\; \int_0^{\underline{\epsilon_m}(A_c,\epsilon_f)} \int \frac{d\lambda_2^U}{dA_c}(u_m - u_f) dF(\epsilon_f, \epsilon_m) \\ &+ \;\; \int_{\overline{\epsilon_m}(A_c,\epsilon_f)}^{\infty} \int \frac{d\lambda_2^L}{dA_c}(u_m - u_f) dF(\epsilon_f, \epsilon_m) \end{aligned} \tag{2.17}$$

where F is the joint density of idiosyncratic productivity in the household.

From equation 2.9 it is easy to establish that the derivative $\frac{d\lambda_2^U}{dA_c}$ is positive and the derivative $\frac{d\lambda_2^L}{dA_c}$ is negative. In order to sign $\frac{d\lambda_2}{dA_c}(u_m - u_f)$, in each relevant region of 2.17, we need to determine the difference in the welfare levels of husbands and wives.

As it turns out, this difference is not of one sign. This is so because the limited commitment model has nothing to say about the absolute level of utility; it simply states that if ever participation is violated, a correction has to be made that makes one of the spouses as well off as if they were single. Since the model does not admit an analytical solution for the conditional expectation, we used numerical methods to compute the relevant integrals. Depending on the level of assets, we found that $E_1[\frac{d\lambda_2}{dA_c}(u_m - u_f)]$ could be both positive or negative, which implies that the effect of limited commitment on household savings is ambiguous.[8]

The more general case for $\gamma > 1$ yields similar results. For this model we can derive the following expression for the leading term in 2.15:

$$E_1\left[\lambda_2 \frac{du_m}{dA_c} + (1-\lambda_2)\,\frac{du_f}{dA_c}\right] = E_1\left[(Ac + \sum_g w(1-\tau_N)\epsilon_g)^{-\gamma}\chi \right. \tag{2.18}$$

$$\left.\left((\frac{1}{1+f(\lambda_2,\epsilon)})^{1-\gamma}\frac{\lambda_2}{(w(1-\tau_N)\epsilon_m)^{(1-\eta)(1-\gamma)}} + (\frac{f(\lambda_2,\epsilon)}{1+f(\lambda_2,\epsilon)})^{1-\gamma}\frac{1-\lambda_2}{(w(1-\tau_N)\epsilon_f)^{(1-\eta)(1-\gamma)}}\right)\right]$$

The above expression suggests that the intrahousehold allocation affects the optimal savings of the family relative to the full commitment model, even beyond the term $E_1\frac{d\lambda_2}{dA_c}(u_m - u_f)$. To see how, first note that the bottom line of 2.18 can be further simplified into:

$$((\frac{1}{1+f(\lambda_2,\epsilon)})^{-\gamma}\frac{\lambda_2}{(w(1-\tau_N)\epsilon_m)^{(1-\eta)(1-\gamma)}} = (\lambda_2^{\frac{1}{\gamma}}\epsilon_m^{\omega} + (1-\lambda_2)^{\frac{1}{\gamma}}\epsilon_f^{\omega})^{\gamma} \tag{2.19}$$

where $\omega = -(1-\eta)(1-\gamma)/\gamma < 0$. Second, assume that male and female productivities in period 2 are perfectly negatively correlated, so that $\epsilon_m + \epsilon_f = \bar{\epsilon}$ which is constant. It is obvious that 2.19 is the only term that matters for household savings, as under these assumptions $(Ac + \sum_g w(1-\tau_N)\epsilon_g)^{-\gamma}\chi$ would be constant, no matter the realizations of ϵ_m and ϵ_f.

The term in 2.19 exerts an influence to household savings because it changes the marginal benefit to the household. Since it is a concave function in ϵ_m, higher uncertainty decreases the marginal utility, even under full commitment when the shares are constant. Moreover, if the shares λ_2 change with the endowment, as they do under limited commitment, they contribute further to the variability of 2.19. This lowers the marginal gain from an extra unit of savings even further. In this example limited commitment means less rather than

[8]This result emerges also in Ligon, Thomas, and Worrall (2000).

more savings. The analysis of the term $E_1 \frac{d\lambda_2}{dA_c}(u_m - u_f)$ is similar with the log log case and, for the sake of brevity, is omitted.

From the analysis of this section we conclude that, under household bargaining, even though individuals behave more like single agents, this does not necessarily lead them to accumulate more assets. Instead, we can construct examples where household savings drop under limited commitment.

One final comment is in order. Note that the covariance structure of wages within the household is extremely important for the sharing rule and, of course, the optimal allocation. In the two period model of this section, more negatively correlated shocks imply that the limited commitment problem in the household is more severe. If, on the other hand, shocks were perfectly correlated yielding $\epsilon_m = \epsilon_f$, then it is trivial to show that household rebargaining would not occur in equilibrium. The optimal weight λ_2 would equal a half, and the demand for savings of a two member household would be identical to the demand of a single earner household. When shocks are not perfectly correlated, the need to accumulate assets to buffer shocks to the labor income is less, and as a consequence couple households accumulate less wealth.

2.4 Calibration

2.4.1 Preferences and Demographics

The demographic parameters have been set so that the model has a stationary demographic structure that matches the age distribution in the US economy. We assume that individuals are born at age 25 and live at most until age 95. Retirement is at age 65. The survival probabilities are taken from Arias (2010), based on the US National Vital Statistics Reports. The model period is set to five years. This means that there are fifteen periods in the model and the retirement age $j_R = 10$. Although we make this assumption for computational reasons, in what follows we report annual values for the parameters.

We set the fraction of households that are married μ equal to .52 which is the corresponding statistic in the PSID data over all age groups. Note that this is a very conservative choice. We deliberately chose not to count divorced individuals and widowers as married, though in the model, we assume that marital status is independent of age (divorce never occurs). Had we chosen to take this assumption to the data the appropriate target for μ would be 77% (see Guner, Kaygusuz, and Ventura (2012a;b)). With $\mu = .52$ roughly 69% of all individuals in our economy are married. Population growth is assumed to be constant $\theta = 0.012$.

Per period utility for each household member is of the following form:

$$u_g(c, l) = [(c^{\eta} l^{1-\eta})^{1-\gamma} - 1]/1 - \gamma$$

We calibrate the preference parameters as follows: first, we follow Conesa, Kitao, and Krueger (2009) and Fuster, Imrohoroglu, and Imrohoroglu (2008), and set $\gamma = 4$.[9] We also choose a value of $\eta = .38$ so that our model produces, in the steady state, average hours worked of one third. With these numbers the intertemporal elasticity of substitution, $(1 - \eta(1 - \gamma))^{-1}$, is equal to .4673.

For married couples we have to determine the utility gains $\overline{\xi}_m$ and $\overline{\xi}_f$ at the Nash bargaining stage and the flow gain ξ that couples enjoy at each period. As discussed earlier, these parameters govern the following two aspects of the intrahousehold allocation. First, $\overline{\xi}_m$ and $\overline{\xi}_f$ determine the transfers from one spouse to another, and along with differences in the age productivity profiles $L_j(g)$, they determine inequality in hours within the household. We pick numbers for these parameters to match average hours worked for married men and women as in the US data; according to the PSID married males worked 2104 hours in 2004, married females 1420 hours, single males 1743 hours and single females 1593 hours. We map these numbers into model units and we normalize the work time to be one third of the time endowment on average in our economy.

Second, the constant gain ξ determines the ability of the household to commit to an allocation that is chosen at the matching stage. The smaller ξ is, the more the household members will be tempted to renege on this allocation and the more frequent rebargaining will occur in every period.

We adopt the following approach: We present the results from three different types of models. The first is a model where commitment is very limited, meaning that ξ is small

[9] Based on empirical evidence by Attanasio and Weber (1995) and Meghir and Weber (1996), which suggests that individual preferences are not separable in consumption and leisure, Mazzocco, Ruiz, and Yamaguchi (2007) argue that a value of γ greater than unity is appropriate.

enough such that the participation constraints bind very frequently in the simulations. In fact, in that model, we target the lowest level of ξ so that the surplus from the marriage is positive and divorce does not occur in equilibrium. The second version is one where ξ is high enough so that the participation constraints never bind. And finally, we consider a version of the model where commitment is between these two extremes, i.e. where participation constraints do bind but half as frequently as in model number one. Considering these three alternatives allows us to investigate thoroughly the impact of the household contract on the aggregate economy and the effects of policy on the intrahousehold allocation.

2.4.2 Technology and Endowments

The technology parameters are chosen as follows. In the model we allow technology A_t to grow at a rate equal to 1.4% per year. In order to represent our economy in the computer, we have to make the standard normalizations as in Aiyagari and McGrattan (1998). Moreover, we set the capital share in value added α equal to .36 and we choose the depreciation rate of capital δ to match an investment to output ratio of 21% in the steady state. This gives us an annual value for this parameter of 5.26%. The subjective discount factor β is calibrated for each model variant so that the economy in the steady state produces the capital output ratio of 2.7. This procedure yields for all values of ξ a discount factor of approximately 1.003.

Individual wages in the model are the product of three components; the gender specific life-cycle profile, the fixed effect, and the temporary idiosyncratic productivity shock.

$$w_{i,t} = L_g(j)\ \alpha_{i,g}\ \epsilon_{i,t} \tag{2.20}$$

Following the bulk of the literature, we take the life-cycle profiles $L_g(j)$ from Hansen (1993). Moreover, our principle to calibrate the fixed effect component and the distribution of the idiosyncratic shocks ϵ is to reproduce the life-cycle cross sectional variance of family earnings as they are documented in Storesletten, Telmer, and Yaron (2004).[10] For the fixed effect, we choose two values α_1, α_2 which we assume are common across gender and marital status. We follow Conesa and Krueger (2006) and assume that $\alpha_1 = e^{-\sigma_\alpha}$ and

[10]Conesa, Kitao, and Krueger (2009); Conesa and Krueger (2006) follow a similar strategy.

$\alpha_2 = e^{\sigma_\alpha}$ where σ_α governs the variance of the earnings ability. For bachelor agents, we calibrate the fractions $p^S_{i,g}$ of high and $1 - p^S_{i,g}$ of low ability in the population to 1/2. For couples, we calibrate the joint probabilities $p^M_{i,k}$ so that our economy reproduces the degree of marital sorting in earnings ability that has been documented in the US data; for instance Hyslop (2001) estimates a .5 correlation of fixed effects within the family in his PSID sample. Hence, we set $p^M_{i,k} = .375 \text{ if } i = k$ and $p^M_{i,k} = .125 \text{ if } i \neq k$ to match this empirical correlation. We set $\sigma_\alpha = .35$ so that the model is consistent with a cross sectional variance of household labor income of .24 for young cohorts (see Storesletten, Telmer, and Yaron (2004)).

The idiosyncratic component ϵ is assumed to be a first order autoregressive process that we discretize as a Markov process with 5 nodes (25 for the couple). We choose the persistence of this process and the variance of the innovation to ϵ to make the model produce a linear rise in the cross-sectional variance of income with age and a value of 0.9 at age 65. Finally, we allow for shocks to ϵ to be contemporaneously correlated within the family and set the correlation equal to .15 (see also Heathcote, Storesletten, and Violante (2010), Hyslop (2001)).

2.4.3 Government

In order to parameterize the steady state tax code, we proceed as follows. The level of government expenditures G is chosen so that in the balanced growth path, the government consumes 21% of output. This spending is financed by the tax levies on consumption, capital and labor income. We follow Fuster, Imrohoroglu, and Imrohoroglu (2008) and fix the consumption tax τ_C to .05, and we set the steady capital income tax τ_K to .35. The value of τ_N is chosen so that the government runs a balanced budget. In our numerical experiment, we eliminate capital income taxation and adjust labor income taxes, while holding the level of expenditures constant to their steady state value.

Our principle to calibrate the social security benefit system is the following: First, as explained previously, we consider the individual as the unit to which benefits are distributed and not the household. Second, we try capture in a parsimonious way, with the functional $SS(g, \alpha_{i,g})$, the fact that social security contains a redistributive component in the US. For instance, in 2004 individuals received 90% of the first 7,300 of their total social security entitlement, 32% for earnings between 7,300 and 44,000, and 15% for earnings above 44,000. We calibrate $SS(g, \alpha_{i,g})$ so that the model economy gives roughly the same redistribution of income in retirement in terms of median lifetime earnings as in the US economy. To give an idea of the numbers, we calculate in the model that men of the highest earning ability (fixed effect) get roughly 1.5 times as much as men of the lowest ability, whereas their lifetime earnings are twice as high. Furthermore, women with the lowest ability receive in benefits roughly 67% of what poor men receive, and women of high ability get slightly (3%) more than poor men. We fix the social security tax rate at 12.5% and solve for the average level of benefits. In the computational experiment, we keep the tax rate constant across environments and vary the level of benefits.

Table 2.1: Calibrated parameters

	Description	**Value**
μ	fraction married households	0.52
θ	annual population growth	1.2%
$\hat{A}$	annual productivity growth	1.4%
α	capital share	0.36
δ	annual depreciation rate	5.26%
β	discount factor	1.003
γ	preference parameter	4
η	preference parameter	0.38
τ_C	consumption tax	5%
τ_K	capital income tax	35%
τ_{SS}	social security tax	12.5%

Notes: For the wage processes see section 2.4.2. For growth rates ($\hat{A}$, θ, δ) the reported values are annual, but we solve on 5-yearly frequency.

2.5 Results

2.5.1 Long Run Effects of the Reform

We report the steady state long-run effects from the reform. In table 2.2, we show the percentage changes in capital, total hours worked, social security benefits and output when the model converges to a steady state with zero capital taxation. The initial steady state values for these quantities are normalized to 100. The first column reports the results from the limited commitment model, the second from the version of the model, where the participation constraints bind albeit less frequently (medium commitment), and the third column reports the results when contracts are complete, i.e. when the participation constraints never bind (full commitment).

Table 2.2: Long-run steady state: quantities

Quantity	Limited	Medium	Full	Single Men	Single Men & Women
K	110.6%	110.8% %	111.0%	109.4%	109.2%
N	92.2%	92.1%	92.2%	92.3%	91.5%
SS	99.0%	98.9%	99.0%	98.5%	98.0%
Y	98.9%	99.0%	99.1%	98.1%	97.3%

Aggregate capital increases by 10.6% in the model with limited commitment, by 10.8% in medium commitment, and by 11% under the full commitment model. Hours worked fall due to the rise in distortionary labor taxation, and they fall by the same amount (to decimal rounding) in all models. In all models, labor taxes have to rise by roughly 100% from the initial to the final steady state to make up for the loss of revenue when capital taxes are set to zero. Since the response of aggregate capital is slightly different across the economies, the fall in output is also slightly different. It is highest in the limited commitment model (1.1%) and lowest in the full commitment model (0.9%). The third row of the table shows that the level of social security benefits falls because the tax base shrinks with the fall in labor income and the tax rate τ_{SS} has been kept constant in the new steady state.

In table 2.3, we present a break down of the response of assets and hours worked by gender and marital status in the three models. We denote by x_g^k the response of quantity $x \in \{a, n\}$ (assets or hours) for household type $k \in S, M$ (single or married) and gender g. All individuals and household types experience the largest steady state increase in assets in the full commitment model. The wealth of single female households increases the least (between 7.5% and 7.9%), single male households accumulate slightly more (between 9.1% and 9.4%), whereas for couple households assets increase between 11.5% and 12.0% in the final steady states.

The fact that couples respond more than singles to a change in capital taxation should come as no surprise given our previous discussion of the role of precautionary savings in the

Table 2.3: Long-run steady state: disaggregated quantities

Quantity	Limited	Medium	Full
		Assets	
a_m^S	109.1%	109.2%	109.4%
a_f^S	107.5%	107.7%	107.9%
a^M	111.5%	111.7%	112.0%
		Hours	
n_m^S	92.8%	92.8%	92.8%
n_f^S	90.3%	90.3%	90.3%
n_m^M	93.2%	93.3%	93.3%
n_f^N	91.2%	91.2%	91.4%
		Saving Rates	
s_m^S	10.97 %	10.96 %	10.97 %
s_f^S	11.87%	11.87%	11.86%
s^M	10.81%	10.75%	10.72%

model. When labor income is risky, the higher the demand for precautionary savings, the lower is the elasticity of capital accumulation with respect to taxes.[11] Single households fit this profile. They have to accumulate wealth in order to insure against productivity shifts. But couple households are different; because labor income shocks are not perfectly correlated in the family, couples also possess intrahousehold insurance. The two spouses can help each other to finance a smooth consumption path through transfers.

To give an idea of how large these transfers are, we calculate in the initial steady state of the models income subsidies from one household member to the other as a fraction of total household resources devoted to finance consumption. We define the transfer as the excess of private consumption over individual income, assuming that each spouse owns half of the household wealth stock each period and finances half of the wealth brought forward to the next period. We find that in the limited commitment model intrahousehold transfers are roughly 12.9% of total consumption spending, whereas in the full commitment model that number is 15.2%. These numbers correspond to all age cohorts in the model. For non-retired households, transfers of income are even greater. We return to this issue in

[11] Note that in an economy with high capital taxation more of the households resources are made out of risky labor income. In this environment, households increase their precautionary savings. In contrast, with low capital taxation, households accumulate wealth due to the higher return but lose a significant portion of the precautionary savings demand, since capital income, at least in the model, is riskless.

section 2.5.3, where we take a close look at the intrahousehold allocation in the models.

In the last three rows of table 2.3, we have added the average saving rates by household type for the three models. We define the savings rate as the ratio of the change in the households net asset position (change in wealth) to total household income (labor and financial income). We compute this statistic for ages 25 to 45, that is in the period of the life-cycle where savings are mainly for precautionary purposes, in contrast to later periods of the life where individuals save to finance retirement. Notice that single female households have the highest savings rate in all models (roughly 11.8%). Single males have an average saving rate of around 11%, and couple households save less out of their total income than all other household types. These statistics are in line with the intuition that the incentive to save in order to buffer shocks to labor income is less for couple households.

The results of table 2.3 suggest that more commitment leads to a weaker desire to save. The average couple household has a saving rate of 10.81% in the limited commitment model, and of 10.72% in the full commitment model. The difference, however, is quantitatively small, or at least too small to imply that household members that face participation constraints of the sorts of the limited commitment model, behave more like single individuals and have a stronger demand for precautionary savings. As we showed in section 2.3, it is extremely difficult to sign the impact of limited commitment on household savings, meaning that savings could be higher or lower under less commitment. The results of this section confirm this point.

One aspect of the household program that may be responsible for changes in the saving behavior of couples across models can be traced to the initial bargaining stage. As we increase the level of utility ξ to enhance commitment, the initial allocation features more equity meaning that the shares are closer to a half. This affects savings in the following way: In a family where for example the husband has a high fixed effect and the wife a low fixed effect, a weight closer to a half gives more importance to the wife's preferences. Because social security redistributes towards poorer individuals, the female household member wants to save less and, therefore, overall household savings fall.[12]Though we acknowledge that these effects are present, and possibly important for household decision making, we do not attempt to analyze their impact here.

[12]This is similar to the reform in the divorce law that Voena (2012) considers.

Aggregate Quantities in Singles Models. In the last two columns of table 2.2, we added the aggregate results from two models where each household is populated by a single individual. The model that we call 'Single Men' is calibrated such that all households are single male households. The model 'Single Men and Women' is a model where half the population is single males and the other half single females. Notice that with bachelor households the response of aggregate capital to the reform is smaller. Aggregate capital increases by 9.4% in the 'Single Men' model and by 9.2% in the 'Single Men and Women' model and, therefore, by less than our benchmark models with singles and couples. These results illustrate that adding a richer and more realistic demographic structure in the economy, matters for economic outcomes. Once more these differences reflect the weaker precautionary savings motives in families of two individuals, which make the distortions from capital taxation larger.

Welfare. In table 2.4, we look at the long-run welfare effects of the change in tax code. We define our welfare measure as the percentage increment in consumption that keeps expected welfare constant across the two economies (with and without the reform). We report the average value of this quantity for all individuals in our economy, assigning equal weight to each individual in the welfare function, and separately for males and females single and married.[13]

[13]We construct average utility as follows:

$$U = \frac{1}{2\mu + (1-\mu)}(\mu \int \sum_g V_g(a, X, \lambda, j)\Gamma_M(da \times dX \times d\lambda \times dj) + \frac{1-\mu}{2} \int \sum_g S_g(a, X, j)\Gamma_{S,g}(da \times dX \times dj)) \tag{2.21}$$

where μ is the fraction of households populated by couples in our economy (there are 2μ married individuals). Since preferences are the same for all individuals the value of the compensation variation is given by: $\left(\frac{U^{tax}}{U^{no\ tax}}\right)^{\frac{1}{\eta(1-\gamma)}} - 1$, where U^{tax} (U^{notax}) is average utility in a steady state with (without) capital taxation. Similarly, when we want to make a welfare assessment for married individuals, we compute expected utility as follows:

$$U_M = \frac{1}{2}(\int \sum_g V_g(a, X, \lambda, j)\Gamma_M(da \times dX \times d\lambda \times dj)) \tag{2.22}$$

Notice that the welfare criterion under 2.22 is different than the average household utility the way we define it in equation 2.4. For example, if we were to use the value function $M(a, X, \lambda, j)$ in our welfare calculation, we would construct average utility for married individuals as:

$$W = \int M(a, X, \lambda, j)\Gamma_M(da \times dX \times d\lambda \times dj) = \int \lambda V_m(a, X, \lambda, j) + (1-\lambda)V_f(a, X, \lambda, j)\Gamma_M(da \times dX \times d\lambda \times dj)$$

The value for W and U_M do not coincide because the planner attaches a weight equal to 1/2 to every individual, but households attach weights λ and $1-\lambda$ respectively. In the ergodic distribution Γ_M, these household weights are generally different from 1/2. Apps and Rees (1988) show that aggregating preferences

All types of individuals are on average better off in the final steady state without capital taxation. The average welfare gain is 1.6% of consumption in the limited commitment model (first column of table 2.4), 1.69% in the medium commitment model (column 2), and 1.78% in the full commitment model (third column). Single females enjoy the largest welfare gains (between 2.96% and 3.16%), whereas the gains are most modest for single male households (ranging from 0.8% to 0.97%). Married women seem to benefit more than married men from the reform under limited commitment (1.76% vs 1.1%), but as the degree of commitment increases the gains become more equally split between the spouses.

Individuals are on average better off in the economy where the response of capital to the reform is larger. This economy, according to our results, is the full commitment economy that exhibits the largest rise in aggregate capital and, consequently, the smallest fall in output. Although we do not report the age profiles of the gains in the table, our results suggest that the reform is costly to younger individuals. For example, in the full commitment economy individuals aged 25–35 are willing to give up 2.16% of their consumption in the old steady state to keep capital taxes high. Similar results obtain in the other two models. Because families are born with zero wealth and, as such, have to rely on labor income to finance consumption they are hurt when labor taxes increase.

Borrowing constraints and the time path of life-cycle productivity are key in understanding the division of welfare gains across household types in the model, and in particular to understanding why female households benefit more from the reform. Note that in our calibration the productivity path of men steeply rises with age (see the results of Hansen (1993)). Male productivity peaks at age 45–50 and the ratio of the maximum to initial productivity is 1.22. Consequently, in the model, men want to borrow against their permanent income to smooth consumption, but cannot do so due to the presence of the borrowing constraints. When capital taxes are replaced with labor taxes young single men experience a fall in income that makes their consumption path even steeper over the life-cycle.[14] Female productivity, on the other hand, is not steeply rising; it peaks at ages 35 to 40 and is roughly 2% higher relative to age 25. Therefore, young single women in the

of individuals into a household utility and maximizing over a policy parameter, can be misleading for policy, because the effects of changes in policies are mediated through the household sharing rule λ.

[14]See Erosa and Gervais (2002) for an analysis of the effect of life-cycle income profiles on the preferences for labor and capital taxes.

model are not made as worse off in the new steady state.

Table 2.4: Long-run steady state: welfare

Compensating Variation	**Limited**	**Medium**	**Full**	**Single Men**	**Single Men & Women**
Total	1.60%	1.69%	1.78%	0.10%	1.00%
Married Males	1.10%	1.23%	1.52%		
Married Females	1.76%	1.75%	1.56%		
Single Males	0.80%	0.87%	0.97%	0.10%	-0.45%
Single Females	2.96%	3.06%	3.16%		2.16%

To understand how these gender differences in the economic environment affect the overall and relative welfare gains for married individuals several remarks are important. First, note that as most of the married household income comes from the husband, couples are more like single men than single women. That is to say that the couple cannot smooth the life-cycle income profile by allocating more hours to the wife at the early stages of the working life. Dual earner families enjoy relatively large welfare gains, but this comes out of the fact that in the final steady state they increase wealth by more than singles and, therefore, benefit more from the new tax scheme.

Second, married women do better than married men according to the welfare measure, but this should come out of how the bargaining position of the spouses change rather than the labor income profiles. Thus, we need to evaluate the impact of the policy change on the backfold position of individuals in the family. To do that, we compute in the initial and the final steady states the compensating variation of each of these two outside options. We find that under the new policy women do even better; their compensating variation is 4%, whereas the analogous object for men is .39% (note that this is relevant under limited commitment). So, on the one hand, women are in a position to bargain for a better allocation, but on the other hand, most of the extra surplus for the couple comes from wealth, which as we showed earlier, does not trigger rebargaining but rather improves commitment. The overall effect is a slight change in the weight (less than 1%) in favor of married women in the final steady state.

Finally, in the last two columns of table 2.4, we report the average welfare gains and loses in the two singles economies. The 'Single Men Model' gives a value for our measure of compensating variation equal to .1% meaning that individuals have to be compensated with a .1% increase in consumption to remain in the old steady state. In the 'Single Men and Women' model, male households lose from the reform. They are willing to give up .45% of consumption to keep capital taxation high. Female households, on the other hand, gain from the reform. The compensating variation for them is 2.16%, one percentage point less than the analogous gain in the full commitment model with singles and couples, but less than a percentage point less than in the limited commitment model. According to these results, gender heterogeneity is an important determinant of the welfare responses in the model, but also considerable welfare gains are attributed to the presence of two earner households.

2.5.2 The Transition to the Steady State

In this section, we report the welfare effects from the change in policy, but instead of focusing on a comparison between steady states, we focus on the impact of the new tax schedule in period 1, right after the reform takes place. Our approach to solve for the equilibrium of the model in this section is to guess a time path of prices and quantities (interest rates, tax rates and benefits), compute the optimal decision rules of households that face this time path, and simulate the model starting from the ergodic distribution of the initial steady state. Thus, the solution characterizes the dynamic adjustment of the economy from the first period in which the reform is implemented to the new long-run steady state. Because the transition is completed in more than 15 model periods, the first generation of individuals that experience the change in policy are not alive in the new steady state. Therefore the welfare results of this section could in principle differ considerably from the results presented in the previous section.

In figure 2.1, we plot the time paths of interest rates, labor taxes, aggregate capital and benefits over 30 model periods. Each period counts for five years of calendar time. We label period 0 the old steady state, and period 1 the first period of the transition, right after the reform takes place. The figure starts from period 1, and shows the adjustment of the economy towards the new steady state. Note that aggregate capital is predetermined in the first period, but taxes, benefits and interest rates, and also wages and hours (not shown) immediately adjust to new values. We report the magnitude of these initial adjustments in the text, but we leave them out of the figure.

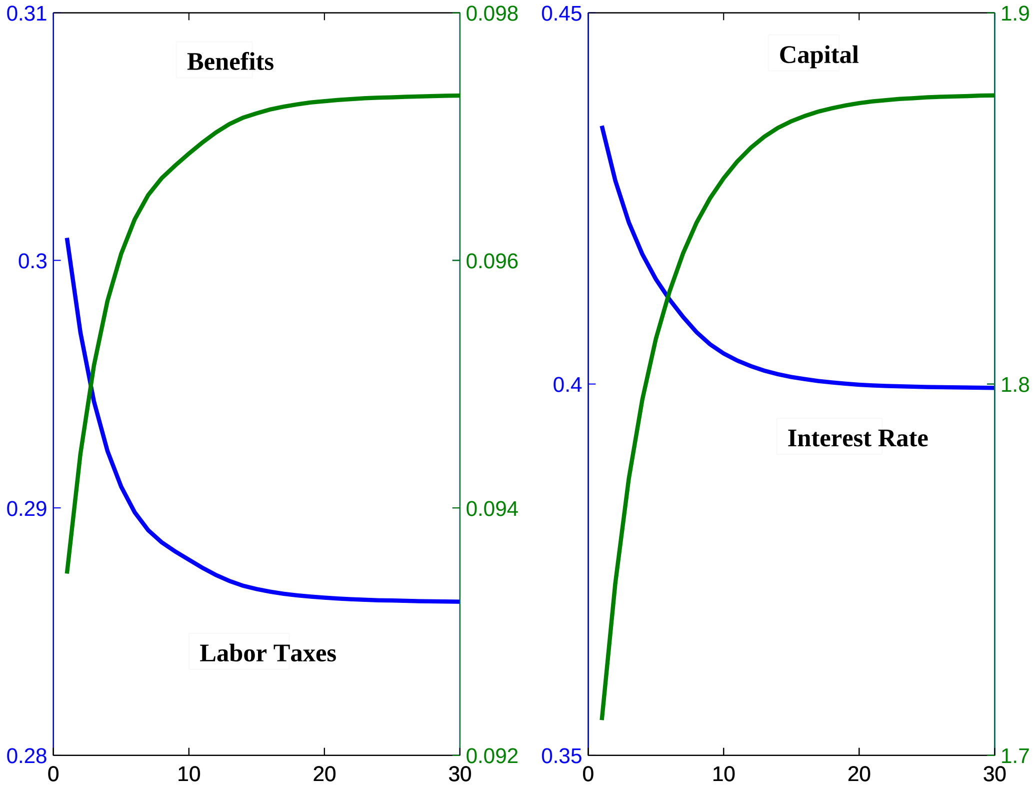

Figure 2.1: Transition paths

Notes: On the left panel the blue line traces the evolution of labor income taxation. The green line represents the level of benefits. The right panel shows the real interest rate (blue line, five annual value) and the time path of the capital stock (green line). The figure shows prices and quantities in the full commitment model. We obtain similar paths in the other models.

In period one, the interest rate jumps from a value roughly .475 to a value of .437 due to the immediate fall in hours. When the capital tax is abolished, the government adjusts upwards labor income taxes to finance spending. From a value of roughly 14% in the old steady state, τ_N instantaneously jumps to about 30%. Because the economy has not build up a higher stock of capital yet (capital is fixed in the short-run), wages are lower than in the long-run steady state, and thus labor taxes have to increase by even more relative to their long-run steady state value.

When the change in policy occurs, benefits fall relative to the initial steady state by roughly 7%. Then they increase along the transition because capital accumulation increases wages and labor income. The time paths for other variables not shown in the figure are as follows: aggregate hours fall by 8.15% on impact and wages rise by 3.25%, due to the decreasing marginal product of labor and the fall in hours. The largest drop in hours is by single females (10%) followed by married females (7.5%). Male hours worked, both for single and married men, fall by about 6.3%. The figure shows the paths for prices and quantities in the full commitment model. The analogous paths for the limited commitment models are similar, and for the sake of brevity, we omit them. We are more interested in tracing how these changes in the tax code affect the welfare of individuals and in investigating which household types stand to gain and which to lose from the reform.

Welfare. In table 2.5, we report our measure of compensating variation, the percentage increase or fall in consumption that individuals would accept to remain in the old steady state. This statistic compares the original steady state welfare with the welfare of individuals in the first period of the transition, right after the change in policy takes place.

Table 2.5: Compensating variation in the first period of the transition

Compensating Variation	**Limited**	**Medium**	**Full**	**Single Men**	**Single Men & Women**
Total	-2.12%	-2.11%	-2.07%	-3.6%	-2.00%
Married Males	-2.27%	-2.28%	-2.32%		
Married Females	-2.69%	-2.69%	-2.59%		
Single Males	-3.29%	-3.27%	-3.22%	-3.6%	-4.00%
Single Females	0.18%	0.21%	0.28%		-0.55%

Table 2.6: Support for the reform

Percentage Support	**Limited**	**Medium**	**Full**	**Single Men**	**Single Men & Women**
Total	56.3%	56.3%	56.4%	39.9%	49.2%
Married Males	52.9%	52.2%	52.3%		
Married Females	51.6%	51.2%	51.1%		
Single Males	46.6%	46.6%	46.7%	39.9%	41.1%
Single Females	66.0 %	66.1%	66.1%		57.2%

On average households that are alive in the first period of the transition, lose from the reform. As capital is fixed in the short-run and households are burdened with higher labor taxes, it is not surprising that they are worse off at the time of the change in policy. Only wealthy households stand to gain especially if their overall income (financial and labor) increases due to the higher return on capital. The table shows that across household types, single male households are willing to pay the most to avoid the policy change. The compensating variation is between -3.22% (full commitment) and -3.29% (limited commitment) for this demographic. Single females, on the other hand, benefit from the reform, but the gain is fairly small, ranging from .18% to .28% in the models.

The second and third rows of the table report the welfare gains for married males and females, respectively. It may seem surprising that married men suffer smaller loses than women in the model. For instance, in the limited commitment model men are willing to give up 2.27% of consumption to keep capital taxes positive, whereas the analogous figure for women is 2.69%. It is surprising given that single women benefit more from the reform than single men. We would have anticipated that under limited commitment the division of gains and loses from the reform would be such that it reflects the improved bargaining position of women.

In section 2.5.3, we show that when the policy changes in the first period of the transition there is indeed more bargaining within households. But rather than women benefiting, it is male spouses that see an increase in their share of resources from this rebargaining. When we simulate the outside options in the old steady state and in the first period, we still find that women do better than men. If we divide assets by two and we evaluate the welfare of singles using the distribution of assets for couples, we find that the compensating variation is -3% for men and -.24% for women. When comparing these figures with the welfare loses of married men and women, it seems obvious that the participation constraints for men become looser and for women tighter under the new policy.

Does that mean that female participation constraints will bind more frequently? It is uncertain since a key factor that determines this, is the initial position of the couple in the bargaining set. Generally, the bargaining set becomes smaller under the new policy, because couples lose part of their labor income and not all families are wealthy enough to benefit from the higher returns to capital. If the initial position of a couple is near the constraint of the husband, it is the husband's constraint that binds more frequently. This is precisely what happens in our simulations.

Finally, notice that rebargaining of the intrahousehold allocation does not significantly affect the welfare loses of men and women. The payoffs are similar under medium commitment and under full commitment, where by definition, there is no rebargaining and yet women still do worse than men. The way individual utility responds to the change in the mixture of capital and labor taxes, also depends on the allocation, i.e. relative consumption and hours, of the two spouses which determines the local relative welfare gains and loses. To be more precise note that there is no reason to think that in a model without rebargaining such as the full commitment economy, both spouses will be as well off under the new policy. The new tax scheme will change the allocation of consumption and hours in the family and thus within families one spouse will be better off than the other spouse. We return to this in section 2.5.3.

Support for the reform. Summarizing welfare gains and loses by the average compensating variation masks a large degree of heterogeneity in the economy. Welfare loses could be very large for a few families, but for the rest there might be moderate gains from the reform. We are, therefore, interested in determining whether the policy change is acceptable to a significant fraction of individuals in the economy. In table 2.6, we show the fractions of the population that benefit from the reform in period 1 in the three models. The total support is roughly 56% in the three economies and slightly larger under full than under limited commitment. Most married couples benefit from the reform and, as we anticipated given the previous findings, men are slightly more in favor than women. The majority of single individuals is also better off, but as the table shows a larger fraction (roughly 66%) of single female households stands to gain than single male households (roughly 46%).

The last two columns show the analogous fractions for the 'Single Men' and 'Single Men and Women' economies. There is a large difference in terms of the percentage support for the reform between the benchmark models and the 'Single Men' economy. In the latter, the change in policy is appealing only to a minority of households (39.9%). Similarly, in the 'Single Men and Women' model the analogous fraction is roughly 49%. Gender heterogeneity clearly exerts an influence here, but note that this model deliberately exacerbates the percentage of female headed households in the economy (we set them equal to 50%). According to the PSID data in 2007 in roughly 34% of households the female was the head (in the sense of being the main earner).[15] By this metric the total support for

[15]We would get an even smaller number if we imposed, as in the model, that marital status is independent of age (no divorce). For example, according to the data from the 2000 US Census 77% of households between age 30 and 40 are married (see Guner, Kaygusuz, and Ventura (2012a;b)). In couples households,

the reform would be roughly 46%.

These results are consistent with previous findings in the literature. For example, Domeij and Heathcote (2004) argue that because wealth is very concentrated in the US economy (a small number of households own the largest part of the stock of wealth) only a small fraction of individuals benefit from the elimination of capital taxation in the transition. In their incomplete markets model with heterogeneous agents, they match the wealth distribution as in the data and show that the change in policy has huge redistributive effects that confer welfare loses to the population. Garcia-Milà, Marcet, and Ventura (2010) perform a similar exercise calibrating their model to match the wealth to income ratios of US households. They, too, verify that a policy that eliminates capital taxation decreases welfare in the majority of households.

In the appendix, we show that the benchmark and the singles only models produce similar wealth and earnings distributions. We show that the Gini coefficient of the wealth distribution is around .55 in all models. Moreover, as discussed previously, we have calibrated the earnings processes to match the between household income inequality in all models as in the US data. Therefore, the environments are close enough in terms of the cross section of households. But the perspective that we offer here is a different one from Domeij and Heathcote (2004); according to our paper, it is the attitudes toward labor supply and savings that differ between couples and single households that explains the differences in the welfare effects from the policy. We are convinced that a model that matches the wealth distribution, as Domeij and Heathcote (2004) do, but also matches the conditional distributions by gender and marital status, will have very interesting implications for the effects of the change in the tax code. Unfortunately, that requires a more complete theory of wealth accumulation and labor supply for families than the one we offer here; a theory that includes fertility, bequest motives etc. We leave this for future work.

2.5.3 Impact of the Tax Schedule on the Household Sharing Rule

In this section, we investigate the impact of the tax reform on the behavior of couples. We have yet to answer the question whether changes in the tax code lead to significant changes in intrahousehold decision rules. For example, in section 2.3.1, we established that

the male partner is typically the head.

increasing labor taxation may, or may not, lead to more frequently binding participation constraints. On the one hand, as after-tax income inequality within the household is reduced, rebargaining will probably occur less often. On the other hand, when total household labor income is lower, the temptation to renege on the contract increases. It seems that for families that are wealthy enough to benefit more from the first channel, the change in policy will lead to an improvement in the risk sharing possibilities. Moreover, comparing the initial steady state to the final steady state, or to the first period of the transition, is likely to make a difference in the results. In the long-run, households accumulate more wealth which definitely improves commitment. In the short-run assets are fixed.

Table 2.7: Participation constraints

	Limited	**Medium**	**Limited**	**Medium**	**Limited**	**Medium**
	Initial Steady State		Final Steady State		Transition	
Total	18.0%	9.6%	17.8%	8.8%	24.5%	10.7%
25-45	27.3%	15.7%	29.6%	15.6%	38.7%	17.3%
50-65	10.9%	5.1%	8.4%	3.2%	13.1%	5.8%
Retired	4.9%	0.3 %	1.8%	0%	6.9%	1.1%

In table 2.7, we compute the frequency with which participation constraints bind in the initial and the final steady states as well as in the first period of the transition. The statistic reported in the table counts the number of times that a change in the weight λ takes place in a panel of families that is representative of the population. We leave out of the table the case of full commitment, since there participation constraints never bind.

Obviously, the limited commitment case features more frequent updating of the sharing rule than the medium commitment model. In the old steady state for 18% of our sample, we detect an adjustment in λ under limited commitment, while under medium commitment the analogous number is 9.6%. Rebargaining takes place mostly at young ages; the fractions are highest for individuals aged 25 to 45 and lowest for retired individuals. There are two opposing effects. First, shocks that occur towards the end of the life-cycle are more permanent, given our calibration of idiosyncratic productivity and, consequently more likely to lead to changes in the sharing rule. Second, by their middle age families have accumulated enough wealth, and as we showed previously in our model, this relaxes the participation constraints. Here it seems that the second effect dominates the first.

In retirement, even though there are no changes in labor income, there are changes in the sharing rule. In some families one of the spouses commands a large share of household resources after having experienced a good run of income shocks right before retirement, and as wealth decumulates during retirement the other spouse needs to be made better off. This explains the rebargaining of contracts after retirement.

According to the table in the final steady state (columns 3 and 4), the participation constraints are relaxed. The frequency of updates drops from 18% to 17.8% in the limited commitment model and from 9.6% to 8.8% in the medium commitment model. The largest gains in terms of intrahousehold risk sharing occur for middle aged and retired households. These families accumulate more assets in the final steady state. Young families may even face tighter constraints in their planning program, meaning that rebargaining may be more frequent for these groups in the final steady state. This was certainly the case for our youngest cohorts (ages 25–30). As discussed previously, young families lose a large fraction of their labor income with the rise in labor taxation and this increases the temptation to rebargain.

In the first period of the transition (columns 5 and 6), the new policy upsets the intrahousehold sharing rule. As the table shows, rebargaining is much more frequent than in any of the steady states. We detect a change in the weight λ on average 24.5% of the times. This rise in the incidence of rebargaining is relevant for all age groups. Young individuals have very low assets and, therefore, the change in policy makes it more tempting to renege. However, retired agents also suffer from a fall in benefits; keeping their wealth constant, this implies tighter participation constraints. This highlights that even a simple policy that replaces capital taxes with higher linear labor taxes can affect intrahousehold decision making.

In figure 2.2, we plot the male spouse's weight λ in the final steady state and in the transition on the vertical axis against the weight in the initial steady state on the horizontal axis. The circles represent households. The lines that begin from the origin are 45 degree lines that represent the points with no change in the weight. If observations are below this line, the male spouse's weight is higher in the initial steady state. The converse holds if observations lie above the line. The top figures are produced from the limited commitment model and the bottom panels from the medium commitment economy. Notice that there is

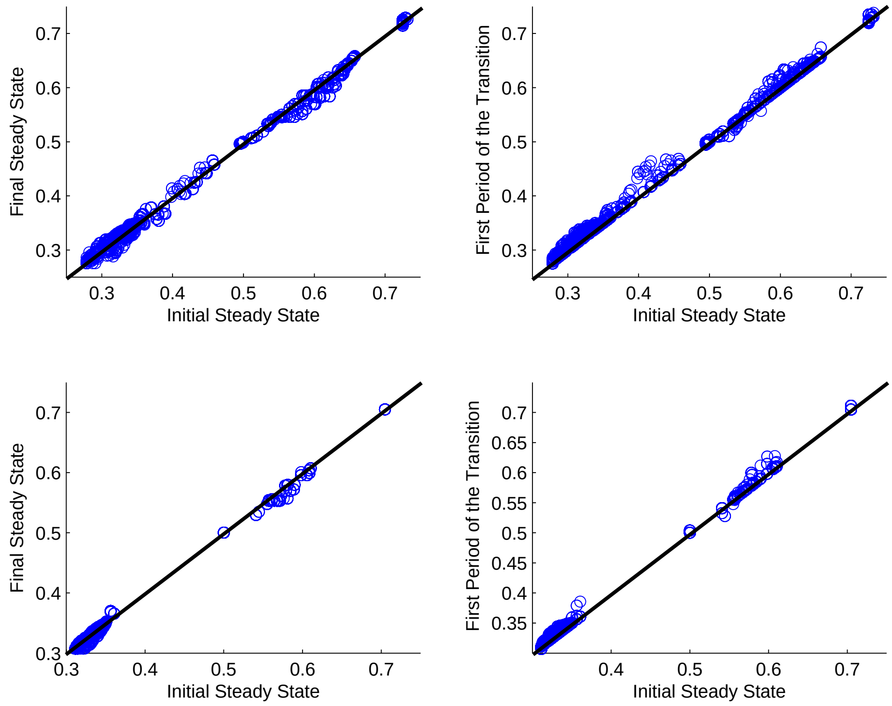

Figure 2.2: Sharing rule λ in the limited and the medium commitment models

Notes: The top panels show the weight λ in the limited commitment model. The bottom panels are for the medium commitment model. Left panels (top and bottom) compare the initial steady state with the final steady state. Right panels compare initial steady state with the first period of the transition.

considerably more volatility in the first environment.

When we plot the initial vs. the final steady state (top and bottom left), changes in the intrahousehold weights do not seem to favor either the male or the female spouse. In this case observations are scattered around the 45 degree line, indicating that there are families where husbands improve their relative position and other families where the wives's position improves. But when we consider initial steady states against the first period of the transition, mostly male household members improve their relative position. This is precisely the point that we made earlier in section 2.5.2, where we explained that rebargaining right after the change in policy tends to favor married men, which produced slightly smaller welfare loses for men in the aggregate.

What do these changes in the sharing rule imply for intrahousehold inequality? If the change in the tax schedule reduces inequality in the household, then this would show up as a rise in the husband's weight when the weight in the initial steady state is low, and a fall in the weight when the initial weight is high. This does not seem to be the case in any of the models considered. We return in a subsequent paragraph to consider more thoroughly inequality within the household.

Labor Supply and Consumption. Figures 2.3 and 2.4 show the effect of the change of the tax code on the labor supply and consumption behavior of households. Figure 2.3 shows the limited commitment model, and figure 2.4 the full commitment model. Both graphs refer to the first period of the transition. On the top left, we show the scatter plot of hours worked by the male spouse as a fraction of total household hours in the initial steady state and the first period of the transition. The figure refers to families aged 25 to 45. The top right shows the same plot for individuals between age 50 and 65. The bottom left shows the consumption shares of the male spouse in the first period of the transition against the initial steady state for non-retired agents, and the bottom right the shares for retired agents. Again if observations are on, or strongly concentrated around the 45 degree lines, there is no significant change of behavior of families.

There is a change in the distribution of work hours for young families (top left of the figures). In principle, married men work more hours when the change in policy happens. There are a few households where the wife's share in total hours increases, but these are households were the wife worked more than the husband in the old steady state. To be more precise, households reduce hours under the new tax code but allocate more hours to the main family earner, which for some households, is the female spouse.

The new policy also changes considerably the labor supply behavior for households aged 50 until retirement. There is a large number of households in which, after the rise in distortive labor taxes, either the male or the female spouse drops out of work altogether. In the figures this is represented by those observations that are at zero or one on the vertical axis (note that it occurs both the limited and the full commitment model). Again the principle seems to be that the household would like to allocate more hours to its main earner. The new policy therefore seems to increase intrahousehold inequality in hours.

According to the bottom panels of the figures, after the change in policy there is in both models a fall in consumption inequality within the household. In the full commitment model this change concerns only non-retired households, while in the limited commitment model it is relevant for all age cohorts. The fall in consumption inequality shows up as

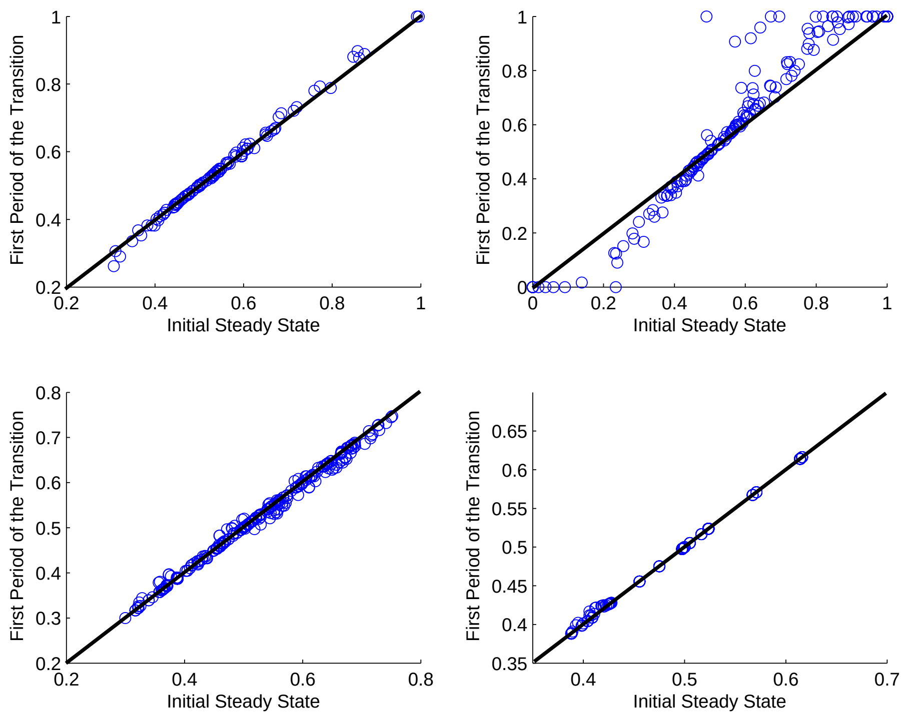

Figure 2.3: Hours and consumption: limited commitment model

Notes: This figure shows the first period of the transition against the initial steady state for various statistics of the limited commitment model. The top panels show hours worked by the male spouse as a fraction of total household hours, the top-left for age 25–45 and the top-right for age 50–65. The bottom panels show the consumption shares of the male spouse, the bottom-left for non-retired and the bottom-right for retired families.

a rise in the husband's consumption share when the initial share is low, and a fall in the share when the initial share is high.

This relative change goes hand in hand with hours inequality. First note that for young households, in order to convince the main earner of to work more hours, there must be a decrease in their consumption share because of the wealth effect to labor supply. Second, for those households where one of the spouses drops out of the labor market, the consumption share of that spouse must increase because she is now off her labor supply curve. To put it differently, at corner solutions individual consumption has to exceed the ratio of the net wage rate to the marginal utility of leisure, since leisure is constrained to unity. The fall in consumption inequality is, therefore, also consistent with the behavior of older cohorts. The limited commitment model adds rebargaining of the allocation. As demonstrated previously, male spouses benefit from those changes in the contracts. As a consequence, consumption inequality does not fall as much as under full commitment.

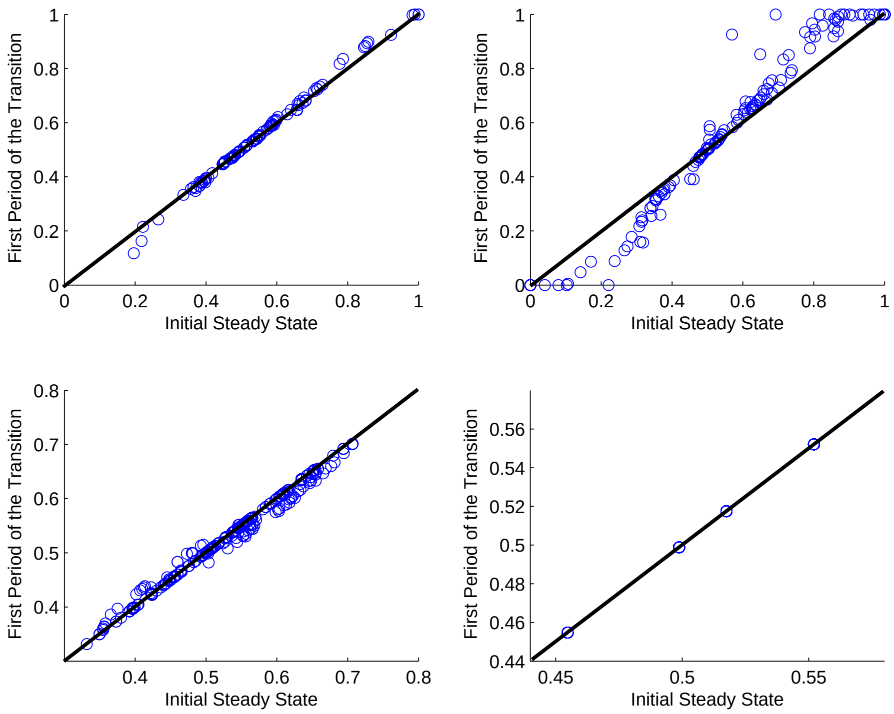

Figure 2.4: Hours and consumption: full commitment model

Notes: This figure shows the first period of the transition against the initial steady state for various statistics of the full commitment model. The top panels show hours worked by the male spouse as a fraction of total household hours, the top-left for age 25–45 and the top-right for age 50–65. The bottom panels show the consumption shares of the male spouse, the bottom-left for non-retired and the bottom-right for retired families.

Transfers. In table 2.8, we ask whether within family transfers of income change in response to the tax reform. The statistic in table 2.8 reports transfers from one spouse to the other spouse as a fraction of total family consumption. We define the transfer as the gap between individual consumption and individual resources assuming that each agent owns half of the wealth stock and finances half of the asset accumulation of the family. As the table shows mean transfers are large (more than 10% of household consumption) and have a discernible life-cycle pattern; they are higher for young families, and as the household ages they decrease. Not surprisingly, more commitment means more transfers. Average transfers are 12.9% in the old steady state in the limited commitment model and 14.5% in the full commitment model.

The table shows that when we change the tax code, intrahousehold transfers of income fall. The main reason for this is that in the new steady state families are wealthier and they finance consumption more out of wealth rather than labor income. As wealth is an

Table 2.8: Transfers

	Limited	**Medium**	**Full**	**Limited**	**Medium**	**Full**
	Initial Steady State			Final Steady State		
Total	12.9%	13.3 %	14.5%	12.5 %	12.9%	13.9%
25-45	15.1%	15.5 %	17.0%	15.1 %	15.5%	17.0%
50-65	12.0%	12.4 %	13.1%	10.6%	10.9%	11.4%
Retired	6.2%	6.7 %	7.4%	6.1 %	6.6%	7.2%

	Limited	**Medium**	**Full**
	Transition, first period		
Total	12.2%	12.6 %	13.7%
25-45	14.5%	15.1 %	16.8%
50-65	10.4%	10.7 %	11.2%
Retired	6.2%	6.7 %	7.4%

equally divided resource in the family, the wife that is the recipient of the of bulk transfers, finances more of her consumption out of her own resources. Indeed we find that transfers fall precisely for those families that have more wealth (middle aged households). This effect is present even in the first period of the transition since households experience a capital gain on savings, because of lower capital taxation, and, therefore, become wealthier.

The change in the labor supply behavior of families that we described in the previous section has exactly the opposite effect on transfers. The spouse that supplies zero hours is effectively off her labor supply curve. She gets more consumption than what the labor market condition would prescribe; since consumption is higher and earned income is zero, the difference must be filled with higher transfers. We find that for households that have one of their members at the corner, transfers are larger.

To illustrate these points, we give a simple derivation of a household that makes its optimal choice in one period. Letting A_c be total financial income of the household and Y be the total after-tax labor income, we can derive male transfers as:

$$T_m = \frac{s_m(Y)Y + A_c/2}{Y + A_c} - \frac{c_m}{Y + A_c} = \frac{(s_m(Y) - \frac{1}{2})Y}{A_c + Y} + \frac{1}{2} - \frac{1}{1 + \phi(\lambda, l_g)} \tag{2.23}$$

where $s_m(Y)$ is the male spouse's share the total labor income of the household. Moreover, $\phi(\lambda, l_g) = (\frac{\lambda}{1-\lambda})^{1/(\eta(1-\gamma)-1))}(\frac{l_m}{l_f})^{(1-\eta)(1-\gamma)/(\eta(1-\gamma)-1))}$ gives the sharing rule given the optimal choice of hours. Notice that we do not express the sharing rule as a function of productivities, because we want to demonstrate how transfers will respond to corner solutions (at corners it is impossible to get closed form solutions).

According to equation 2.23 transfers change when labor or capital income changes, but also the share s_m and the sharing rule ϕ exert an influence. For households where both the husband and the wife work, after the reform we can assume that s_m is roughly constant. Furthermore if we concentrate on the full commitment equilibrium it should be that ϕ is also constant.

More wealth decreases transfers if $s_m > \frac{1}{2}$, that is if the male spouse contributes more than half the household's labor income. This is the case for all households where transfers from male to female spouses are positive. Moreover note that under the new policy total household labor income falls and this fall contributes to a further decrease in transfers. But when the wife drops out of the labor market, the share s_m increases from below one to unity and the value of ϕ also changes. The first effect increases transfers; the second increases transfers insofar as the ratio $\frac{l_m}{l_f}$ is greater after the change in policy. This is because the female spouse is off her labor supply curve.

There is a final channel through which transfers change in the model; changes in the sharing rule. We explained earlier that, especially in the first period of the transition, household contracts are rebargained and that male spouses draw higher weights λ. To the extent that in these families transfers run from men to women, the new contract should prescribe lower transfers to the female spouse. We find that this effect is present, though relevant mostly for younger cohorts in the limited commitment model.

Consumption Inequality. In order to better understand inequality of consumption within the household in figure 2.5 we plot the following statistic in the initial and the final steady states:

$$\left| \frac{c_{m,i}}{c_{m,i} + c_{f,i}} - \frac{c_{f,i}}{c_{m,i} + c_{f,i}} \right| \tag{2.24}$$

In words 2.24, represents the absolute difference in the consumption share of the male and the female spouse. If different from zero it implies that the two spouses command a different share of household resources and, therefore, there is consumption inequality in the family. The figure shows the limited commitment model (top) and the full commitment model (bottom) in the final steady state and in the initial period, where the policy change occurs. Observations that lie below the 45 degree line mean less inequality within the household in the final steady state. Because we divide by aggregate household consumption, 2.24 is independent of wealth and precautionary savings, and hence it is useful to compare in the two environments.[16]

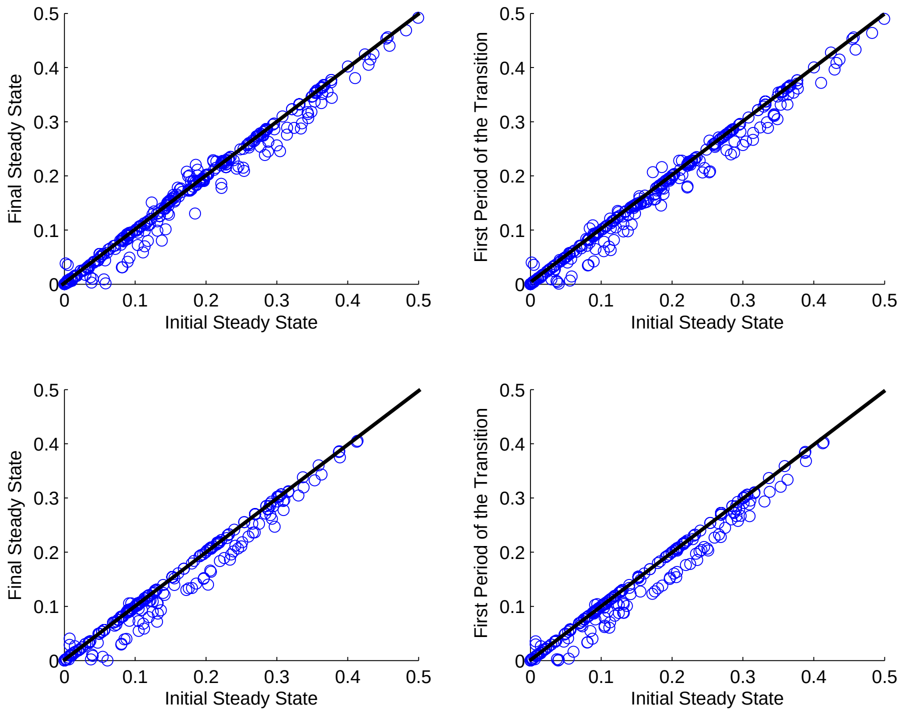

Figure 2.5: Absolute differences in consumption shares

Notes: The figure shows the absolute difference in consumption shares in the limited commitment model (top) and the full commitment model (bottom). The plots on the left show this in the final steady state against the initial steady state, and the ones on the right the first transition period against the initial steady state.

There is a drop in the absolute differences in consumption shares within the household

[16]We explain some of the properties of 2.24. For retired individuals where $l_m = l_f = 1$ applies we can write:

$$\left|\frac{c_{m,i}}{c_{m,i}+c_{f,i}} - \frac{c_{f,i}}{c_{m,i}+c_{f,i}}\right| = \left|(\left(\frac{\lambda_i}{1-\lambda_i}\right)^{IES} - 1)\frac{1}{(\frac{\lambda_i}{1-\lambda_i})^{IES}+1}\right| \tag{2.25}$$

where IES is the intertemporal elasticity of substitution $(1-\eta(1-\gamma))^{-1}$. The second is for non retired couples:

$$\left|\frac{c_{m,i}}{c_{m,i}+c_{f,i}} - \frac{c_{f,i}}{c_{m,i}+c_{f,i}}\right| = \left|(1-\psi_i\frac{\lambda_i}{1-\lambda_i})^{1/\gamma})\frac{1}{(\psi_i\frac{\lambda_i}{1-\lambda_i})^{1/\gamma}+1}\right| \tag{2.26}$$

We can show that 2.25 is a convex function that is centered around 1/2 and that 2.26 is also convex but centered around $\frac{1}{1+\psi_i}$. ψ_i is the following function of the ratio of male to female wages $\psi_i = (\frac{\epsilon_m}{\epsilon_f})^{-(1-\eta)(1-\gamma)/\gamma}$ for household i.

under the new regime in all the models. It is less in the limited commitment model because, as noted above, higher labor taxes make it more tempting to renege on the household contract, especially in young households. Since men have typically a higher consumption share than women, rebargaining increases inequality. But this increase is not enough to balance a second channel that decreases inequality within the household.

We said earlier that in households where one spouse drops out of the labor market, that spouse must be compensated with higher consumption. Effectively, the constraint $l_g \leq 1$ forces that individual to take less leisure than she would if she were on her labor supply curve. Under nonseparable utility, there must be a rise in her consumption share and, consequently, a drop in the difference with the family's main earner.[17]

To give an idea of the magnitude of the drop in intrahousehold consumption inequality, we compute the cross-sectional average of 2.24. In the old steady state the average is 3.52% in the limited commitment model, and 2.9% in the full commitment model. In the new steady state it drops to 3.41% (by 3.1%) in the limited, and to 2.8% (by 3.5%) in the full commitment model. In the first period of the transition, there is a drop of only 2.23% in the limited commitment model relative to the original steady state. Clearly, the difference is due to rebargaining. When we used the mean standard deviation of consumption instead of 2.24 as a measure of inequality we obtained very similar implications.

Finally, note that inequality between married households in the model is three times as large as intrahousehold inequality (0.033 vs. 0.1 in terms of standard deviation). When the change in policy takes place, however, we find that the two statistics move in opposite directions. Inequality between households increases by nearly 10%, whereas the mean standard deviation within the household falls by nearly 5%. The reason is that in the new steady state a larger fraction of consumption for households and individuals is financed by wealth. Since wealth is more unequally distributed than labor income across households, this increases interhousehold inequality. Of course the converse holds within the couple; wealth is a common resource in the family.

[17] In terms of the one period model, we can show that the male spouse's consumption is given by $\frac{1}{1+\phi(l_m,l_f,\lambda)}(A_c + Y)$ where A_c is financial income, Y is total after-tax labor income of the family and $\phi(l_m, l_f, \lambda) = (\frac{\lambda}{1-\lambda})^{(1/(\eta(1-\gamma)-1)))}(\frac{l_m}{l_f})^{((1-\eta)(1-\gamma)/(\eta(1-\gamma)-1)))}$. The argument above is that $\phi(l_m^*, 1, \lambda) > \phi(l_m^*, l_f^*, \lambda)$ under the new policy, where l_g^* is the optimal labor supply given by the standard labor market condition. We claim, in the text, that females, who would like to take more leisure, but hit the bound of one, have to increase their consumption. This reduces consumption inequality in all models.

Are both spouses better off? In the previous section, we presented a welfare assessment of the change in the tax code. We gave detailed results on the welfare effects by gender and marital status and looked at the fraction of individuals that benefited from the new policy. We showed that for married men and women there were some differences in the welfare evaluation. In that section, we saw that a change in policy gives rise to considerable rebargaining of the household contract when commitment is limited. It also implies that transfers from male to female spouses drop considerably right after the change in policy, since for several households, the labor supply of one of the spouses is at a corner.

It is not difficult to imagine that for certain families the change in policy benefits one of the spouses but not the other. This does occur in our simulations. We find this in the limited commitment model in 3.7% of married couples, in the full commitment model in 2.1%, and in the medium commitment in 2.6%. These families are mostly in the working years, but older than age 35 (for very young households both spouses are worse off under the new policy). Moreover, it is mostly married men that are made better off, and wives are made worse off.

To understand this result, note that there are two forces that determine the division of the welfare gains in the model. First, there is the rebargaining of the marital contract that was highlighted earlier, and second there is the change in the labor supply behavior that makes one of the spouses drop out of the labor market. Under limited commitment the changes in the weight λ favor men, and therefore married men tend to be made better off and married women worse off. Under full commitment, where bargaining never occurs after the matching stage, the differences in welfare are driven exclusively by the restrictions to labor supply. Since household secondary earners would like to take more leisure (but this is not feasible), their welfare may fall even though the family as a whole may be made better off. Young households obviously discount the possibility that one of the two spouses will be at a corner in the future.

2.6 Conclusion

In this paper, we study the welfare effects of a reform that eliminates capital taxation, in a model with gender and marital status heterogeneity, uncertain labor income and incomplete financial markets. Calibrated to the US data, our model suggests that males and females, couples and singles, formulate their decisions in very different economic environments, and hence respond differently to changes in the tax code. In couple households, given an empirically plausible covariance structure of wages, spouses can provide insurance to one another against labor productivity shocks. We show that this means that the distortive effect of capital taxes on wealth accumulation is larger for these households and hence for the economy overall.

In our model, decision making within the couple is represented as a contract under limited commitment. When the labor income of one spouse increases, the household must allocate more weight to her well-being. The household gives up some risk sharing to satisfy a participation constraint. We investigate how the tax code affects the intrahousehold allocation and especially the risk sharing possibilities of the couple. We show that lower capital taxes, which lead to wealth accumulation, mean more insurance within the family, but that higher labor taxes, though they make the distribution of disposable income less dispersed, increase the temptation to renege on past commitments. In our quantitative model, we find that when the policy changes many households respond by revising the intrahousehold allocation.

We view this paper as a first step towards a larger research project aiming to incorporate, in a unified framework, a realistic demographic structure and a realistic formulation of intrahousehold decision making. We believe that to this end, there is a number of important extensions that need to be made to the model in order for it to represent a theory of optimal household behavior and thus to be useful as a benchmark for policy evaluation. The first set of extensions is to add those features to the model that improve matching the wealth distribution by gender and marital status. On top of this list is the incentive of individuals to leave bequests to their descendants, but also modeling carefully marriage and divorce decisions that give rise to selection effects as in the data. A second set is to extend this model to consider nonlinear taxation. A very important implication of risk sharing within the family is that it can limit the scope of insurance provided through the tax system. For example, progressive taxation will promote equity between households by taxing at higher marginal rates wealthier families, but little is known about its effects on inequality within the household. We are convinced that the model proposed in this paper can be used to study these questions jointly.

Appendix to Chapter 2

2.A Participation

In the data, many women (especially married) do not participating in the labor market at all. In our model, we assume that the choice of hours is made at the intensive margin, though do get corner solutions, and, therefore, non-participation.

We address here whether not having an explicit participation is a serious omission. It turns out not to be, because the model has a five yearly horizon In table 2.9, we show the labor market participation, for men and women, single or married, as we calculated it from the PSID data. We compute the fraction of people that have worked at least one hour in a window of s years, ending in 2007 and starting in $2007 - (s - 1)$.

Table 2.9: Cumulative labor market participation up to 2007

	s=1	**s=3**	**s=5**	**s=7**	**s=9**	**s=11**	**s=12**
Men							
Single	85.44%	89.51%	92.78%	94.64%	95.93%	96.03%	96.37%
Married	93.20%	96.04%	97.08%	97.84%	98.79%	98.90%	98.96%
Total	91.26%	94.40%	96.00%	97.04%	98.07%	98.18%	98.31%
Women							
Single	82.89%	87.27%	89.29%	91.99%	93.16%	93.53%	93.89%
Married	79.26%	85.42%	89.34%	92.05%	93.55%	94.94%	95.17%
Total	80.40%	86.00%	89.33%	92.03%	93.43%	94.50%	94.76%

The table shows that the fraction of men and women that have worked in the 5-year period 2002–2007 (the corresponding value of s equals 5). For married women, this is about 10 percentage points higher than in annual data ($s = 1$). So the participation decision is less of an issue on a horizon of five years, as in our model.

In figure 2.6, we compare the model's prediction of labor market participation to the data. Notice that the model can generate non-participation among the female population but most non-participation is concentrated towards retirement.

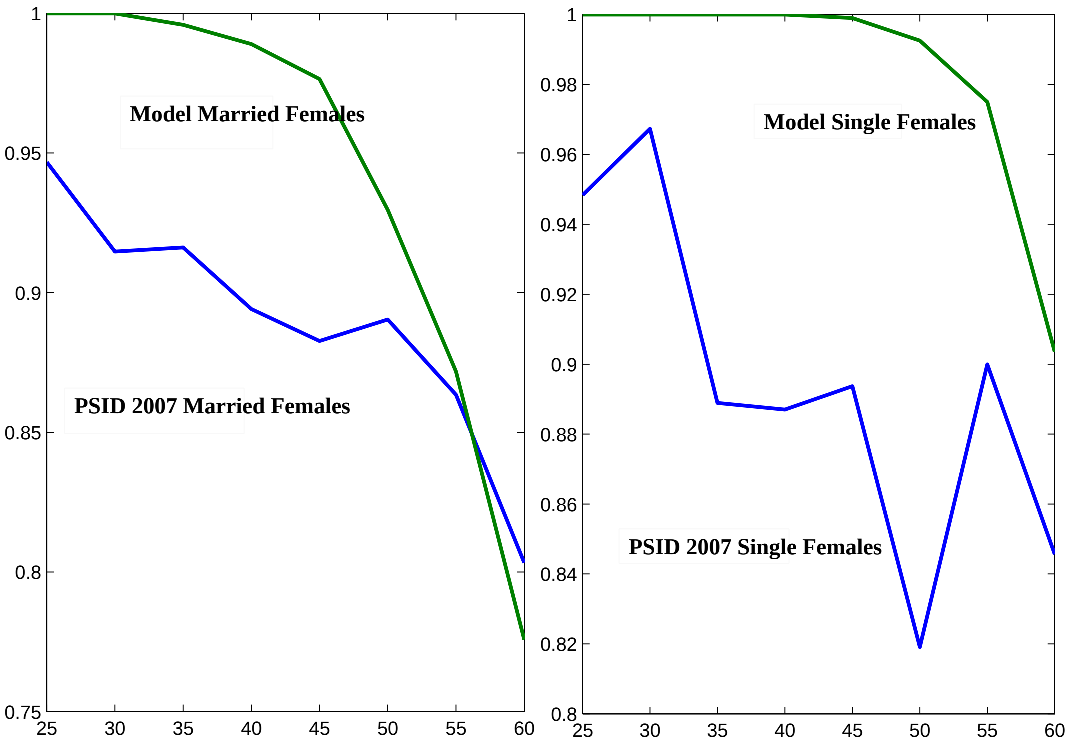

Figure 2.6: Models and data: participation of women in employment

2.B Derivations in the Two Period Model

In this section, we derive explicitly the formulas from the two period model of section 2.3 that were omitted from the text. We assume that household members value the consumption-leisure bundle according to a utility function of the form $\frac{(c_g^{\eta} l_g^{1-\eta})^{1-\gamma}}{1-\gamma}$. The optimal consumption and leisure choices in period 2 satisfy:

$$\lambda_2 \eta c_m^{\eta(1-\gamma)-1} l_m^{(1-\eta)(1-\gamma)} = (1-\lambda_2)\eta c_f^{\eta(1-\gamma)-1} l_f^{(1-\eta)(1-\gamma)} \quad \text{And} \quad \frac{(1-\eta)c_g}{\eta l_g} = w(1-\tau_N)\epsilon_g$$

Assuming an interior solution, we can substitute the intraperiod consumption-leisure optimality condition into the consumption first-order condition and obtain:

$$\lambda_2 \frac{c_m^{-\gamma}}{(w(1-\tau_N)\epsilon_m)^{(1-\eta)(1-\gamma)}} = (1-\lambda_2)\frac{c_f^{-\gamma}}{(w(1-\tau_N)\epsilon_f)^{(1-\eta)(1-\gamma)}}$$

which gives that female consumption is $f(\lambda_2,\epsilon) = (\frac{\lambda_2}{1-\lambda_2}(\frac{\epsilon_f}{\epsilon_m})^{(1-\eta)(1-\gamma)})^{-1/\gamma}$ times male consumption in the model. Solving for the optimal choices, we can write male and female utility as:

$$\left(\frac{A_c + \sum_g w(1-\tau_N)\epsilon_g}{(1+f(\lambda_2,\epsilon))(w(1-\tau_N)\epsilon_m))^{1-\eta}}\right)^{1-\gamma} \frac{\chi}{1-\gamma} + \xi \geq \left(\frac{\frac{A_c}{2} + w(1-\tau_N)\epsilon_m}{(w(1-\tau_N)\epsilon_m)^{1-\eta}}\right)^{1-\gamma} \frac{\chi}{1-\gamma}$$

$$\left(\frac{f(\lambda_2,\epsilon)}{(1+f(\lambda_2,\epsilon))} \frac{A_c + \sum_g w(1-\tau_N)\epsilon_g}{(w(1-\tau_N)\epsilon_f)^{1-\eta}}\right)^{1-\gamma} \frac{\chi}{1-\gamma} + \xi \geq \left(\frac{\frac{A_c}{2} + w(1-\tau_N)\epsilon_f}{(w(1-\tau_N)\epsilon_f)^{1-\eta}}\right)^{1-\gamma} \frac{\chi}{1-\gamma}$$

where $\chi = (\eta^\eta(1-\eta)^{1-\eta})^{1-\gamma}$.

Rearranging, we can express the sharing rule with the following nonlinear equations:

$$(\frac{1}{(1+f(\lambda_2,\epsilon))})^{1-\gamma} \leq \tilde{\xi}\,(\frac{(w(1-\tau_N)\epsilon_m)^{(1-\eta)}}{A_c + \sum_g w(1-\tau_N)\epsilon_g})^{1-\gamma} + (\frac{\frac{A_c}{2} + w(1-\tau_N)\epsilon_m}{A_c + \sum_g w(1-\tau_N)\epsilon_g})^{1-\gamma} \quad (2.27)$$

$$(\frac{f(\lambda_2,\epsilon)}{(1+f(\lambda_2,\epsilon))})^{1-\gamma} \leq \tilde{\xi}\,(\frac{(w(1-\tau_N)\epsilon_f)^{(1-\eta)}}{A_c + \sum_g w(1-\tau_N)\epsilon_g})^{1-\gamma} + (\frac{\frac{A_c}{2} + w(1-\tau_N)\epsilon_f}{A_c + \sum_g w(1-\tau_N)\epsilon_g})^{1-\gamma} \quad (2.28)$$

where $\tilde{\xi} = -\frac{\xi(1-\gamma)}{(\eta^\eta(1-\eta)^{1-\eta})^{1-\gamma}} > 0$.

The effect of changes in labor taxes. Equations 2.27 and 2.28 define the upper and the lower bound that the weight λ_2 needs to respect in order for the participation constraints to be satisfied. The partial derivatives of the right hand side of equation 2.27 with respect to $(1-\tau_N)$ are:

$$(1-\gamma)\left[(\tilde{\xi}\,(\frac{A_c\,(1-\eta)}{1-\tau_N} - \eta \sum_g \; w\;\epsilon_g)\;\kappa_1(A_c,\epsilon) + (A_c\;w\;(\epsilon_m - \frac{\sum_g \epsilon_g}{2}))\kappa_2(A_c,\epsilon))\right] \quad (2.29)$$

where $\kappa_1 = \frac{(w(1-\tau_N)\epsilon_g)^{(1-\eta)(1-\gamma)}}{(A_c+\sum_g w(1-\tau_N)\epsilon_m)^{2-\gamma}} > 0$, $\kappa_2 = \frac{(\frac{A_c}{2}+w(1-\tau_w)\epsilon_m)^{-\gamma}}{(A_c+\sum_g w(1-\tau_w)\epsilon_g)^{2-\gamma}} > 0$. The derivative of equation 2.28 is similar and for the sake of brevity omitted. As discussed in text, 2.29 illustrates that the effect of changes in labor taxation on the household sharing rule depends on the level of wealth of the household A_c. If $A_c = 0$, it reduces to:

$$-(1-\gamma)\left[\tilde{\xi}\eta\sum_g \; w\;\epsilon_g\right]\;\kappa_1(A_c,\epsilon) > 0 \tag{2.30}$$

As the LHS of 2.27 is decreasing in λ_2, a positive partial derivative means that λ_2 has to increase by less to satisfy the participation constraint of the male spouse. Therefore, in the case of $\epsilon_m >> \epsilon_f$ where the lower bound applies, the disturbance to the household sharing rule is smaller. The converse may obtain if $A_c > 0$. As in the case of log separable utility, an overall negative derivative 2.29 yields that lowering labor taxes makes it more difficult for household members to commit to an allocation.

The effect of changes in capital taxes. We derive the partial derivative of equation 2.27 with respect to financial income as:

$$(\gamma-1)\left[\tilde{\xi}\,(\frac{(w(1-\tau_N)\epsilon_m)^{(1-\eta)}}{A_c+\sum_g w(1-\tau_N)\epsilon_g)^{2-\gamma}}+(\frac{(\frac{A_c}{2}+w(1-\tau_N)\epsilon_m)^{-\gamma}}{(A_c+\sum_g w(1-\tau_N)\epsilon_g)^{2-\gamma})}(\epsilon_m-\frac{\sum_g \epsilon_g}{2})\right] \tag{2.31}$$

The leading term in 2.31 is always positive, meaning that an increase of financial income relaxes the constraint. The second term is positive only when $\epsilon_m > \epsilon_f$. Since equation 2.27 defines the lower bound on λ_2, it binds only when male productivity exceeds female productivity. Therefore, higher financial wealth or lower capital taxation enhance the households commitment. This proves proposition 3 in the main text.

2.C Competitive Equilibrium

In this section we briefly define the time invariant competitive equilibrium Given a level of expenditure G in the steady state, the tax schedule $\{\tau_K, \tau_W, \tau_C, \tau_{SS}\}$, social security policy and unintended bequests, the competitive equilibrium is a set of value functions $\{S_g, M, V_g\}$, household decision rules for consumption, savings and leisure, and measures of households over the state vector of assets, productivity, age, gender, marital status and the sharing rule λ such that:

1. Given prices, S_m, S_f and M solve the functional equations and optimal policies derive. In particular, optimal policies are functions $c_{S,g}(a, X, j)$, $a'_{S,g}(a, X, j)$, $n_{S,g}(a, X, j)$ for consumption, assets and hours for singles and analogously $c_{M,g}(a, X, \lambda, j)$, $a'_M(a, X, \lambda, j)$, $n_{M,g}(a, X, \lambda, j)$ for couples.

2. Prices w and r satisfy:

$$w = (1-\alpha)K^{\alpha}N^{-\alpha} \qquad r = \alpha K^{\alpha-1}N^{1-\alpha} - \delta$$

where N is the aggregate labor input in units of effective labor.

3. The social security policy satisfies:

$$\begin{aligned} wN\tau_{SS} &= (\sum_g \frac{1-\mu}{2} \int SS_g(\alpha, j)\Gamma_{S,g}(da \times dX \times \{j_R, \ldots, J\}) \\ &+ \mu \int SS_g(\alpha, j)\Gamma_M(da \times dX \times d\lambda \times \{j_R, \ldots, J\})) \end{aligned}$$

where $\Gamma_{S,g}$ is the measure of bachelors over relevant states and Γ_M is the analogous object for married couples.

4. Accidental bequests satisfy:

$$\begin{aligned} B &= \frac{1}{\Phi^o}(\sum_g \frac{1-\mu}{2} \int a'_{S,g}(a, X, j)(1-\psi_j)\Gamma_{S,g}(da \times dX \times \{1, \ldots, j_R - 1\}) \\ &+ \mu \int a'_M(a, X, \lambda, j)(1-\psi_j)\Gamma_M(da \times dX \times d\lambda \times \{1, \ldots, j_R - 1\}) \end{aligned}$$

5. The government budget constraint is balanced:

$$
\begin{aligned}
G &= w\tau_N(\sum_g \frac{1-\mu}{2}\int n_{S,g}(a,X,j)L_g(j)\epsilon_g\alpha_g\Gamma_{S,g}(da\times dX\times\{1,\ldots,j_R-1\}) \\
&+\sum_g \mu\int n_{M,g}(a,X,\lambda,j)\alpha_g\epsilon_g L_g(j)\Gamma_M(da\times dX\times d\lambda\times\{1,\ldots,j_R-1\})) \\
&+\tau_C(\sum_g \frac{1-\mu}{2}\int c_{S,g}(a,X,j)\Gamma_{S,g}(da\times dX\times dj) \\
&+\sum_g \mu\int c_{M,g}(a,X,\lambda,j)\Gamma_M(da\times dX\times d\lambda\times dj)) \\
&+\tau_K(\sum_g \frac{1-\mu}{2}\int(ra+B)\Gamma_{S,g}(da\times dX\times dj+\mu\int(ra+2B)\Gamma_M(da\times dX\times d\lambda\times dj)
\end{aligned}
$$

6. Market Clearing:

$$
K=\sum_g\int\frac{1-\mu}{2}a\Gamma_{S,g}(da\times dX\times dj)\;+\;\mu\int a\Gamma_M(da\times dX\times d\lambda\times dj)
$$

$$
\begin{aligned}
N &= \sum_g \frac{1-\mu}{2}\int n_{S,g}(a,X,j)L_g(j)\epsilon_g\alpha_g\Gamma_{S,g}(da\times dX\times\{1,\ldots,j_R-1\}) \\
&+\sum_g \mu\int n_{M,g}(a,X,\lambda,j)\alpha_g\epsilon_g L_g(j)\Gamma_M(da\times dX\times d\lambda\times\{1,\ldots,j_R-1\})
\end{aligned}
$$

7. The measures $\Gamma_{S,g}$ and Γ_M are consistent. In particular, for all subsets $\mathcal{A},\mathcal{X},\Lambda,\mathcal{J}$ of the state space such that $1\notin\mathcal{J}$

$$
\Gamma_{S,g}(\mathcal{A},\mathcal{X},\mathcal{J})=\psi_j\int_{X'\in\mathcal{X},\;a'_{S,g}\in\mathcal{A},\;j+1\in\mathcal{J}}\Gamma_{S,g}(da\times dX\times dj)
$$

$$
\Gamma_{M,g}(\mathcal{A},\mathcal{X},\Lambda,\mathcal{J})=\psi_j\int_{X'\in\mathcal{X},\;a'_{M,g}\in\mathcal{A},\;\lambda'\in\Lambda,\;j+1\in\mathcal{J}}\Gamma_{M,g}(da\times dX\times d\lambda\times dj)
$$

2.D Stationary Distributions of the Calibrated Models

In table 2.10, we show the Gini coefficients from the stationary distributions of wealth and earnings in the initial steady state. The benchmark models as well as the 'Singles Only' economies produce similar levels of wealth and earnings concentration (coefficients roughly .54 to .55 and .36 to .38, respectively). In the US data, the analogous statistics are .743 and .449, respectively. It is not surprising that the model produces distributions that feature less concentration than the data. This is a property of models of heterogeneous agents and wealth accumulation (for a summary of the literature see Castañeda, Díaz-Gimínez, and Ríos-Rull (2003)).

Table 2.10: Wealth and earnings distribution in the initial steady state

Quintile	Limited	Full	Single Men	Single Men & Women	Fraction Couples PSID 2007
			Wealth Distribution		
1	0.44	0.43			0.2597
2	0.39	0.40			0.4044
3	0.52	0.52			0.6173
4	0.64	0.64			0.7097
5	0.79	0.79			0.7945
Gini	0.551	0.552	0.539	0.541	0.7438
			Earnings Distribution		
1	0.20	0.20			0.2190
2	0.34	0.34			0.3246
3	0.62	0.61			0.5624
4	0.71	0.72			0.7659
5	0.90	0.90			0.9088
Gini	0.381	0.382	0.345	0.3512	0.4498

The table provides additional information. It shows for each quintile of the wealth and earnings distributions the number of couples households as a percentage of the total number of households in that bracket. Not surprisingly a couples household with two earners accumulates more wealth and has nearly twice as much labor income than a typical single earner household. This brings couples to the top of the wealth and earnings distributions. According to table 2.10, the model does a remarkable job in matching the earnings quintiles, and very good job in matching the wealth quintiles (although it predicts a larger fraction of couples in the first quintile than the data).

Chapter 3

Industrial Policies and Growth[1]

3.1 Introduction

A persistent puzzle in the study of cross-country differences in economic performance since World War II is the dramatic reshuffling in relative positions between East Asian and Latin American countries. This reshuffling is most vividly illustrated by the comparison in Figure 3.1 between Argentina and South Korea. Panel A shows the absolute level of GDP per worker, in constant 1996 dollars in the two countries. South Korea started out in the mid-1950s with productivity about a quarter of the productivity of Argentina, and ended up a half-century later about a third more productive. In panel B the same series are normalized to 1 at the beginning of the sample to more sharply illustrate the difference in performance.

Argentina and South Korea are just illustrative examples: similar, though somewhat less dramatic, comparisons could be made for the other large Latin American economies, such as Brazil, Mexico, and Venezuela, on one hand, and others high performers in East Asia, particularly Taiwan, on the other. One exception is Chile, which performs very well, and on which we return below.[2]

[1]This chapter draws on work that was carried out jointly by Francesco Caselli, John Coleman, and me. The work was motivated by Francesco Caselli's and John Coleman's idea to assess the role of policies in the reshuffling in relative positions between East Asian and Latin American countries. I have carried out most of the analytical and numerical analyses and written around 90% of the text; general decisions about the direction of the paper were made equally between the three authors.

[2]While over 1960–2010 Chile performed best amongst the Latin American economies and saw an improvement in real GDP per worker by 140%, it did by far not grow as rapidly as the East Asian economies.

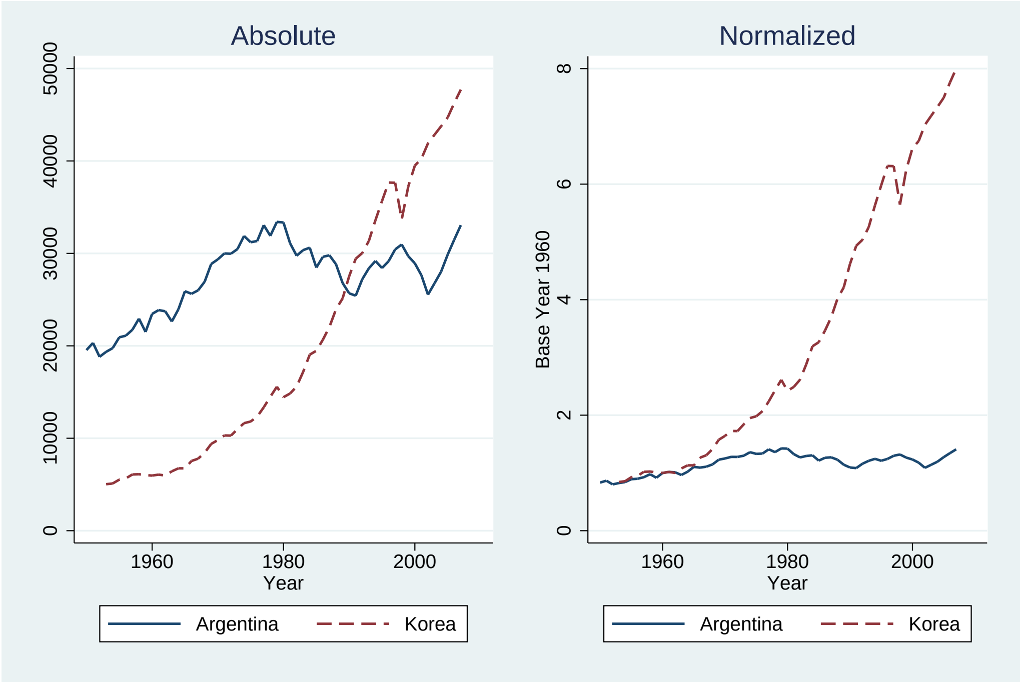

Figure 3.1: GDP per worker in constant 1996 dollars

Notes: Source: Penn World Table 6.1

The reason why the comparison between Latin American and East Asian countries over the post-war period is interesting and puzzling is that countries in this set shared broadly similar economic institutions. In particular, they were market economies with a high degree of government intervention and guidance, particularly in the sphere of international trade, where all countries pursued various forms of import-subsitution and export promotion strategies. Indeed in the unending dispute over the costs and benefits of industrial policy, supporters of government intervention typically point to the 'success' of East Asia, while its detractors tend to cite the disappointing performance of Latin American countries. Why policies with a similar underlying philosophy seemingly worked well in one place but failed in the other has not satisfactorily been resolved.

In this paper we study the dynamic response of a two-sector, manufacturing and agriculture, economy to the introduction of import tariffs on manufacturing goods similar to those that characterized government policy in many low- and middle-income market economies in the first several decades of the post-war period. We show that this response depends on the level of productivity in the agricultural sector. If the agricultural sector is very productive, the domestic market for manufacturing goods is large. Hence, manufacturing firms choose to take advantage of the tariff barriers to operate as domestic monopolies. Because of this the manufacturing sector remains relatively small, and accumulation and growth are subdued. On the other hand if agricultural productivity is low, domestic manufacturers face too little domestic demand, and choose instead to compete on international markets. Since in these markets they are price takers, they have no strategic incentive to contain their scale of operations. This leads to fast accumulation and growth. This mechanism can explain the contrasting experience of Latin America and East Asia as countries in the former generally had much higher agricultural productivity. It can also explain within-Latin America differences as Chile had much lower agricultural productivity.

The key assumption in generating this pattern is that firms cannot (systematically) price discriminate between domestic and foreign markets. In particular, they cannot charge the monopoly price at home and then also sell on the international market at the (much lower) world price. We believe this assumption to be plausible, as such practices invariably appear to lead to accusations of dumping and to retaliatory measures by trading partners.

We quantify the relevance of our mechanism by calibrating our model to the experiences of Argentina and South Korea. Besides tariffs, we also add export subsidies, since these tended to be a prominent feature of industrial policy in both countries (e.g. Amsden (2001)). Nevertheless, we find that the key policy to understand differences in performance is the tariff protection of manufacturing. In particular, in counterfactual simulations we find that in the long-run Korean firms would have started supplying the world market, even if there had been no policy measures taken.

Our paper is related and contributes to various strands of the literature on structural transformation and trade. Matsuyama (1992) analyzes the role of agricultural productivity in an endogenous growth model and predicts for a small open economy a positive link onto economic growth. Our work differs in the assumptions made. While Matsuyama's mechanism for growth is a learning-by-doing externality in manufacturing, we do not impose such spillovers. In our setup, the size and the growth rate of the manufacturing sector depends on the dynamics of skilled labor, as in Caselli and Coleman (2001). Industrial policies and agricultural productivity will affect workers' decisions on skill acquisition. In a closed economy framework Gollin, Parente, and Rogerson (2002) show that countries with relative low productivities in agriculture allocate a relative large fractions of resources into food production. Their result relies on the closed economy assumption which implies that a subsistence level in food consumption must be satisfied by domestic production. In our setup monopolistic producers in manufacturing decide whether to export or not. In situations with no international trade the Gollin, Parente, and Rogerson (2002) result will survive, but when there is international trade production factors will be allocated according to comparative advantage.

3.2 The Model

We consider a small open economy with two sectors, farm (F) and manufacturing (M), employing unskilled (U) and skilled (S) labor respectively. As in Caselli and Coleman (2001), labor incurs an idiosyncratic cost in transitioning from U to S. In terms of time, this cost is $\phi\xi^i$, where ξ^i is distributed among members of a generation with density $\mu(\xi^i)$ and ϕ a constant related to overall efficiency of education. Each worker is endowed with one unit of time, which he can devote to working and/or acquiring skills. Member i of each newly born generation faces the following choice at (and only at) the beginning of life. Either he can immediately join the farm sector, to which he then supplies one unit of labor for each of the periods in which he remains alive. Or he can devote the first ξ^i time units of his life to acquiring skills and supply one unit of labor to the manufacturing sector for each of the remaining periods he stays alive. We assume that $\phi\xi^i$ is distributed among members of each generation with time-invariant density function $\mu(\xi^i)$. Hence, ξ^i measures the amount of time it takes for person i to acquire the skills to become a non-farm worker, relative to other members of the same generation. For simplicity, we assume $\phi\xi^i < 1$ for every i, such that education never 'spills over' into periods of life subsequent to the first. For any person alive at time t, the probability of dying in period $t+1$ is the constant $1-\lambda$. In each period, a generation of size $(1-\lambda)L$ is born. Then at time t the size of the generation born at $t-j$ is $(1-\lambda)\lambda^j$. Note that this assures that the size of the total population is L in every period. Within a dynasty, there is intergenerational altruism and perfect intergenerational correlation of types. There is no aggregate uncertainty.

Assuming Stone-Geary preferences, the consumption basket is given by

$$C_t = \frac{(C_{F,t} - \gamma)^\theta C_{M,t}^{1-\theta}}{\theta^\theta (1-\theta)^{1-\theta}} \tag{3.1}$$

where γ is the subsistence level of farm good consumptions. These preferences feature for $\gamma > 0$ an income elasticity for F goods smaller than one. As in Caselli and Coleman (2001), we assume perfect intergenerational correlation of types within a dynasty and intergenerational altruism and that at each point in time a dynasty has exactly one member; once that person dies another person is born into that dynasty. The model therefore admits a representative consumer, who maximizes $U = \sum_{t=0}^{\infty} \beta^t u(C_t)$, where β is the discount factor.

The manufactured good has differentiated varieties, which are aggregated with a CES technology according to

$$C_{M,t} = \left[\int_0^1 c_{M,t}(i)^{\frac{\varepsilon-1}{\varepsilon}} di \right]^{\frac{\varepsilon}{\varepsilon-1}} \quad \text{with } \varepsilon > 1$$

where the elasticity of substitution between varieties of the manufactured goods is ε and assumed to be greater than one.

In manufacturing, production of variety i is subject to decreasing returns according to

$$y_M(i) = A_M \cdot (l_S(i))^\alpha \;\text{ for } i \in [0,1], \text{ with } 0 < \alpha < 1 \tag{3.2}$$

where A_M is the manufacturing sector's productivity and $l_S(i)$ is skilled labor employed by manufactures producer i.[3] Production in the non-manufacturing sector is subject to constant returns to scale and given by

$$Y_F = A_F \cdot L_U \tag{3.3}$$

where A_F is the F sector's productivity, and L_U unskilled labor employed.

All goods are tradeable on the international market and are used for consumption only. The agricultural sector is perfectly competitive and non-protected or subsidized. We use

[3]Decreasing returns ensure that in the open economy a producer, at given prices and wages, demands a finite number of skilled workers.

the F good as the numeraire. In the manufacturing sector, however, industrial policies, such as import tariffs (τ) and export subsidies (s) apply, which we assume to be common to all varieties. Moreover, for all varieties of manufactured goods there exists a perfect substitute on the world market at price p^*.

The producer of variety of the manufactured good can choose between selling only to the domestic market, where he has some market power, or exporting and charging on both the domestic and the international market the world price. If there was no international trade, there would be monopolistic competition in manufacturing, and the producer of variety i would charge the monopolistic price $p^M(i)$. But in the small open economy, competition with imported goods imposes an upper bound a domestic firm can achieve on the domestic market. When supplying the domestic market only, manufacturing firm i will therefore charge

$$p(i) = \min\left\{p^M(i), (1+\tau)p^*(i)\right\} \tag{3.4}$$

Moreover, the firm the producer will choose to export and charge p^* on the domestic and the international market if that results in higher profits. For a sufficiently large domestic market the monopolist will choose to sell on the domestic market only, whereas for a sufficiently small domestic market the producer will choose to export. An export subsidy, though, will encourage a firm to export and charge p^*.

We will assume balanced trade to rule out counterfactual implications for net foreign assets, and impose therefore $nx_F + p^* nx_M = 0$. Finally we assume that the government balances its budget in every period through a lump-sum tax T to finance the outlay on industrial policies, the spending on export subsidies minus the collected tariff revenues. If tariff revenues exceed payments on subsidies, T is negative, representing a lump-sum payment to households.

As mentioned above, we assume that policies are common to all varieties in manufacturing. Since productivity is common to all producers, the unconstrained domestic equilibrium is the standard monopolistic competition symmetric equilibrium. Since we also assume symmetry on the world level by having a common world price for all varieties, we mainly focus on symmetric equilibria with $p(i) = p$, but due to a discontinuous jump in labor demand when switching from the domestic mode of production to exporting, there is also a situation with an asymmetric equilibrium, as discussed later.

3.3 Equilibrium

In any period t, the representative consumer choose consumption to maximizes utility subject to her per-period budget constraint

$$P_{t+1}B_{t+1} = E_t - P_t C_t + (1 + r_t)P_t B_t$$

where E_t denotes net income, P_t the price index of the consumption bundle C_t, and B_t real bond holdings at time t. The intertemporal optimality condition is the usual Euler equation

$$u'(C_t) = \beta(1 + r_{t+1})u'(C_{t+1}) \tag{3.5}$$

Within any period, the demand for the two consumption goods is the solution to the following expenditure minimization problem

$$\min_{C_{F,t},C_{M,t}} C_{F,t} + P_{M,t}C_{M,t} \text{ s.t. } \frac{(C_{F,t} - \gamma)^{\theta}(C_{M,t})^{1-\theta}}{\theta^{\theta}(1-\theta)^{1-\theta}} = C_t$$

which implies for relative consumption

$$C_{F,t} = \frac{\theta}{1-\theta}P_{M,t}C_{M,t} + \gamma \tag{3.6}$$

and for consumer demand for F and M goods

$$C_{F,t} = \theta P_{M,t}^{1-\theta}C_t + \gamma = \theta E_t + (1-\theta)\gamma \tag{3.7}$$

$$C_{M,t} = (1-\theta)\frac{C_t}{P_{M,r}^{\theta}} = (1-\theta)\frac{E_t - \gamma}{P_{M,t}} \tag{3.8}$$

where $P_{M,r}$ is the consumer price of the basket of manufactured goods (in units of F goods) and $E_t = P_t \cdot C_t$ denotes the household's consumption expenditure. The implied *consumption-based price index* is $P_t = P_{M,t}^{1-\theta} + \frac{\gamma}{C_t}$. Since the economy cannot borrow from abroad, and bonds are in zero net supply, clearing of the bond market requires

$B_{t+1} = B_t = 0$, and the amount the representative consumer spends on consumption is in equilibrium equal to net income

$$E_t = \frac{1}{L}\left[w_{U,t} \cdot L_{U,t} + w_{S,t} \cdot L_{S,t} + \Pi_{M,t} - T_t\right] \tag{3.9}$$

where $\Pi_{M,t} = \int_0^1 \pi_{M,t}(i)di$ are aggregate profits in manufacturing and T_t is the lump-sum tax levied to balance the government budget.

The minimization of expenditure on varieties $i \in [0,1]$ of the manufactured good with corresponding prices $p_t(i)$, gives the demand for differentiated variety $i \in [0,1]$ of the manufactured good and the price index for manufactured goods as

$$c_{M,t}(i) = \left(\frac{P_{M,t}}{p_t(i)}\right)^{\varepsilon} C_{M,t} \text{ for all } i \in [0,1] \tag{3.10}$$

$$P_{M,t} = \left[\int_0^1 p_t(i)^{1-\varepsilon}di\right]^{\frac{1}{1-\varepsilon}} \tag{3.11}$$

A newborn worker, who is subject to an exogenous survival probability $\lambda \in (0,1)$, invests in skills if the present value of wages as a skilled worker exceeds those of a unskilled worker plus the idiosyncratic cost of acquiring skills ξ^i. Define the following discount factor

$$Q_{s,t} := \prod_{k=t}^{s}\left(\frac{1}{1+r_k}\right) \text{ for } s > t \text{ and } Q_{t,t} = 1$$

where by (3.5) the equilibrium interest rate is $r_{t+1} = \frac{u'(C_t)}{\beta u'(C_{t+1})} - 1$. At time t expected present value of wages from skill type $j = U, S$, taking the death probability into account is

$$h_{j,t} = \sum_{s=t}^{\infty} Q_{s,t}\lambda^{s-t}w_{j,s} \text{ for } j = U, S$$

Income maximization subject to the time cost $\phi\xi^i$ implies that at time t individual i of the new-born generation acquires skill if $h_{S,t} - \phi\xi^i w_{S,t} \geq h_{U,t}$. This defines a cutoff value

$$\bar{\xi}_t = \frac{1}{\phi}\frac{h_{S,t} - h_{U,t}}{w_{S,t}}$$

such that all newborns with $\xi^i \leq \bar{\xi}_t$ choose to acquire skills, whereas all those with $\xi^i > \bar{\xi}_t$

choose to worker in non-manufacturing. Notice that $\bar{\xi}_t \geq 0$, since skilled labor can be employed as unskilled labor without cost, and therefore $w_S \geq w_U$. Moreover, profit maximization in non-manufacturing and clearing of the market for unskilled labor implies due to the production technology (3.3) that the wage rate for unskilled workers is equal to the marginal product in the F sector, $w_U = A_F$. The cutoff value for the time cost is therefore

$$\bar{\xi}_t = \frac{\sum_{s=t}^{\infty} Q_{s,t}\lambda^{s-t}\left(w_{S,s} - A_F\right)}{w_{S,t}} \tag{3.12}$$

Out of the newborns (generation 0), who are endowed with one unit of labor each, time spent in education is

$$l_{e,t}^0 = L\phi \int_0^{\bar{\xi}_t} \xi^i \mu(\xi^i) d\xi^i \tag{3.13}$$

where $\mu(\xi^i)$ is the pdf of ξ^i. Similarly, the new-born's supply of skilled and unskilled labor is

$$l_{S,t}^0 = L \int_0^{\bar{\xi}_t} (1 - \phi\xi^i)\mu(\xi^i) d\xi^i \tag{3.14}$$

$$l_{U,t}^0 = L \int_{\bar{\xi}_t}^{\infty} 1 \cdot \mu(\xi^i) d\xi^i \tag{3.15}$$

The evolution of the distribution of labor supply over time, where a fraction $(1 - \lambda)$ of workers is replaced by newborns, is given by

$$L_{U,t}^s = \lambda \cdot L_{U,t-1}^s + (1 - \lambda) \cdot l_{U,t}^0 \tag{3.16}$$

and similarly, since education "does not spill" from one period to the next,

$$L_{e,t} = (1 - \lambda) \cdot l_{e,t}^0 \tag{3.17}$$

$$L_{S,t}^s = \lambda \cdot (L_{S,t-1}^s + L_{e,t-1}) + (1 - \lambda) \cdot l_{S,t}^0 \tag{3.18}$$

To note is that skilled labor supply is increasing the net present value of skilled wages. An increase in $w_{S,s}$ for $s \geq t$ raises $\bar{\xi}_t$ which increases $l_{S,t}^0$ and in turn $L_{S,t}^s$.

Demand for unskilled labor, which is only employed in the competitive F sector, is

$$L_{U,t}^{d} = \frac{1}{A_F} Y_{F,t}$$

In the manufacturing sector, where producers have some market power on the domestic market but also the possibility to sell abroad, firms will choose the mode of production that maximizes their profits. Since firms in the M sector are infinitesimally small and skilled labor is perfectly mobile within the sector, the individual firm i takes wages for skilled labor as a given. But firms do decide on whether to sell only domestically or also to export, and at which price. They cannot price discriminate between the two markets and they have to supply the domestic market to be able to export.

To highlight what their choices are when they are not constrained by the cum-tariff import price and opt not to export, we first consider a situation without international trade.

3.3.1 No International Trade

On the domestic market, the monopolistic producer of variety $i \in [0,1]$ of the manufactured good faces a downward sloping demand curve, which is in the absence of international trade given by domestic consumption demand. Consequently, the producer maximizes profits, $p_t(i) \cdot y_{M,t}(i) - w_{S,t} \cdot l_{S,t}(i)$, subject to the production function (3.2) and the consumer demand function (3.10). Substituting in, the firm's optimization problem becomes,

$$\max_{p_t(i)} \pi_{M,t}(i) = p_t(i) \left(\frac{P_{M,t}}{p_t(i)} \right)^{\varepsilon} LC_{M,t} - w_{S,t} \left(\frac{1}{A_M} \left(\frac{P_{M,t}}{p_t(i)} \right)^{\varepsilon} LC_{M,t} \right)^{\frac{1}{\alpha}}$$

which has first order condition $p_t(i) = \frac{1}{\alpha} \frac{\varepsilon}{\varepsilon - 1} w_{S,t} \left(\frac{1}{A_M} \right)^{\frac{1}{\alpha}} \left(\left(\frac{P_{M,t}}{p_t(i)} \right)^{\varepsilon} LC_{M,t} \right)^{\frac{1-\alpha}{\alpha}}$. The second order condition holds since profits are concave in $p_t(i)$ due to $\varepsilon > 1$. Notice that marginal cost are $MC(y_{M,t}(i)) = w_{S,t} \left(\frac{1}{A_M} \right)^{\frac{1}{\alpha}} (y_{M,t}(i))^{\frac{1-\alpha}{\alpha}}$, and the optimal price is a constant markup on (the increasing) marginal cost. Solving for $p(i)$ gives firm i's optimal price in the case of no international trade, which we denoted by $p_t^M(i)$, as

$$p_t^M(i) = \left[\frac{1}{\alpha}\frac{\varepsilon}{\varepsilon-1}w_{S,t}\left(\frac{1}{A_M}\right)^{\frac{1}{\alpha}}(LC_{M,t})^{\frac{1-\alpha}{\alpha}}\right]^{\frac{\alpha}{\alpha+\varepsilon(1-\alpha)}} P_{M,t}^{\frac{\varepsilon(1-\alpha)}{\alpha+\varepsilon(1-\alpha)}} \tag{3.19}$$

The equilibrium is symmetric with $p_t^M(i) = p_t^M$ for all firms $i \in [0,1]$, which implies by (3.11) also $P_{M,t} = p_t^M$. Moreover $c_{M,t}(i) = C_{M,t}$, $y_{M,t}(i) = Y_{M,t} = LC_{M,t}$, and $\pi_{M,t}(i) = \Pi_{M,t}$. By (3.2), labor demand of producer i is given by $l_{S,t}^d(i) = \left(\frac{y_{M,t}(i)}{A_M}\right)^{\frac{1}{\alpha}}$. The equilibrium price of a variety of the manufactured good as well as for the basket of manufactured goods, is therefore

$$P_{M,t} = p_t^M(i) = \frac{1}{\alpha}\frac{\varepsilon}{\varepsilon-1}w_{S,t}\left(\frac{1}{A_M}\right)^{\frac{1}{\alpha}}(LC_{M,t})^{\frac{1-\alpha}{\alpha}} \tag{3.20}$$

which describes the equilibrium price as a function of aggregate consumption of the manufactured good. Moreover, maximized profits and demand for skilled labor are

$$\Pi_{M,t} = \pi_{M,t}(i) = \left(\frac{LC_{M,t}}{A_M}\right)^{\frac{1}{\alpha}} w_{S,t}\left(\frac{1}{\alpha}\frac{\varepsilon}{\varepsilon-1} - 1\right) \tag{3.21}$$

$$L_{S,t}^d = \int_0^1 l_{S,t}^d(i)di = \left(\frac{LC_{M,t}}{A_M}\right)^{\frac{1}{\alpha}} \tag{3.22}$$

The decentralized equilibrium is such that all firms maximize their profits, all workers maximize their income through their skill acquisition choice, consumers maximize utility, the government budget is balanced, and all markets clear. Here no international trade occurs and production must equal domestic consumption of each good. Moreover the government does not collect import tariff revenue nor pays export subsidies, so no lump-sum tax is imposed to satisfy the government's budget constraint. With $Y_{F,t} = C_{F,t}$, $Y_{M,t} = C_{M,t}$, and $T_t = 0$ equations (3.5) to (3.22) describe the equilibrium.

3.3.2 With International Trade

We consider a small open economy that takes the world price as given. The crucial difference to a closed economy is that every producer faces a demand curve that is perfectly elastic at some prices, which depend on the world price for manufactured goods and industrial policy measures (which are common to all varieties). It is

$$y^d_{M,i}(p_t; p^*, \tau_t) = \begin{cases} \infty & \text{for} \quad p_t < p^*_t \\ L\left(\frac{P_{M,t}}{p_t(i)}\right)^{\varepsilon} C_{M,t} & \text{for} \quad p^* \leq p_t \leq (1+\tau)p^* \\ 0 & \text{for} \quad (1+\tau_t)p^* < p_t \end{cases} \quad \text{for } \forall i \in [0,1]$$

Firms have the possibility (i) to supply only the domestic market, (ii) to supply both the domestic and the foreign market, or (iii) not to produce at all. They cannot price discriminate between the two markets and they have to supply the domestic market to be able to export. Depending on the world price p^*, import tariffs τ_t, export subsidies s_t, as well as the behavior of other firms different strategies are optimal for producer i. For now, we restrict attention to symmetric equilibria. We show in the next section that the symmetric equilibrium is unique if it exists. There are four possible scenarios:

1. The cum-tariff import price of substitutes from the world market is so low that it restricts domestic firms and they produce less than the quantity consumed domestically Consequently, there are net imports of the manufactured good. We refer to this scenario as *case 1*.

2. The cum-tariff import price of substitutes from the world market is so low that it restricts domestic firms' pricing, but they produce to satisfy domestic demand, such that there are no imports (*case 2*).

3. The domestic monopolistic producers are not constrained by import prices and do not export either. They are at their domestic interior optimum, and there is no international trade (*case 3*).

4. The incentive to export is sufficiently strong, and domestic firms produce for both the domestic and the international market. There are exports of manufactured goods.(*case 4*).

All firms will choose the mode of production that maximizes their profits. We consider each case in turn, starting with the unconstrained domestic optimum.

Suppose at prevailing prices, the producer of variety i of the manufactured good prefers not to export, given the behavior of other firms. Moreover suppose the firm's price setting is not restricted by the cum-tariff price of competing imports (*case 3*). Since the producer is only supplying the domestic market, the profit maximization problem is as in section 3.3.1. Moreover, since the equilibrium is symmetric, the outcome is exactly the same as above, with $p_t^{(3)} = P_{M,t}^{(3)} = p_t^M$ as derived in (3.20), and $nx_{M,t}^{(3)} = 0$.

However, it might be that the cum-tariff import price of the perfect substitutes from international markets is below this by the producer desired price p_t^M. If the producer was charging a price above $(1+\tau_t)p^*$, though, it would lose all demand. Hence the upper bound on domestic prices (3.4) imposed by competing imports is binding (*case 1 or 2*). As long as it is still profitable to produce at all, the domestic producer will underprice the competing imports by setting $p_t(i) = (1+\tau_t)p^*$, and choose quantities to maximize profits of selling at this price on the domestic market where consumer's demand is given by (3.10); the maximization problem is

$$\begin{aligned} \pi_{M,t}(i) &= \max_{y_{M,t}(i)} (1+\tau_t)p^* y_{M,t}(i) - w_{S,t}\left(\frac{y_{M,t}(i)}{A_M}\right)^{\frac{1}{\alpha}} \\ \text{s.t. } y_{M,t}(i) &\leq c_{M,t}(i) = \left(\frac{P_{M,t}}{(1+\tau_t)p^*}\right)^{\varepsilon} LC_{M,t} \end{aligned}$$

This implies $y_{M,t}(i) = \min\{A_M\left(\frac{\alpha(1+\tau_t)p^* A_M}{w_{S,t}}; \left(\frac{P_{M,t}}{(1+\tau_t)p^*}\right)^{\varepsilon} LC_{M,t}\right)^{\frac{\alpha}{1-\alpha}}$ and $l_{S,t}(i) = \left(\frac{y_{M,t}(i)}{A_M}\right)^{\frac{1}{1-\alpha}}$, which is the same for all producers, since the world price and the tariff are the common to all varieties.[4] Due to the symmetry $P_{M,t} = (1+\tau_t)p^*$, and it follows $Y_{M,t} = \min\left\{A_M\left(\frac{\alpha(1+\tau_t)p^* A_M}{w_{S,t}}\right)^{\frac{\alpha}{1-\alpha}}; LC_{M,t}\right\}$. Hence there is always some domestic production of manufactured goods, but the quantity produced might be less than the quantity consumers demand at price $(1+\tau_t)p^*$. If $Y_{M,t} = LC_{M,t}$, there are no imports of the manufactured goods, and the economy is in *case 2* with $nx_{M,t}^{(2)} = 0$ and

$$Y_{M,t}^{(2)} = LC_{M,t} \tag{3.23}$$

and $L_{S,t}^{d(2)} = \left(\frac{LC_{M,t}}{A_M}\right)^{\frac{1}{\alpha}}$, and $\Pi_M^{(2)} = (1+\tau_t)p_t^* LC_{M,t} - w_S\left(\frac{LC_{M,t}}{A_M}\right)^{\frac{1}{\alpha}}$. If, on the contrary, $Y_{M,t} = A_M\left(\frac{\alpha(1+\tau_t)p^* A_M}{w_{S,t}}\right)^{\frac{\alpha}{1-\alpha}} < LC_{M,t}$, *case 1* applies, net imports $nx_{M,t} = Y_{M,t} -$

[4]Notice that at the optimum $\pi_{M,t}(i) \geq (1-\alpha)\left(\frac{\alpha^{\alpha}(1+\tau_t)p^* A_M}{w_{S,t}^{\alpha}}\right)^{\frac{1}{1-\alpha}} > 0$, indicating that there are always some profits from producing.

$LC_{M,t} < 0$ occur and the manufacturing sector is summarized by

$$Y_{M,t}^{(1)} = A_M \left(\frac{\alpha(1+\tau_t)p^* A_M}{w_{S,t}} \right)^{\frac{\alpha}{1-\alpha}} < LC_{M,t} \tag{3.24}$$

and $L_{S,t}^{d(1)} = \left(\frac{\alpha(1+\tau_t)p^* A_M}{w_{S,t}} \right)^{\frac{1}{1-\alpha}}$ and $\Pi_{M,t}^{(1)} = (1-\alpha) \left(\frac{\alpha^\alpha(1+\tau_t)p^* A_M}{w_{S,t}^\alpha} \right)^{\frac{1}{1-\alpha}}$. In either case 1 or 2, $P_{M,t} = (1+\tau)p^*$.

Finally, suppose firm i prefers supplying both the domestic and the international market (*case 4*). In this case, the firm charges the world price, i.e. $p_t^{(4)} = p^* = P_{M,t}^{(4)}$, which is common to all varieties, and accrues an export subsidy of $s_t \cdot p^*$ per unit sold abroad. It chooses the quantity produced to maximize profits

$$\begin{aligned} \pi_{M,t}(i) &= \max_{y_{M,t}(i)} p^* y_{M,t}(i) + s_t p^* nx_{M,t} - w_{S,t} \left(\frac{y_{M,t}(i)}{A_M} \right)^{\frac{1}{\alpha}} \\ \text{s.t. } nx_{M,t}(i) &= y_{M,t}(i) - Lc_{M,t}(i) > 0 \end{aligned}$$

which implies off corners

$$Y_{M,t}^{(4)} = A_M \left(\frac{\alpha(1+s_t)p^* A_M}{w_{S,t}} \right)^{\frac{\alpha}{1-\alpha}} > LC_{M,t} \tag{3.25}$$

Therefore, provided the firm is actually exporting and $nx_{M,t}^{(4)} = A_M \left(\frac{\alpha(1+s_t)p^* A_M}{w_{S,t}} \right)^{\frac{\alpha}{1-\alpha}} - LC_{M,t} > 0$, $L_{S,t}^{d(4)} = \left(\frac{\alpha(1+s_t)p^* A_M}{w_{S,t}} \right)^{\frac{1}{1-\alpha}}$ and $\Pi_M^{(4)} = (1-\alpha) \left(\frac{\alpha^\alpha(1+s_t)p^* A_M}{w_{S,t}^\alpha} \right)^{\frac{1}{1-\alpha}} - s_t p^* LC_{M,t}$.

Each producer in manufacturing opts for the mode of production maximizing profits. Figure 3.2 shows the optimal behavior of an individual firm in the manufacturing sector, which takes price as well as aggregate consumption and wages as a given. For low world prices exporting is not attractive and firm i opts to be a domestic monopolist of variety i. When the cum-tariff import price of perfect substitutes ($(1+\tau)p^*$) is low, the producer is constrained in price setting. For very low prices, the firm produces less than domestic demand for their good at the prevailing price. For sufficiently high cum-subsidy import prices, the firm is able to charge the profit maximizing price to the domestic market (p^M). In this situation the firm is not producing up to the amount at which the price is equal to marginal cost, but producing less in order to maximize revenue. However, when the world price cum subsidy is sufficiently high, the firm will opt to supply both the domestic and the international market and charging the world price. In this case, it is optimal for the firm to expand production until revenue per unit sold, price plus export subsidy, equals marginal cost. For this reason, firm i's labor demand and output supplied feature a jump at the world price for which the domestic and the international strategy yield the same profits.

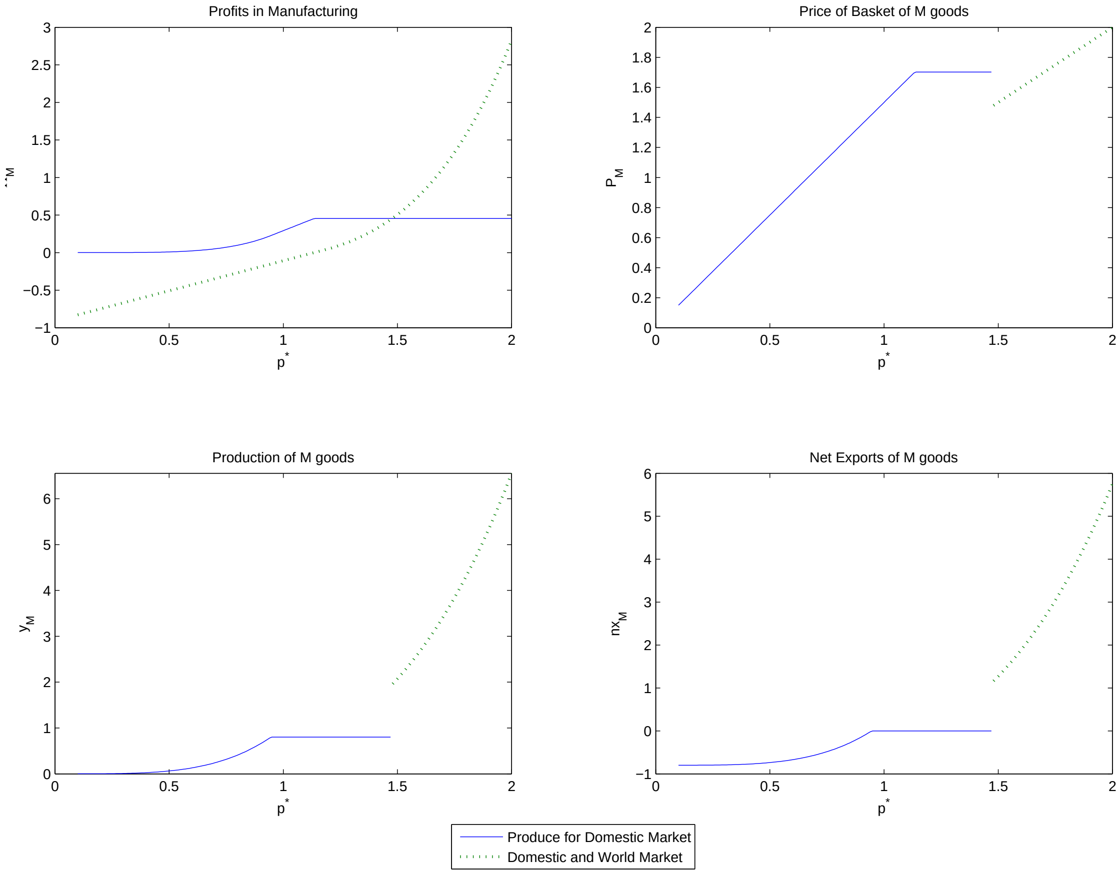

Figure 3.2: Manufacturing in symmetric equilibrium (conditional on C_M and w_S; for $\tau > 0$ and $s > 0$)

For the same reason, the demand for skilled labor as a function of the skilled wage is discontinuous, as illustrated in figure 3.3. For sufficiently low wages, exporting is optimal and therefore a rather high labor demand. But at some higher wage, the firm switches to the domestic mode of production resulting in a downward jump in labor demand.

In general, we focus on symmetric equilibria. As we show in section 3.3.3, if a symmetric equilibrium exists, it is unique. But due to the intrinsic discontinuities of the model, a symmetric equilibrium does not always exist. There is the possibility that the supply of

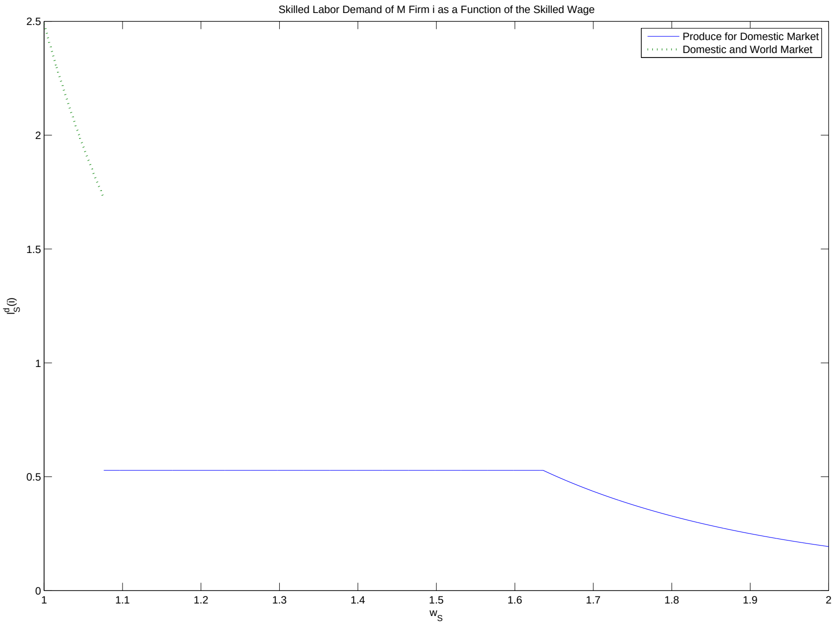

Figure 3.3: Skilled labor demand (conditional on C_M and p^*; for $\tau > 0$ and $s > 0$

skilled labor passes through (”intersects”) labor demand in figure 3.3 in the discontinuity region. In this case, the skilled wage would be bounded between a high value, at which firms would hire only for sales on the domestic market the quantity of workers l_S^{dom}, and a low value, at which all firms want to supply the world market for which they require l_S^{exp} skilled workers. In a symmetric equilibrium the aggregated labor demand would not equal supply. However, at the points of discontinuity, firms are just indifferent between exporting or domestic production as both strategies yield the same profits. Therefore we assume that in this situation *some* firms are exporting and *some are not,* such that the labor market clears.

In particular, when manufacturing firms are indifferent between domestic monopoly and exporting, we let the measure $\frac{L_S^s - l_S^{dom}}{l_S^{exp} - l_S^{dom}}$ of firms be exporters, who charge the world price p^* and hire l_S^{exp} skilled workers. The remaining $\frac{l_S^{exp} - L_S^s}{l_S^{exp} - l_S^{dom}}$ firms supply the domestic market only where they charge price p^M and demand l_S^{dom} units of skilled labor. The price of the basket of manufactured goods (3.11) and aggregate production of M goods are in that case

$$
\begin{aligned}
P_{M,t} &= \left(\frac{L^s_{S,t} - l^{dom}_{S,t}}{l^{exp}_{S,t} - l^{dom}_{S,t}} (p^*)^{1-\varepsilon} + \frac{l^{exp}_{S,t} - L^s_{S,t}}{l^{exp}_{S,t} - l^{dom}_{S,t}} (p^M_t)^{1-\varepsilon} \right)^{\frac{1}{1-\varepsilon}} \\
Y_{M,t} &= \frac{L^s_{S,t} - l^{dom}_{S,t}}{l^{exp}_{S,t} - l^{dom}_{S,t}} A_M (l^{exp}_{S,t})^{\alpha} + \frac{l^{exp}_{S,t} - L^s_{S,t}}{l^{exp}_{S,t} - l^{dom}_{S,t}} A_M (l^{dom}_{S,t})^{\alpha} \qquad (3.26)
\end{aligned}
$$

This ensures that all markets clear. In our simulations we also verify numerically that this indeed an equilibrium. In all other situations, we consider the symmetric equilibrium.

The decentralized equilibrium is such that all firms maximize their profits, all workers maximize their income through their skill acquisition choice, consumers maximize utility, the government budget is balanced, trade balances, and all market clears. The government budget requires for the lump-sum tax/transfer on households

$$
T_t = \begin{cases} \tau_t p^* nx_{M,t} < 0 & \text{if} \quad nx_{M,t} < 0 \\ s_t p^* nx_{M,t} > 0 & \text{if} \quad nx_{M,t} > 0 \end{cases}
$$

The trade balance and market clearing for both goods requires

$$
\begin{aligned}
nx_{F,t} &= -p^* nx_{M,t} \\
Y_{F,t} &= C_{F,t} + nx_{F,t} \\
Y_{M,t} &= C_{M,t} + nx_{M,t}
\end{aligned}
$$

The four equations above, and (3.5) to (3.26), where only the equations of the manufacturing firms' profit maximizing case apply. Drawing on the recursive structure of the system, we solve for the transitional dynamics using a shooting algorithm, where the state variables are $L^s_{S,t-1}$ and $L_{e,t-1}$.[5]

3.3.3 A Note on the Uniqueness of the Symmetric Equilibrium (when it exists)

In the case of the closed economy, it is easy to show that there is strategic complementarity, i.e. when the price of the basket increases it is optimal for the individual firm to charge a

[5]In steady state wages and interest rates are constant, i.e. $w_{S,t} = w_S$ and $r_t = r = \frac{1-\beta}{\beta}$ by (3.5), and

higher price. According to (3.19), firm i's optimal interior price $p_t^M(i)$ as a function of the basket $P_{M,t}$ is

$$p_t^M(i) = k \cdot P_{M,t}^{\frac{\varepsilon(1-\alpha)}{\alpha+\varepsilon(1-\alpha)}}, \text{ with } k = \left[\frac{1}{\alpha}\frac{\varepsilon}{\varepsilon-1}w_{S,t}\left(\frac{1}{A_M}\right)^{\frac{1}{\alpha}}(LC_{M,t})^{\frac{1-\alpha}{\alpha}}\right]^{\frac{\alpha}{\alpha+\varepsilon(1-\alpha)}} > 0$$

Hence

$$\begin{aligned}
\frac{\partial p_t^M(i)}{\partial P_M,t} &= k\frac{\varepsilon(1-\alpha)}{\alpha+\varepsilon(1-\alpha)}P_{M,t}^{\frac{\alpha}{\alpha+\varepsilon(1-\alpha)}} > 0 \\
\frac{\partial^2 p_t^M(i)}{\partial P_{M,t}^2} &= -k\frac{\varepsilon\alpha(1-\alpha)}{(\alpha+\varepsilon(1-\alpha))^2}P_{M,t}^{\frac{-2\alpha-\varepsilon(1-\alpha)}{\alpha+\varepsilon(1-\alpha)}} < 0 \\
\lim_{P_{M,t}\to 0}\frac{\partial p_t^M(i)}{\partial P_{M,t}} &= \infty
\end{aligned}$$

Therefore there exists a unique fixed point for the interior optimal price (since all firm's solve their individual problem (3.19) and the price of the basket is determined from these individual solutions according to (3.11)).

What changes in the open economy? On the one hand, the cum-tariff price of imports imposes a ceiling on prices a producer can charge on the domestic market. This constraint is binding when $(1+\tau_t)p^* < p_t^M(i)$. Since$\frac{\partial \pi_{M,t}(i)}{\partial p_t(i)} > 0$ for $p_t(i) = (1+\tau_t)p^* < p_t^M(i)$ (recall that $p_t^M(i)$ is the maximizer of profits if there were no competing imports) and since the profit function is concave in $p_t(i)$, it is optimal for a firm producing for the domestic market only to charge a price as close as possible to the interior optimal price ($p_t^M(i)$). But since $p_t^M(i) = p_t^M$, as implied by (3.19), all firms will set the same price $p_t^{(2)} = (1+\tau_t)p^*$. On the other hand, producers are giving the option to sell both domestically and internationally.

the labor market is characterized by

$$\begin{aligned}
\bar{\xi}_t &= \bar{\xi} = \frac{1}{\phi}\frac{1+r}{1+r-\lambda}\frac{w_S - A_F}{w_S} \\
l_{S,t}^0 &= l_S^0 = L\int_0^{\bar{\xi}}(1-\phi\xi_i)\mu(\xi_i)d\xi_i \\
L_{U,t}^s &= L_{U,t-1}^s = L_{U,t}^s = l_U^0 \text{ from (3.16)} \\
L_{e,t} &= L_{e,t-1} = L_e = (1-\lambda)\cdot l_e^0 \text{ from (3.17)} \\
L_{S,t}^s &= L_{S,t-1}^s = L_S^s = \lambda l_e^0 + l_S^0 \text{ from 3.18) and (3.17)}
\end{aligned}$$

In this case they will charge the world price p^*, which is common to all varieties. So again, the equilibrium is necessarily symmetric when it exists.

3.4 Comparative Statics

To illustrate the model's properties with regard to international trade, abstracting from the transitional effects of skill acquisition, we conduct various comparative statics exercises of the model's steady state.

3.4.1 Changing the World Price

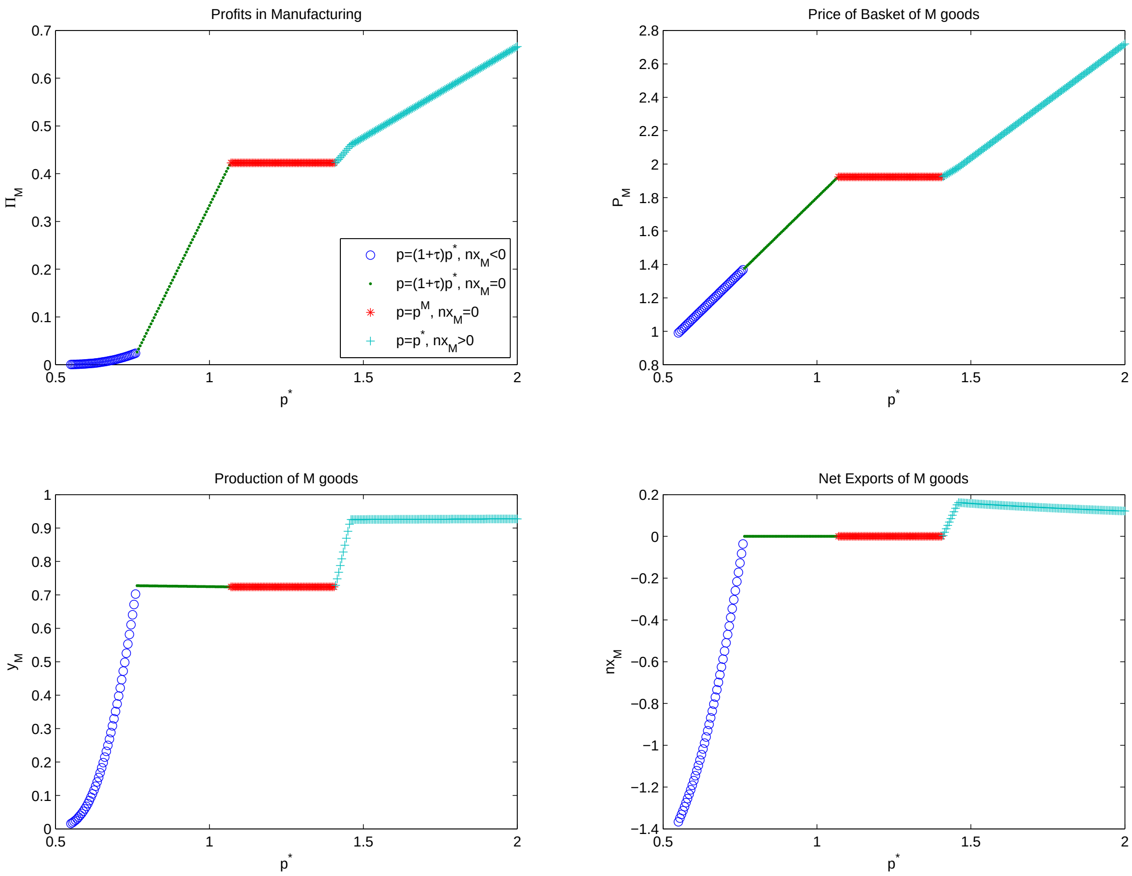

Figure 3.4: Steady state against world price

Figure 3.4 shows equilibrium profits in the manufacturing sector as well as price and quantity of manufactured goods as a function of the world price. The figure uses the baseline calibration, with agricultural productivity $A_F = 1$, and policies $\tau = 0.8$ and

$s = 0.05$. When the world price for manufactured products is sufficiently low, domestic firms are constrained by the cum-tariff price of imports. For very low prices domestic production is smaller than the quantity demand at this price and there are imports of manufactured goods (*case 1*); for somewhat higher price there is no international trade (*case 2).* At higher world prices, there is a range in which the monopolistic producers gain from the protection through import tariffs such that they can achieve their interior optimum for sales on the domestic market (*case 3*). But for a sufficiently high world price highest profits are earned when exporting (*case 4*). This includes a range for which not all firms can export since the supply of skilled labor is too low - that is the range for which we impose the asymmetric outcome, as described above. Two comments are in order. First, for most of the range of world prices, net exports of manufactured goods are (weakly) increasing in p^*. However, for relative world prices so high that the small open economy specializes perfectly in manufacturing, a further increase in p^* lowers nx_M, since production is already as high as possible but domestic consumption of M goods increases due to a positive income effect from exporting at a higher price. But since this wealth effect only arises when the economy is a net exporter, nx_M remains positive. The second important remark is that the patterns of trade as shown in figure 3.4 depend on the calibration in the sense that for different parameters or policies, not all the four cases might emerge. For instance, there are policy vectors such that the economy with domestically constrained manufacturing firms and no imports (*case 2*) switches directly to exporting manufactures (*case 4*) as p^* rises.

3.4.2 Agricultural Productivity – Domestic Market Size for Manufactured Goods

As a comparative statics exercise, we compare the outcome above with an economy that has lower agricultural productivity, here $A_F = 0.75$. We show the equilibrium outcome in figure 3.5, where we reproduce figure 3.4, which used $A_F = 1$, by the dotted lines. Comparing the two shows, the higher the productivity in non-manufacturing (A_F), the higher are the thresholds of world prices at which manufacturing firms switch their mode of production in equilibrium.

This is due to differences in the size of the domestic market for manufactured goods

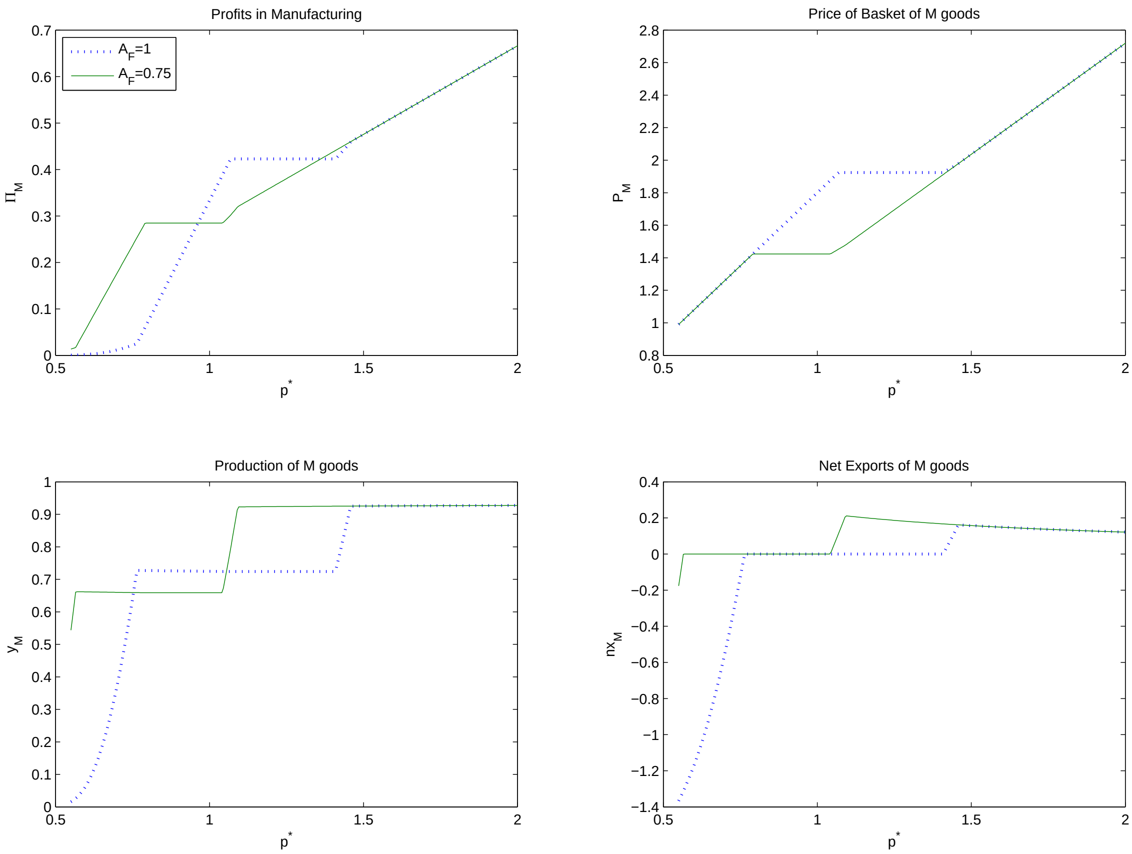

Figure 3.5: Steady state against world price for different agricultural productivities

Notes: This graph shows the outcome in manufacturing in steady states against p^* for $A_F = 0.75$ (solid line) and $A_F = 1$ (dotted line).

that result from the differential agricultural productivity. A rise in A_F affects the economy in two crucial ways. On the one hand, it increases the marginal productivity of labor in the unskilled sector. As long as not all newborns acquire skills, that is $\bar{\xi} < 1$ in (3.12), this also raises the wage rate for skilled labor (w_S), which commands a premium over unskilled labor. On the other hand, higher productivity leads to an improvement in national income (3.9), which consumers spend overproportionally on consumption of manufactured goods C_M (3.6). This positive income effect shifts out the demand curve domestic producers are facing, and the domestic market for manufactured goods grows.

But also the increase in skilled wages can be viewed as an increase in the domestic market for manufactures. If the domestic monopolistic producers are unconstrained in their price setting on the domestic market (*case 3*), they charge p^M according to (3.20) as a mark-up on their marginal cost, which have increased along with w_S and A_F. Their profits (3.21) hence increase, even at constant C_M, since the domestic price for manufactured goods increases with skilled wages. In countries with more productive agriculture the autarky relative price for manufactured goods is therefore higher. This makes it less attractive for producers to sell their products on the world market where they take prevailing prices as a given. Moreover, higher domestic agricultural productivity lowers profits from exporting ($\Pi_M^{(4)}$) per se, as it makes skilled labor more expensive, but does not result in higher prices on the international market.

For the behavior of firms that can choose between monopolistically supplying the domestic market or selling at the given world price, and receiving a subsidy per unit sold abroad, this implies,that an increase in non-manufacturing productivity raises the threshold of the world price at which the country starts exporting. Differences in agricultural productivity can therefore explain in principle different reactions to similar policies. A protected manufacturing sector in a country with a more productive agricultural sector is more likely to choose the domestic monopoly mode of production over the export-led mode. Because agriculture has been much more productive in Latin American countries than in East Asian countries, this might explain why Korea or Taiwan, but not Argentina, started to export manufactured goods, despite the similarity in policies.

3.4.3 Trade Policies

Changes in trade policies affect the patterns of international trade. Figure 3.6 illustrates the pattern of trade. It shows the regions in the policy space, formed by pairs of import tariffs and export subsidies, in which manufactured goods are exported, imported, or not traded with the rest of the world at all.

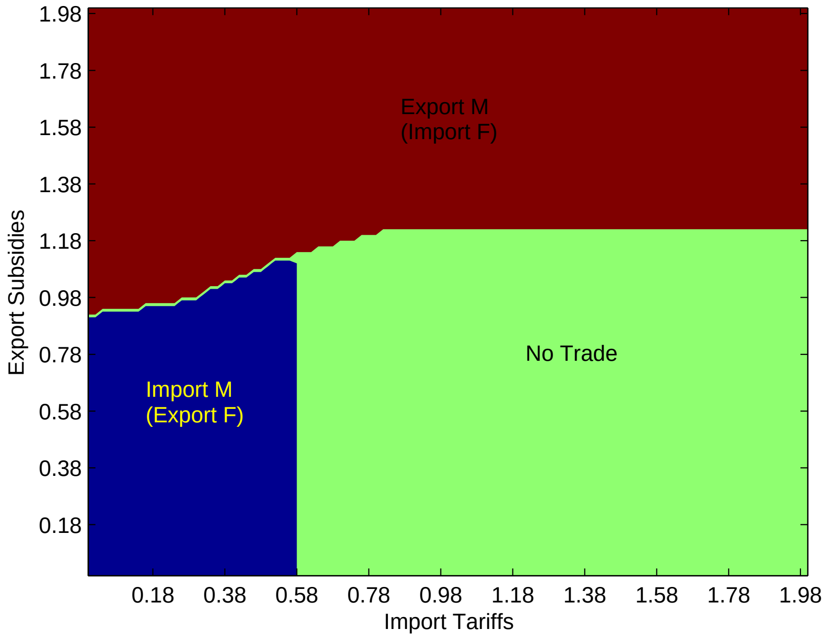

Figure 3.6: Steady state trade patterns against trade policies

For sufficiently high export subsidies on manufactured goods, these goods are exported in equilibrium. When protection in the form of tariffs on manufactured good is sufficiently low, in equilibrium these products are imported. With tariffs exceeding a certain level, manufactured goods are never imported. They are exported when export incentives are sufficiently high; otherwise there is no international trade.

When tariffs are low and subsidies are relatively high, there is an interaction between the two effects: As protection is low, the import-competition imposes a binding constraint on prices in the domestic market $((1+\tau)p^*)$. When selling domestically and exporting the unit price is principally lower (p^*), but per unit sold abroad the producer also accrues the export subsidy. The boundaries between the import versus the export region of manufactured good reflects the trade-off between these two alternatives. The lower the import tariff, the lower is the price a producer can charge on the domestic market and the more favorable is exporting. The boundary between importing and exporting manufactured goods hence slopes upward for sufficiently low tariffs.

Moreover, also for tariffs exceeding the no-import-threshold the edge of the export-region is upward sloping. Although tariffs are prohibitive, the constraint on prices in the domestic market of $(1+\tau)p^*$ remains binding - domestic monopolistic firms set this price to keep imports out of the market, but are not at their interior optimal price ($p^M > (1+\tau)p^*$). Only when import protection is such that firms are at their interior optimum and charging $p^M \leq (1+\tau)p^*$, profits from selling domestically are independent of trade policies. Then the boundary of the export to no-trade region is flat.

3.5 Calibration

We calibrate the model for the South Korean relative to Argentine growth take-off. Under the assumption of permanently constant trade policies, we choose parameters to match initial targets in the data. For Argentina we assume that it was in a steady state. But for South Korea, that saw the end of the Korean War in 1953, we assume that it has been on a transition path starting out with zero skilled labor in 1950, the beginning of the Korean War. This is motivated with Krueger (1979)'s observation that before Korea's division the North was specialized in manufacturing, with the South specializing in agriculture and mining. In our numerical experiment we will then assume that in 1960 the path of actually policies gets revealed, and subsequently implemented.

We take as many parameters as possible from the existing literature and choose the remaining ones to match moments in the data. As in Caselli and Coleman (2001), we calibrate the model such that education 'does not spill' from one period to another. Therefore we set the length of a model period to 5 years. Also as Caselli and Coleman (2001), we assume for the utility function $u(C_t) = log(C_t)$ and for the parameters governing the consumption aggregator (3.1) $\theta = 0.01$ and $\gamma = 0.2205$. Moreover we take the idiosyncratic cost of skill acquisition $\xi^i \sim \mu(\xi^i)$ as

$$\mu(\xi^i) = \begin{cases} 3(\xi^i)^2 & \text{for } 0 \leq \xi^i \leq 1 \\ 0 & \text{otherwise} \end{cases} \tag{3.27}$$

We set λ to match the average life-expectancy in Argentina and Korea. In data from the World Bank, the average life-expectancy at birth over 1960–2008 is 70.16. Assuming that workers would leave the labor force at age 66, and if not acquiring skills enter the labor force at age 14, we set $\lambda = 0.904$, which corresponds to an expected time in the labor force of 52 years (or 10.4 model periods). For the discount factor we assume a factor of 0.95 a year, implying for our model at five year frequency $\beta = 0.7738$. The elasticity of substitution between the different varieties of manufactured goods is set to $\varepsilon = 3.5$, consistent with Broda and Weinstein (2006)'s estimates based on disaggregated US imports data. Moreover, we normalize $A_M = 1$ and $L = 1$.[6]

Table 3.1: Tariffs and subsidies to feed into the model

Year	τ_t^{ARG}	τ_t^{KOR}	s_t^{ARG}	s_t^{KOR}
1950	0.2145	0.2362	0	0
1955	0.8931	0.2831	0	0
1960	1.4704	0.484	0	0.9466
1965	1.0046	0.4162	0	0.274
1970	0.4406	0.3759	0	0.2816
1975	0.3603	0.3063	0	0.1954
1980	0.28	0.247	0	0.2033
1985	0.2843	0.2283	0	
1990	0.193	0.1372	0	
1995	0.131	0.0903	0	
2000	0.1503	0.0948	0	
2005	0.1174	0.0879	0	
2010	0.0978	0.0875	0	

For the history of industrial policies we draw on various sources, our reading of the economic history literature and the World Bank's data on average collected tariffs. Whenever available, we take the World Bank's data on average tariffs. For all other years, we take values reported in the literature. We linearly interpolate the tariffs between the

[6]Over 1960–2010, the population in both Argentina and Korea has increased, but the population in Korea relative to Argentina has been roughly constant, with fluctuations only between 1.2 and 1.35.

years with data, and add the contributions of other import measures taken, such as foreign exchange taxes, special tariffs, and estimated contribution of quantitative restrictions of imports. For policies in South Korea, our main source for a quantification of import protection and export promotion in manufacturing is Kim (1991), which we supplement with various other sources that we report in table 3.5 of the appendix. For historic values of Argentine import tariffs we mainly rely on Amsden (2001); the details are given in appendix table 3.6.

Since we do not have consistent data on export subsidies for Argentina, we could in principle use our model to infer subsidies. As illustrated in figure 3.6, we could employ net export data to use the model to back out export subsidies for manufactures $s^j_{t,}$ for country j in year t, conditional on all other parameters. However, in the data, taking five year averages, Argentina has been a net importer of manufactures in all periods since 1960. As a consequence the model cannot pin down an export subsidy for manufactures– while the export incentive was in place, in our model the average firm in manufacturing would not take it. Therefore we set for periods with net imports of manufactured goods export subsidies to zero. Finally we take non-overlapping 5-year averages of import tariffs and export subsidies, since our model is calibrated to a five year frequency. We list the histories of import tariffs and export subsidies that we feed into the model in table 3.1. We assume that in the final steady state there are no policy measures taken and $\tau = s = 0$. For the periods after the last observed value, we impose a linear decline in the measures to their steady state values of zero over 50 years.

All parameters fixed so far are summarized table 3.2. There are five remaining para-

Table 3.2: Fixed parameters

	Description	**Value**
L	population size	1 (normalization)
A_M	productivity in manufacturing	1 (normalization)
β	discount factor	0.7738
λ	survival probability	0.904
ε	CES elasticity of M varieties	3.5 (Broda and Weinstein (2006))
θ	asymptotic expenditure share on F goods	0.01 (Caselli and Coleman (2001))
γ	subsistence level in C_F	0.2205 (Caselli and Coleman (2001))

Notes: The model is calibrated to a five years frequency.

meters, α, ϕ, p^*, A_F^{ARG}, A_F^{ARG}, to be calibrated jointly against targets in the data, which we list in table 3.3. While we would like to choose parameter values to match moments in the data for one base year prior to 1960, when the Korean policy change took place, due to data limitations we cannot. We are aiming at matching relative GDP per capita of South Korea and Argentina, the share of unskilled labor in both countries, and the share of net exports in GDP in the two countries.

Table 3.3: Calibration targets

Moments to Match	**Data**	**Model**	
		calibration to 1955	**transition in 1960**
Unskilled Labor Share: $\frac{L_U}{L_U+L_S}$			
Argentina	18.38% in 1960	12.11%	12.28%
South Korea	66.60% in 1960	87.69%	73.88%
Net Export of Manufactures (share of GDP): $\frac{p^* nx_M}{GDP}$			
Argentina	-4.29% in 1962	0	-0.51%
Korea	-7.82% in 1962	-7.71%	-15.22%
Relative real (chain weighted) per Capita GDP: $\frac{Y_F^{ARG}+p^* Y_M^{ARG}}{Y_F^{KOR}+p^* Y_M^{AKOR}}$			
Argentina to Korea	4.68 in 1955	3.7570	7.2516

For the value share of net manufacturing exports in GDP, we combine several data series published by the World Bank: We multiply "Manufactures exports (% of merchandise exports)" by "Merchandise exports (current US$)" and "Manufactures imports (% of merchandise imports)" by "Merchandise imports (current US$)", take their difference and divide by "GDP (current US$)". This series starts in 1962. For the share of unskilled labor we employ data from the ILO's LABORSTA Database, Table 1c, to compute the share of employment in agriculture and farming in total employment (excluding the unemployed); we can go back until 1960. For GDP, which in the model is defined as $GDP = Y_F + p^* Y_M$, we have data from the World Penn Tables Real GDP per capita (Constant Prices: Chain series) already since 1953.

As explained above, for the calibration exercise we assume that both economies were under constant industrial policies before 1960 (Argentina was in steady state and Korea in a transition from zero skilled labor in 1950) and that in 1960 the path of actually policies gets revealed and subsequently implemented. Therefore we proceed in the following way. First, we choose the five parameters to match the targets for 1955, treating the statistics that we could compute for 1960 or 1962 as the targets for 1955. The model implied statistics from this exercise are shown in column 3 of table 3.3. Next, as we compute the model's transition from 1960, taking the stock of skilled labor of 1955 as the initial condition, we can compute the model implied moments for 1960, which we list in column 4 of table 3.3. This strategy leads to the calibrated values of the parameters shown in table 3.4.

Table 3.4: Calibrated parameters

	Description	**Value**
p^*	world relative price	1.950
α	output elasticity in M sector	0.975
A_F^j	agricultural productivity in Argentina	2.205
A_F^j	agricultural productivity in South Korea	0.321
ϕ	overall efficiency of education	0.9449

3.6 Results

In this section we present the model implied transition paths for the two countries, starting with their given stock of skilled labor at the beginning of 1960, towards a long-run free-trade steady state. As described above, we assume from the last data point a linear trend in tariff and export policies to zero over 50 years (10 periods).

3.6.1 Transition of Argentina

Figure 3.7 shows the model implied transition path (solid lines) for Argentina under the actual policies up to the year 2012. The dotted line shows the corresponding data.[7] Starting from a very high protection, as import tariffs on manufactures are lowered over time (top left panel), while import subsidies are constantly at zero (top mid panel), the country imports more and more manufactured goods, and as a consequence employment in manufacturing declines. For many periods, supply of skilled labor is in excess of demand in manufacturing, which lowers the wage for skilled workers down to the level of unskilled labor, and some of the skilled workforce is hired by the agricultural sector. Only in the

[7]The data for per capita GDP is normalized such that it takes on the 1960 value of the model analogue.

longer run[8], when the excess supply has been cleared through newborn unskilled workers replacing older workers, the skilled wage rises again above the price for unskilled labor. The model predicts that as import protection is lowered, the economy specializes more

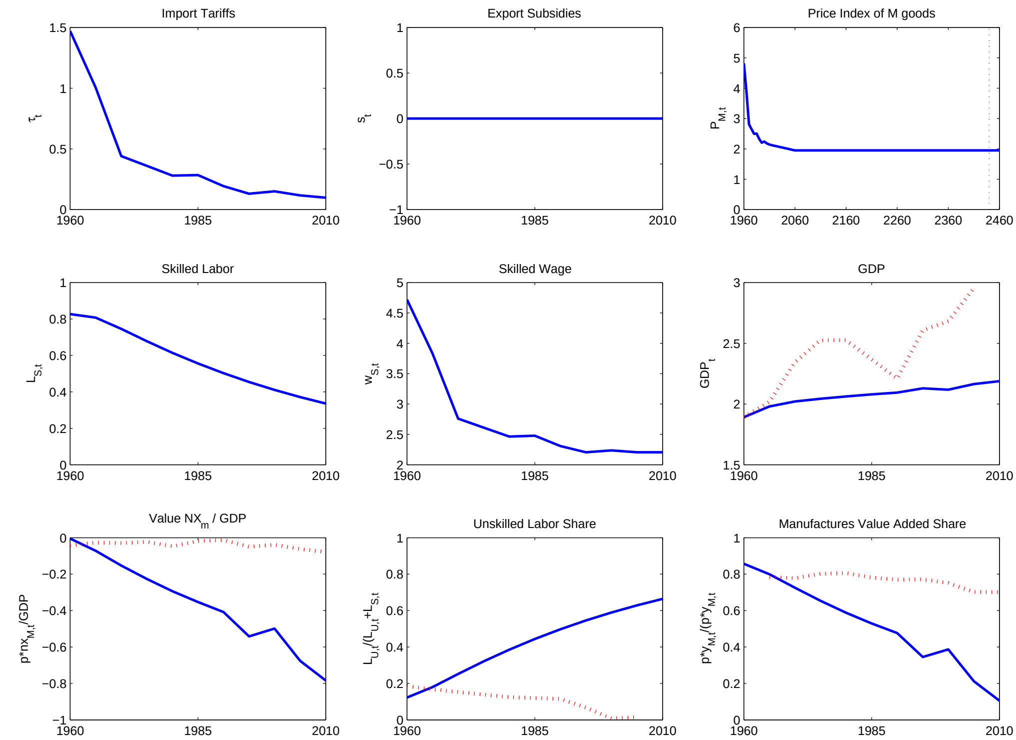

Figure 3.7: Transition path of Argentina

Notes: Given the history of import tariffs (upper-left panel) and export subsidies (upper-mid), the solid lines show the model implied transition path. For GDP, manufacturing exports relative to GDP, share of unskilled labor, and manufacturing's value added share, the dotted lines show the corresponding data.

and more in agriculture. As a consequence, the value added share and net exports of manufactures relative to GDP decline, as seen in the data, albeit the model exacerbates these changes.

3.6.2 Transition of South Korea

Figure 3.8 shows the calibrated model's implied transition path for South Korea and the corresponding data (dotted line). Both import tariffs (top left panel) and export subsidies (top mid panel) for manufactured goods were relatively high in 1960. Subsequently both these policy measures are reduced. The economy converges to a steady state in which

[8]The full transition paths to the steady state, which lies in the distant future, are given in appendix 3.C.

it specializes in manufacturing and is a net exporter of these goods. Consequently, the share of manufactures in value added and in total employment rises. Despite the reduction

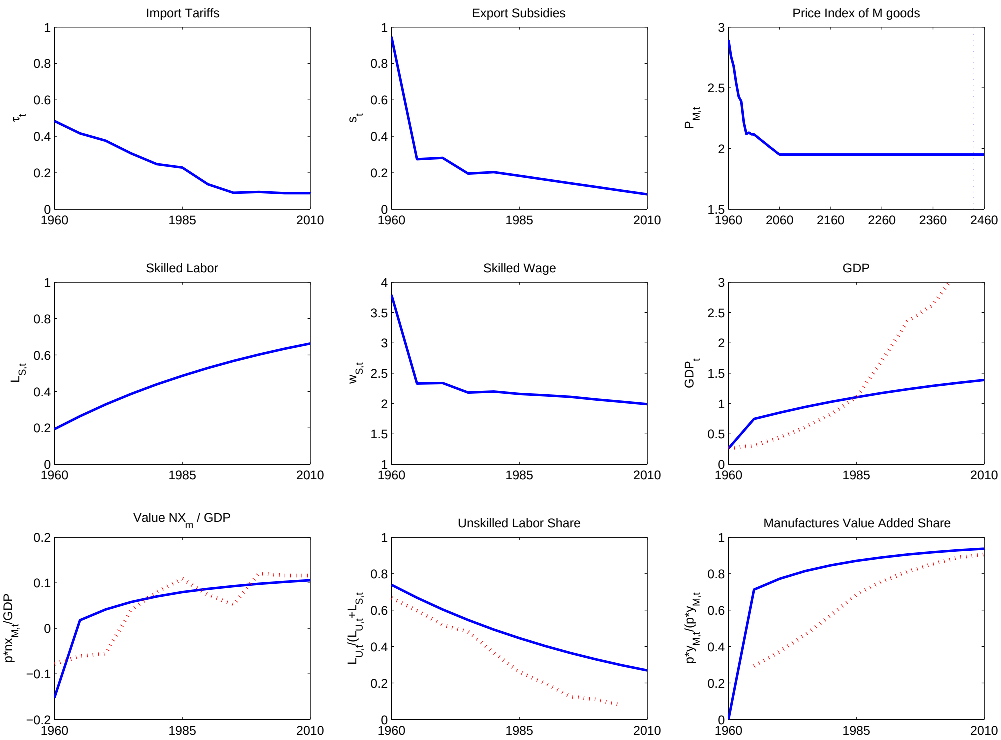

Figure 3.8: Transition path of Korea

Notes: Given the history of import tariffs (upper-left panel) and export subsidies (upper-mid), the solid lines show the model implied transition path. For GDP, manufacturing exports relative to GDP, share of unskilled labor, and manufacturing's value added share, the dotted lines show the corresponding data.

in export subsidies over time, in South Korea the manufacturing sector and its exports keep rising. While the model predicts in principle the rise of manufacturing that we see in the data, in terms of employment shares and value added shares it lacks somewhat in the timing. But given that we do not assume any productivity growth or capital accumulation, the model does remarkably well in matching the trends.

3.6.3 Comparing the Transition Experiences

While both countries see a huge decline an import tariffs, the transition experience is very different. Despite falling incentives for Korean firms to export manufactures, the economy's export of manufactured goods are rising over time. In Argentina, who in the model did not see a fall in export subsidies, net exports are predicted to decline further.

The differential response is due to comparative advantage. As over time import tariffs and export subsidies are removed, the economies move towards free trade. Since Korea's agricultural productivity is low compared to the international relative price of these goods, its economy specializes in manufacturing and is net exporting, even in the absence of trade policies. In Argentina on the other hand, the agricultural sector is very productive, and as a consequence the economy exports agricultural goods and imports manufactures when trade is liberalized.

In figure 3.9 we plot the model-implied relative performance of Korea to Argentina. While the model predicts that Korea overtakes Argentina in terms of skilled labor, it does not predict this for per capita GDP. This is not surprising as we do not allow for capital accumulation.

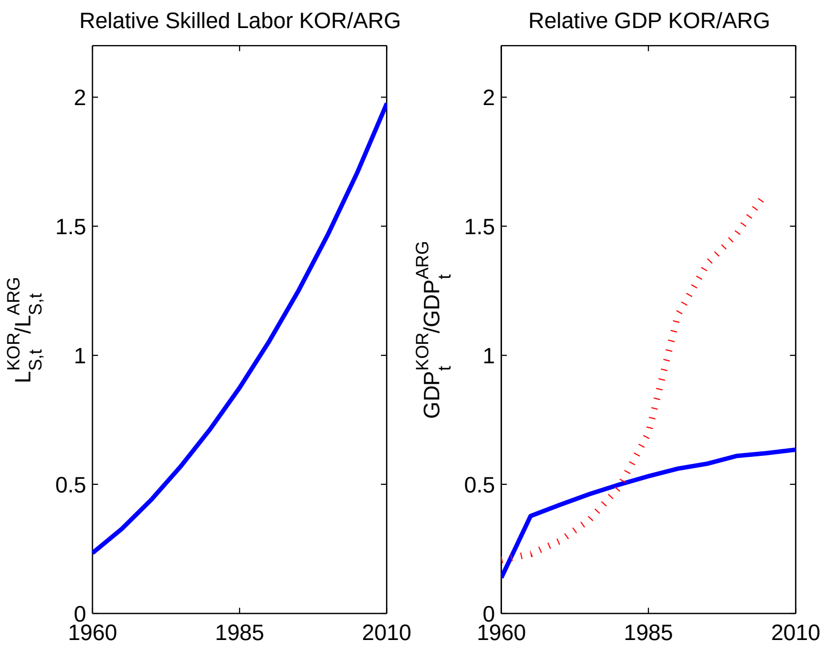

Figure 3.9: Relative growth experience

3.6.4 First Set of Counterfactuals: If Argentina had South Korean Policies

In figure 3.10 we show the transition Argentina, given their initial amount of skilled labor, would have experienced if they had adopted the same import tariffs on manufactures as Korea. Similarly figures 3.11 and 3.12 plot the transitional dynamics if Argentina had offered Korean export subsidies, or both policies as Korea respectively. The dashed line replicates the transition path of the benchmark model under actual policies, and the dotted lines show the actual data.

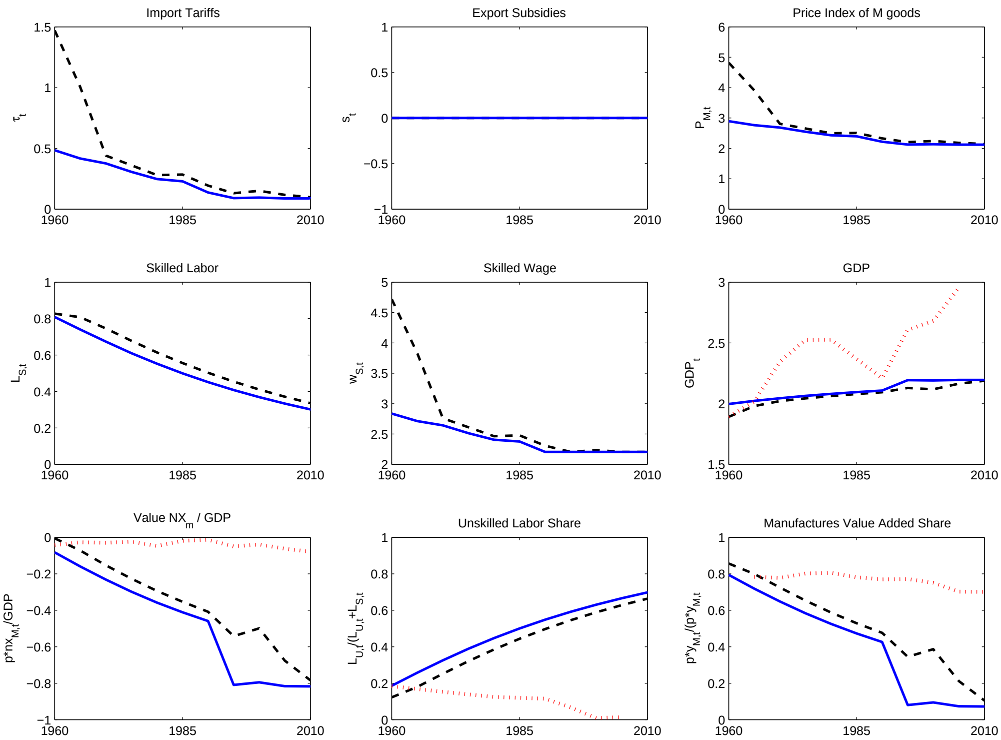

Figure 3.10: If Argentina had South Korean tariffs

Notes: This solid lines show the transition path implied under counterfactual policies (displayed as solid lines in upper-left and upper-mid panel). The dashed line replicates the transition path under actual policies (dashed in upper-left and upper-mid). In the last four panels, the dotted lines show the data.

From these policy experiments we can draw two conclusions for Argentina. First, measures of export promotion of Korean magnitude would not have any effect on the Argentine economy, as figure 3.11 shows. Even with such export subsidies, our calibrated model suggests that Argentine firms would not have opted to export, but to continue to exploit the relatively high domestic monopoly rents. Second, if Argentina had reduced tariffs to Korean levels (or even further), their GDP would have been higher (see figure 3.10)– due to increased gains from international trade.

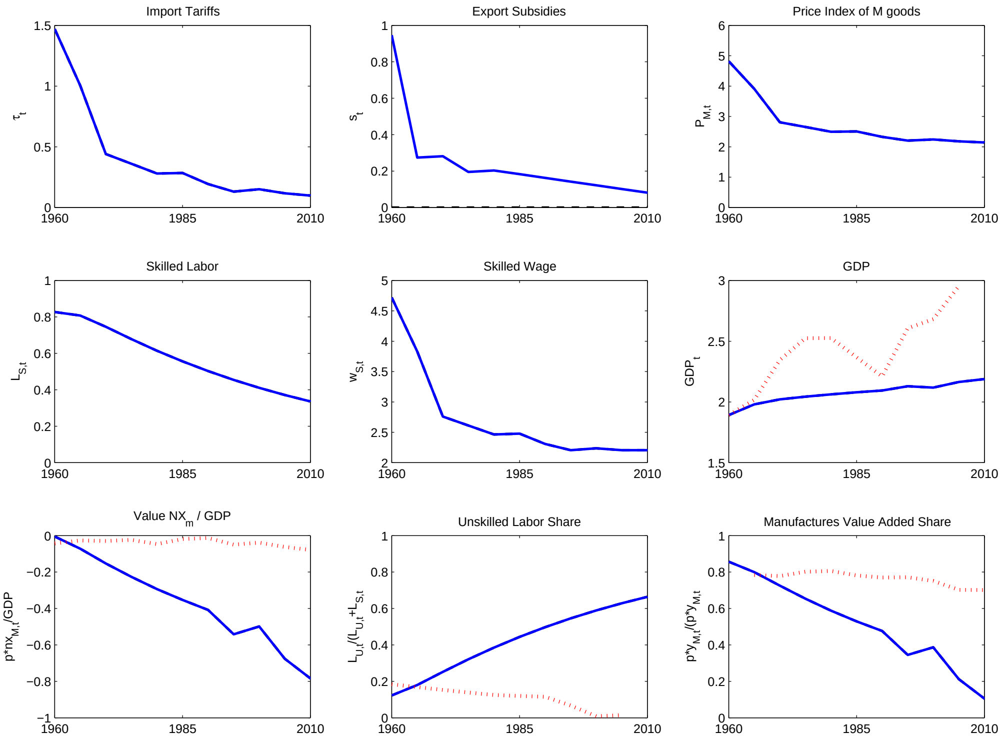

Figure 3.11: If Argentina had South Korean subsidies

Notes: This solid lines show the transition path implied under counterfactual policies (displayed as solid lines in upper-left and upper-mid panel). The dashed line replicates the transition path under actual policies (dashed in upper-left and upper-mid). In the last four panels, the dotted lines show the data.

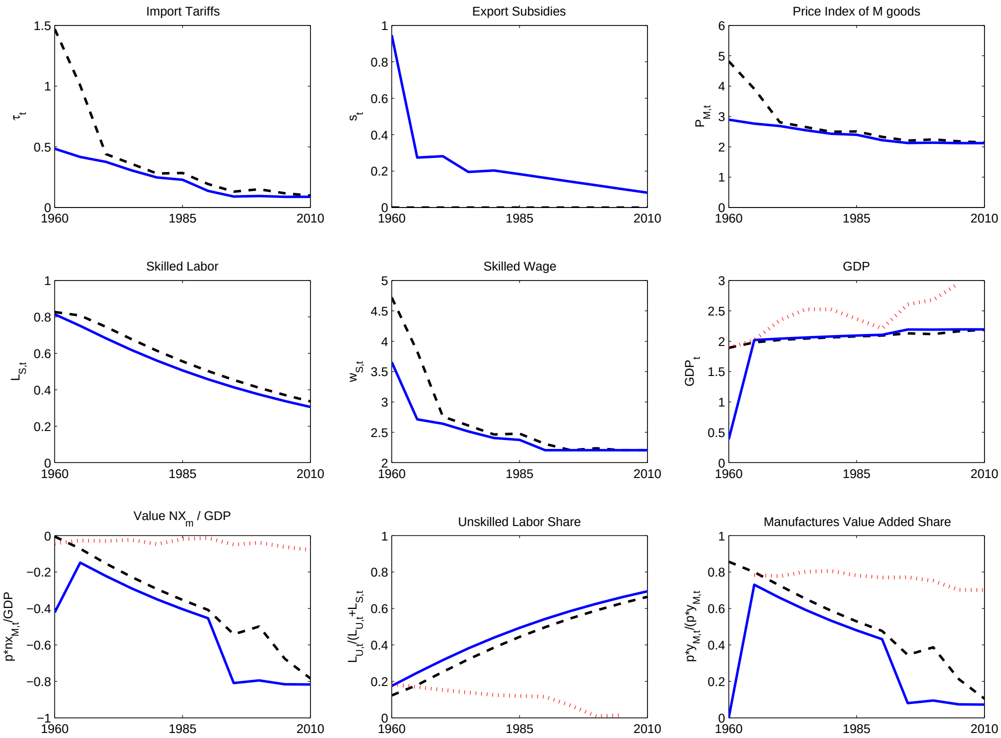

Figure 3.12: If Argentina had all South Korean policies

Notes: This solid lines show the transition path implied under counterfactual policies (displayed as solid lines in upper-left and upper-mid panel). The dashed line replicates the transition path under actual policies (dashed in upper-left and upper-mid). In the last four panels, the dotted lines show the data.

3.6.5 Second Set of Counterfactuals: If South Korea had the Policies of Argentina

Next we show the implied transition of Korea if they had adopted Argentine policies. Figure 3.10 plots the transition under Argentine import tariffs, figure 3.11 under no export subsidies (as in our model variant for Argentina), and figure 3.12 when both policies are as in Argentina. Again, the dashed lines replicates the transition under the actual Korean policies, and the dotted line the data.

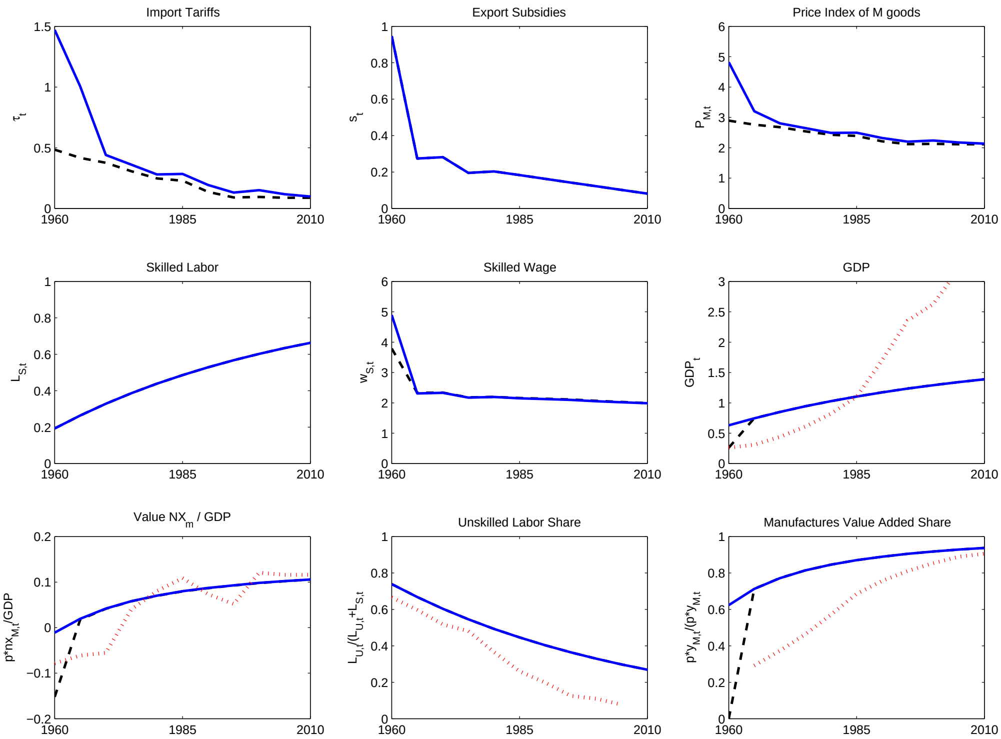

Figure 3.13: If South Korea had Argentine tariffs

Notes: This solid lines show the transition path implied under counterfactual policies (displayed as solid lines in upper-left and upper-mid panel). The dashed line replicates the transition path under actual policies (dashed in upper-left and upper-mid). In the last four panels, the dotted lines show the data.

The policy experiments for South Korea point out various results. Figure 3.10 shows, if Korea had chosen tariffs on manufactures as high as the Argentine ones, it would have affected the economy only in the 1960s, when the country was actually importing manufactured goods. Then they would have imported less. But the calibrated model suggests that South Korea firms would have eventually switched to exporting, even if no export subsidies had been installed, as in figure 3.11. Therefore higher import tariffs would

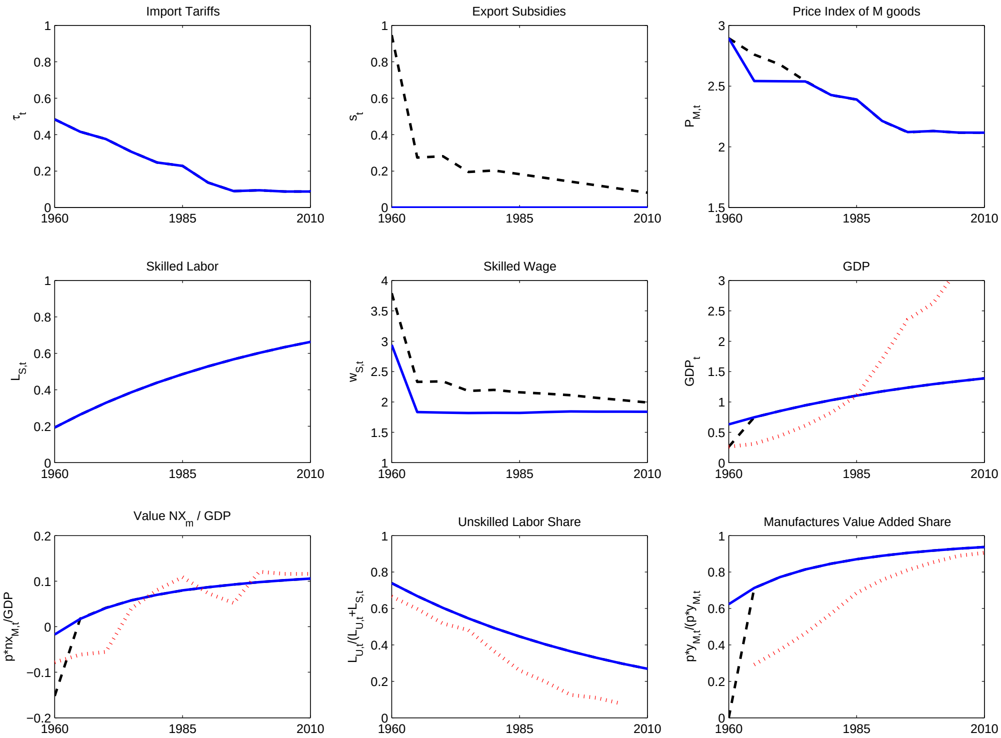

Figure 3.14: If South Korea had no export subsidies

Notes: This solid lines show the transition path implied under counterfactual policies (displayed as solid lines in upper-left and upper-mid panel). The dashed line replicates the transition path under actual policies (dashed in upper-left and upper-mid). In the last four panels, the dotted lines show the data.

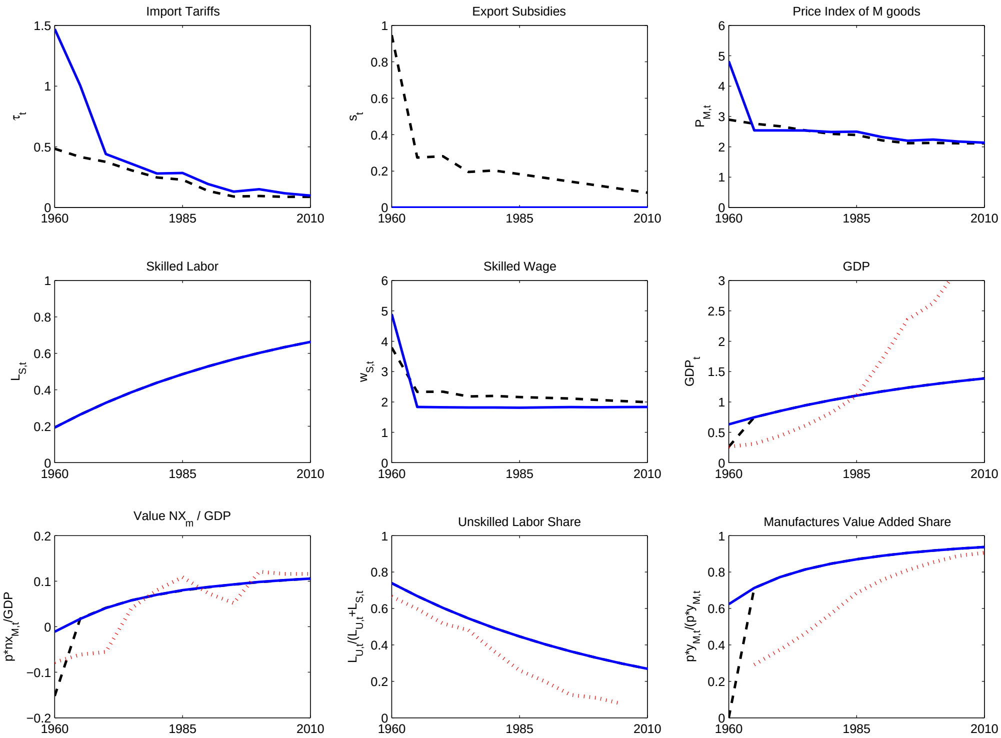

Figure 3.15: If South Korea had both tariffs and subsidies of Argentina

Notes: This solid lines show the transition path implied under counterfactual policies (displayed as solid lines in upper-left and upper-mid panel). The dashed line replicates the transition path under actual policies (dashed in upper-left and upper-mid). In the last four panels, the dotted lines show the data.

only have had an effect before the country had build up a sufficiently large stock of skilled labor. However, the calibrated model also suggests that export subsidies had no effect at all on the acquisition of skills. In fact, the profits producers can achieve from exporting are so large compared to domestic profits, that they always prefer selling abroad. As a consequence, the continuum of producers competes for skilled workers to the extent that the market clearing wage is so high, that all newborns choose to acquire skills ($\bar{\xi} = 1$). With export subsidies, manufacturing firms' labor demand is even stronger, resulting in an even higher skilled wage, which, however, does not translate into a higher supply of skilled workers.

3.6.6 Third Set of Counterfactuals: Keeping Initial Policies

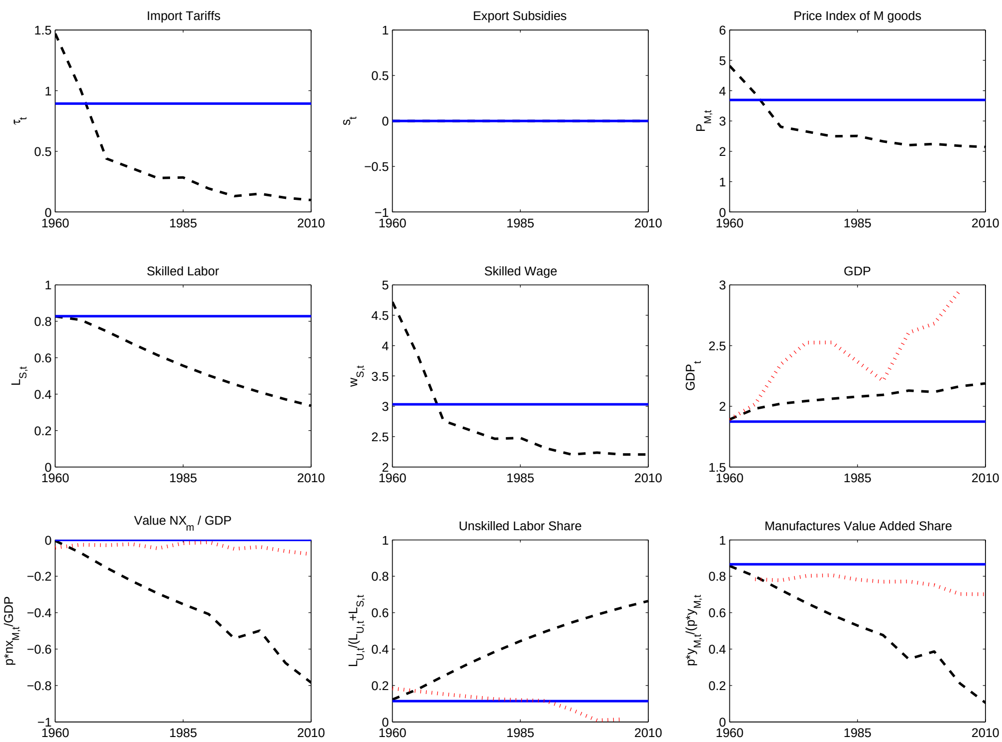

Figure 3.16: If Argentina had kept 1955 policies

Notes: This solid lines show the transition path implied under counterfactual policies (displayed as solid lines in upper-left and upper-mid panel). The dashed line replicates the transition path under actual policies (dashed in upper-left and upper-mid). In the last four panels, the dotted lines show the data.

In figures 3.16 and 3.17 we show the transition that would have occurred if both countries kept their policies throughout time as they were in 1955. Since the calibration for

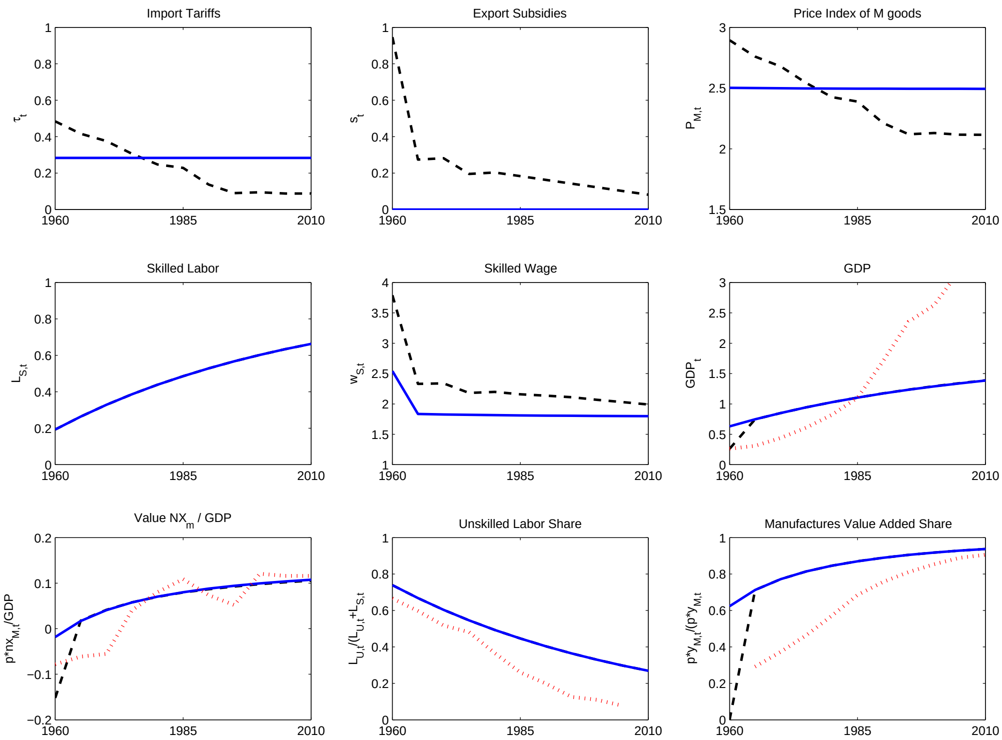

Figure 3.17: If South Korea had kept 1955 policies

Notes: This solid lines show the transition path implied under counterfactual policies (displayed as solid lines in upper-left and upper-mid panel). The dashed line replicates the transition path under actual policies (dashed in upper-left and upper-mid). In the last four panels, the dotted lines show the data.

Argentina was to steady state, keeping policies over time obviously implies that no variable changes at all. For Korea, however, sticking to the 1955 policies permanently implies a transition path very similar to the data and the path under actual policies (figure 3.8). This confirms the previous finding; policies were not important in the Korean experience. The structural change of South Korea was driven by comparative advantage in manufacturing which was initially held back by a lack of skilled labor.

3.7 Conclusions

We find that export promotion played no important role in the South Korean growth take-off. Comparative advantage, originating in differences in agricultural productivity, rather than policies, is what we find key in explaining the growth experience of Argentina and Korea. In Korea, the comparative advantage in manufacturing is so big that even in the absence of subsidies Korean firms would have started supplying the world market. In the 1960s Korea had been a net importer of these goods not because of policy measures, but because it was lacking skills in the workforce. Over time, more and more workers acquired skills, allowing a stronger expansion of production and exports of manufactures. Argentina's comparative advantage on the other hand lies in agriculture. Even export subsidies at Korean levels would not have had a substantial effect on manufacturing in Argentina, since the comparative advantage in agriculture has been too strong to make a switch to exporting manufactures attractive.

Appendix to Chapter 3

3.A Derivation of Consumer Demand

At any point in time t, a household i maximizes utility subject to his budget constraint. This can be solved as an expenditure minimization problem. To ease notation we drop the time subscript for now.

$$\min_{C^i_T, C^i_M} C^i_F + P_M C^i_M \text{ s.t. } \frac{(C^i_F - \gamma)^\theta (C^i_M)^{1-\theta}}{\theta^\theta (1-\theta)^{1-\theta}} = C^i$$

which gives demand for F and M goods as

$$\begin{aligned} C^i_F &= \theta P_M^{1-\theta} C^i + \gamma = \theta E^i + (1-\theta)\gamma \\ C^i_M &= (1-\theta)\frac{C^i}{P_M^\theta} = (1-\theta)\frac{E^i - \gamma}{P_M} \end{aligned}$$

where P_M is the consumer price of the basket of manufactured goods and $E^i = P \cdot C^i$ denotes the household's consumption expenditure.

With the assumption of intergenerational altruism and perfect intergenerational correlation of types within a dynasty, the model admits a representative consumer.[9] The

[9] Formally,

$$\begin{aligned} \int C_F(E^i(\xi_i))\mu(\xi_i)d\xi_i &= \int \left[\theta E^i(\xi_i) + (1-\theta)\gamma\right] \mu(\xi_i)d\xi_i \\ &= \theta \int E^i(\xi_i)\mu(\xi_i)d\xi_i + (1-\theta)\gamma = C_F\left(\int E^i(\xi_i)\mu(\xi_i)d\xi_i\right) \end{aligned}$$

and

$$\int C_M(E^i(\xi_i))\mu(\xi_i)d\xi_i = C_M\left(\int E^i(\xi_i)\mu(\xi_i)d\xi_i\right)$$

Since there is a unit mass of agents, the consumption aggregates are $C_F = \int C_F(E^i(\xi_i))\mu(\xi_i)d\xi_i$, $C_M =$

consumption-based price index is $P = P_M^{1-\theta} + \frac{\gamma}{C}$ such that $C_F + P_M C_M = P \cdot C = E$ where $E = \int E^i(\xi^i)\mu(\xi^i)d\xi^i$.

The minimization of expenditure on varieties $i \in [0,1]$ of the manufactured good with corresponding prices $p(i)$

$$\min_{c_M(i)} \int_0^1 p(i) \cdot c_M(i)\, di \text{ s.t. } C_M = \left[\int_0^1 c_M(i)^{\frac{\varepsilon-1}{\varepsilon}} di\right]^{\frac{\varepsilon}{\varepsilon-1}}$$

gives the price index for manufactured goods

$$P_M = \left[\int_0^1 p(i)^{1-\varepsilon} di\right]^{\frac{1}{1-\varepsilon}}$$

and the representative household's consumption demand for variety $i \in [0,1]$ as

$$c_M(i) = \left(\frac{P_M}{p(i)}\right)^{\varepsilon} C_M \text{ for all } i \in [0,1]$$

$\int C_M(E^i(\xi_i))\mu(\xi_i)d\xi_i$ and $C = \int C(E^i(\xi_i))\mu(\xi_i)d\xi_i$.

3.B Histories of Trade Policies

Table 3.5: Import protection and export promotion in Korea's manufacturing sector

	Import Tariffs					Export Subsidy
Year	Tariff [%]	+Other [%]	Source	World Bank	For Model [%]	Kim (1991) [%]
1949	10		Kim (1991); Krueger (1979)		10.00	
1950	40		Westphal and Kim (1982)		40.00	
1951					32.70	
1952	25.4		Kim (1991)		25.40	
1953					26.37	
1954					27.34	
1955					28.31	
1956					29.28	
1957	30.25		Kim (1991)		30.25	
1958		7.5	Kim (1991)		39.67	130.4
1959		31.1	Kim (1991)		65.20	172.0
1960		31.28	Kim (1991); Krueger (1979)		67.30	136.2
1961		0.6	Kim (1991)		38.55	18.1
1962	39.87	0.1	Kim (1991)		39.97	16.6
1963					39.75	48.8
1964		1.5	Kim (1991)		41.12	31.3
1965		3.2	Kim (1991)		42.70	14.8
1966		2.8	Kim (1991)		42.17	19.0
1967		3.1	Kim (1991)		42.35	23.1
1968	39.12	2.2	Kim (1991)		41.32	28.1
1969		1.6	Kim (1991)		39.20	27.8
1970		1.8	Kim (1991)		37.87	28.4
1971		1.2	Kim (1991)		35.75	29.6
1972		0.8	Kim (1991)		33.82	26.9
1973	31.5	0.1	Kim (1991)		31.60	23.7
1974		0.0	Kim (1991); Krueger (1979)		31.06	21.2
1975					30.61	16.7
1976					30.17	16.9
1977	29.72		Kim (1991)		29.72	19.2
1978					27.25	19.5
1979	24.77		Kim (1991)		24.77	20.2
1980					24.19	21.3
1981					23.61	
1982				23.7	23.70	
1983				23.7	23.70	
1984	21.88		Kim (1991)	21.9	21.90	

Notes: Columns 2 and 3 show import protection in the form of tariffs and other measures, reported by the authors of column 4. Column 5 reports the average tariffs published by the World Bank, and column 6 the values for tariffs that we take for our model. Column 7 lists the export subsidies reported by Kim (1991).

Table 3.5 summarizes our reading of the economic history literature on South Korean policies. Columns 2 and 3 show import tariffs and estimated contributions of other import protection measures that were installed in certain years, e.g. a foreign exchange tax. Column 4 reports the source from which we take this information. In column 5 we report the World Bank's data on South Korean tariffs, taken from "Average MFN Applied Tariff Rates in Developing and Industrial Countries, 1981-2009 (Unweighted in %)". Column 6 lists the values we take for feeding into our model, for which we take averages over five years. Where there are gaps in the series, we interpolate linearly. Since we have World Bank data only from 1981 onwards we have for earlier years to rely on the values reported in the economic history literature. Comparing the World Bank data (column 6) for the early 1980s with the values from Kim (1991), Table 3.4 "Simple Average tariff rates", (column 1) shows that they are consistent. The values for export subsidies that we use in the model are drawn from Kim (1991), Table 3.1 "Gross [incl. indirect tax and tariff exemptions] export subsidies", and shown in column 7.

Table 3.6: Import protection in Argentina's manufacturing sector

Import Tariffs of Argentina

Year	Tariff [%]	Source	World Bank	For Model [%]
1945	12.2	Amsden (2001)		12.20
1946	12.2	Amsden (2001)		12.20
1947	12.2	Amsden (2001)		12.20
1948	12.2	Amsden (2001)		12.20
1949	12.2	Amsden (2001)		12.20
1950	12.2	Amsden (2001)		12.20
1951				27.62
1952				43.04
1953				58.47
1954				73.89
1955				89.31
1956				104.73
1957				120.16
1958				135.58
1959	151	Cavallo and Cottani (1991)		151.00
1960				150.27
1961				149.53
1962	148.8	Amsden (2001)		148.80
1963				132.69
1964				116.57
1965				100.46
1966				84.34
1967				68.23
1968				52.11
1969	36	Amsden (2001)		36.00
⋮				
1982			28	28

Notes: Columns 2 shows import tariffs reported by the authors shown in column 4. Column 5 reports the average tariffs published by the World Bank. Column 6 shows the values for tariffs that we take for our model.

Similarly, we construct a series of Argentine tariffs to feed into the model. Since data from the World Bank is only available after 1981, we use for previous years values reported by various authors. For Argentina our main source is Amsden (2001). Table 3.6 lists the data employed. For years where we do not have a value from the literate nor from the World Bank database, we interpolate linearly.

3.C Full Transition Paths

The main text shows the transition implied by the model for the periods where we can compare to the data, up to 2010. The economy reach the steady state at a later point in time. Figures 3.18 and 3.19 show the full transition paths.

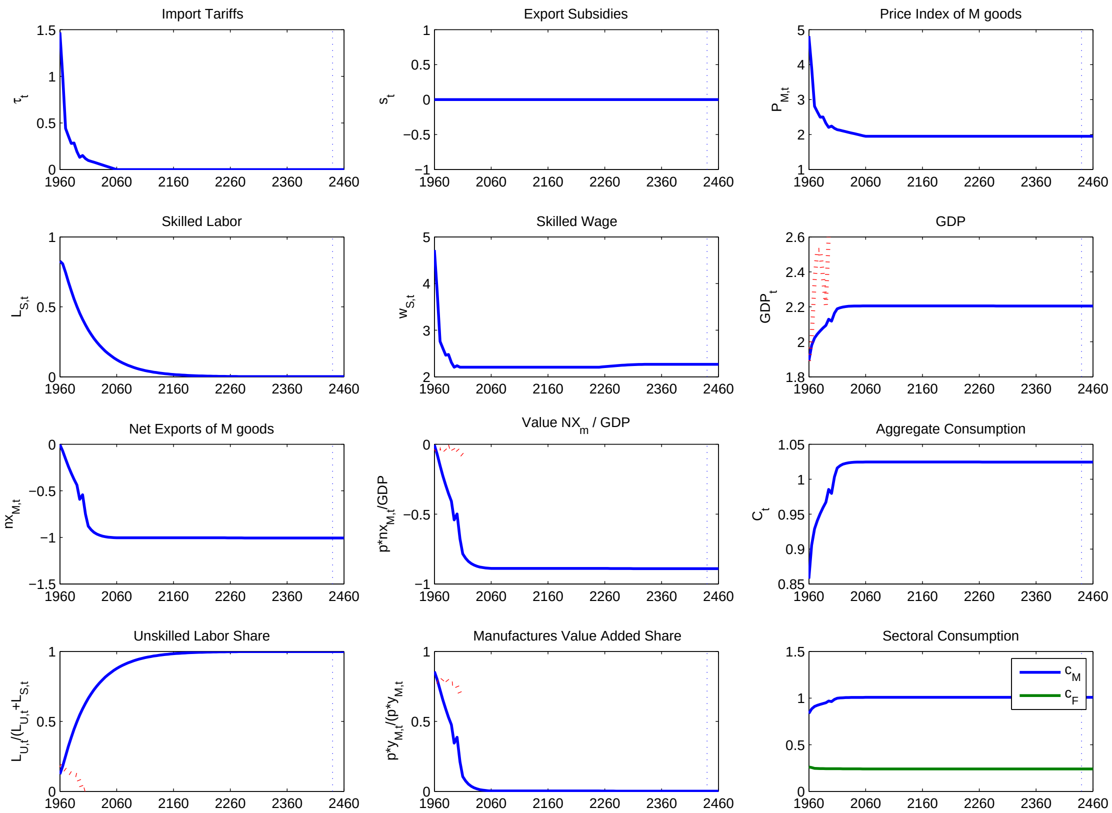

Figure 3.18: Full transition path of Argentina

Notes: Given the history of import tariffs (upper-left panel) and export subsidies (upper-mid), the solid lines show the model implied transition path. For GDP, manufacturing exports relative to GDP, share of unskilled labor, and manufacturing's value added share, the dotted lines show the corresponding data.

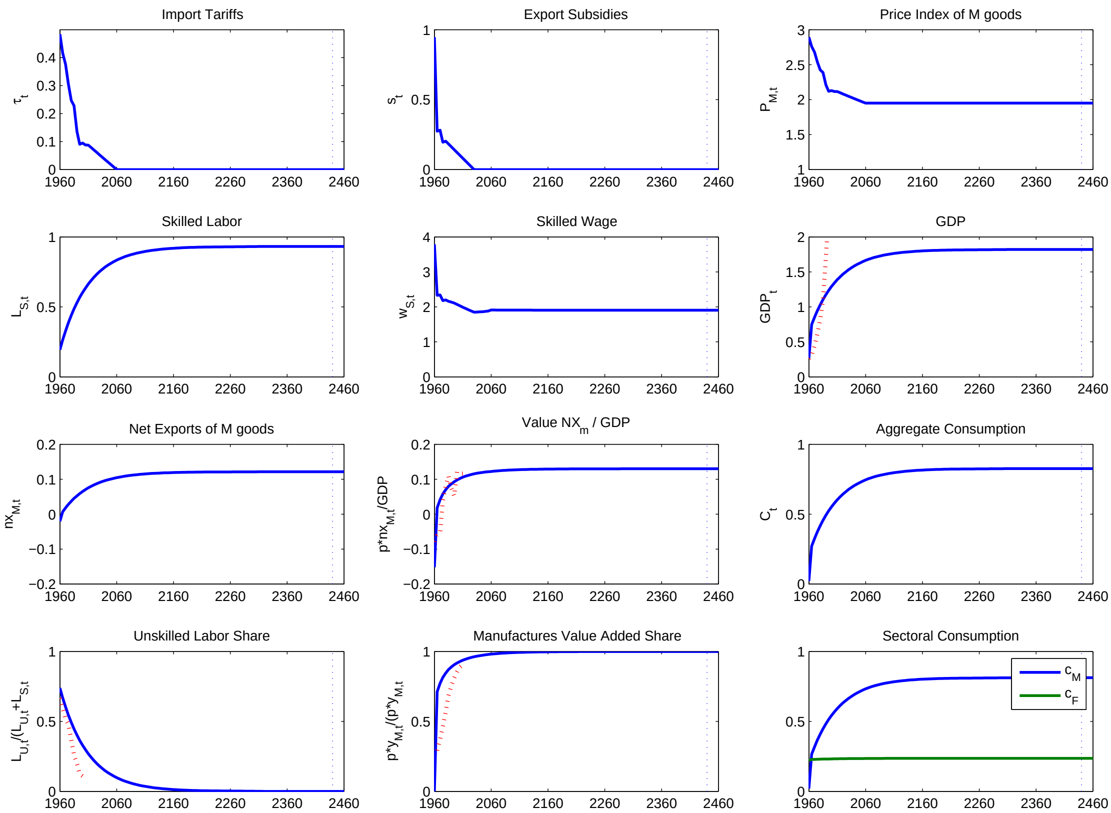

Figure 3.19: Full transition path of South Korea

Notes: Given the history of import tariffs (upper-left panel) and export subsidies (upper-mid), the solid lines show the model implied transition path. For GDP, manufacturing exports relative to GDP, share of unskilled labor, and manufacturing's value added share, the dotted lines show the corresponding data.

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