Essays on the Impact of China's One-Child Policy on Economic Development

by

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Abstract

My dissertation focuses on the macroeconomic consequences of China's one-child policy. The first chapter examines the effects of China's one-child policy on savings and foreign reserve accumulation. Fertility control increases the saving rate both by altering saving decisions at the household level, and by altering the demographic composition of the population at the aggregate level. As in Song, Storesletten and Zilibotti (2011), government-owned firms are assumed to be less productive but have better access to the credit market compare to entrepreneurial firms. As labor switches from less productive to more productive firms, demand for domestic bank borrowing decreases. As saving increases while demand for loans decreases, domestic savings are invested abroad, generating a foreign surplus.

In the second chapter of my dissertation, I provide a theoretical framework for examining the effects of China's one-child policy on its long run economic growth. The model incorporates within family intergenerational transfers and a "quantity/quality" tradeoff. When a population control policy is implemented, parents increase investment in their children's education in order to compensate for reduction in future transfers. As in Galor and Weil (2010), technological progress is assumed to be driven by two forces: the population size and the level of education. With population control, the total population decreases and the average level of education increases. Thus, the overall effect on technological progress is ambiguous without specifying functional forms for technology and human capital.

The third chapter provides a quantitative exploration of the model from the second chapter. The calibrated results are consistent with the model, in which population, technological progress, and income per capita move in endogenous cycles. The impact of China's one-child policy depends on the timing of the policy. If the policy is enforced when the population is large enough, hence when the rate of technological progress is high, it increases GDP growth both in the short-run and in the long-run.

Keywords: China; one-child policy; saving; foreign reserve accumulation; economic growth

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Chapter 1

Born Like China, Growing Like China

1.1 Introduction

In 1979 China introduced the so-called "one-child policy", in an effort to reduce population growth and improve economic conditions. This paper studies the effects of this policy on saving, investment, and foreign reserve accumulation. It constructs a dynamic overlapping generations model, calibrated to match the unique demographic features of the Chinese experience. Echoing the results of Song, Storesletten, and Zilibotti (2011), the model shows that China's recent current account surpluses may have nothing to do with exchange rate manipulation, but instead reflect the unique internal characteristics of the Chinese economy. Unlike Song et. al., however, I am able to explain the rapid rise in China's saving rate without appealing to exogenous changes in financial market regulations. Instead, I show it can be entirely explained by the one-child policy.

China's household saving rate has been increasing at a rapid rate. The average urban household saving rate rose steadily from 12.0% in the early 1980's to about 30% in 2010. The one-child policy influenced saving at both aggregate and household levels. On the one hand, it shifted China's demographic composition, which influences the aggregate savings rate, even if household saving rates remain unchanged. At the same time, however, the one-child policy also impacted saving at the household level. In countries like China, where the social pension system is not well established, within-family intergenerational transfers are very important. Parents raise and educate their children when they are young, and children financially support their parents when they retire. Intergenerational transfers are not just based on cultural norms, but are also stipulated by Constitutional Law. Children provide a crucial source of old age support in China. Thus, when exogenous fertility control is implemented, household's consumption and saving decisions will be influenced.

In addition to explaining China's "Saving Puzzle", the one-child policy can also explain China's "Allocation Puzzle". Over the past couple of decades, China has been experiencing rapid economic growth, sustained capital accumulation, and a growing foreign surplus. This combination is puzzling from the perspective of neoclassical growth theory, which predicts that capital should flow from rich countries to poor countries. Based on this theory, we should expect to see capital flow into China, given its rapid growth and poor initial economic conditions. (Lucas (1990)). Allowing for productivity differences across countries doesn't help to explain the puzzle. If productivity levels are converging across countries, then the theory predicts that countries experiencing relatively rapid convergence should be net international borrowers. The data indicate precisely the opposite. (Gourinchas and Jeanne (2013)). In addition, Jeanne and Ranciere (2011) and Bacchetta, Benhima and Kalantzis(2013) found that neither the precautionary motive against aggregate shocks, nor the presence of idiosyncratic shocks is sufficient enough to explain international reserve accumulation in China.

In this paper, I show that demographically induced changes in saving can explain the build-up of a large foreign surplus in China. I borrow one key element from Song, Storesletten and Zilibotti's (2011) model. Their model features financial and contractual imperfections that affect different types of firms asymmetrically. There are two types of firms in their model, domestic private enterprises (DPE), and state-owned enterprises (SOE). SOE are less productive but have better access to credit. DPE must finance their investment through internal savings. I use this idea in my model in order to explain changes in the domestic demand for loans. As capital in the DPE sector accumulates, labor switches from the lower productivity SOE sector to the higher productivity DPE sector. As investment in the financially integrated SOE sector shrinks, demand for domestic bank borrowing decreases. Domestic savings are invested abroad, generating a foreign surplus.

The data suggest that the process of factor reallocation and the pace of foreign reserve accumulation in China accelerated around the year 2000. Song et. al. account for this acceleration by assuming that credit constraints were exogenously relaxed around this time. In this paper, I instead explain this acceleration *endogenously* by incorporating into their model a key demographic characteristic of China's post-reform experience. I show that these demographically induced changes in saving can explain why China's economy apparently underwent a structural break around the year 2000.

Related Literature In subsequent work with Wang (Song, Storesletten, Wang, and Zilibotti (2015)), they incorporate the low birth rates following the one-child policy. However, their paper focuses on the welfare effects of alternative pension reforms. They use their earlier work to calibrate the wage and interest rate process, and conclude that in a fast growing economy like China, delaying pension reform implies larger welfare gains. In addition, the gain from delaying is larger with a lower fertility rate. In this paper, I extend the model by taking inter-generational transfers *within families* into consideration, which is excluded in the two previous papers by Song et. al.. In addition, my paper is aimed more at explaining the "allocation puzzle" through the effects of the one child policy on aggregate saving.

There are a few other recent papers that study the links between exogenously imposed fertility restrictions and China's household saving rate. Choukhmane, Coeurdacier and Jin(2014) examine the impact of the one-child-policy on saving decisions through intergenerational transfers that depend on the quantity and quality of offspring. Their model shows that even though households tend to increase education investment in the only child, the increase in the only child's future income is not enough to compensate for the overall loss in transfers when parents retire. In addition, they exploit a "twin" experiment. Their regression analysis suggests that an additional twin child reduces the saving rate on average by $6-7\%$. Their findings support the notion that fertility changes alter households' saving decisions. Wei and Zhang (2014) also argue that the one child policy altered household saving behavior. They argue that the one child policy caused a gender imbalance in China, because Chinese families favor sons. Chinese parents with a son raise their savings in order to improve their son's relative attractiveness for marriage. They provide statistical evidence to support their theory. They show that savings by otherwise identical households with a son tend to be greater in regions with a higher sex ratio (number of men per woman). They also show that the aggregate local savings rate is higher in provinces where the local sex ratio is higher.

Although this previous literature has provided evidence of the linkages between the one-child policy and household savings, this paper is the first to provide empirical evidence showing that the one child policy can explain the Allocation Puzzle and the build-up of a large foreign surplus in China. In sections 1.2, I develop a simple three-period overlapping generations model to illustrate the economic mechanisms at work. In section 1.3, I extend the model to allow realistic lifetimes. I then calibrate the model's parameters, and solve it numerically.

1.2 Model

In this section, I outline the benchmark model. I extend Song, Storesletten and Zilibotti(2011)'s model by incorporating within family intergenerational transfers. Households now pay a cost to raise their children when they are young, and then get support from their children when they are old. As the number of children and siblings decreases, households' saving decisions and private firms' capital accumulation decisions will also be affected.

Consider an economy that is populated by three overlapping generations, referred to as children, adults, and the old. Individuals do not make economic decisions when they are children; they start entering the market when they become adults. There are two types of agents, workers and entrepreneurs. Workers enter the economy when they become adults and supply one unit of labor inelastically. They retire from the labor market when they become old. Entrepreneurs also enter the market when they become adults. They have the same life expectancy as workers. They are assumed to work at their parents' firm as managers in the first period. They then become entrepreneurs, and have their own firms in the second period. Each cohort consists of a measure of N_t of workers and μN_t of entrepreneurs. All individuals have kids when they become adults in the first period, and they need to pay $Q(n^k) = q(log(n^k) + 1)$ as a cost in terms of income for raising n^k children. q is a scalar which measures the percentage cost in terms of income; it is identical for all agents. In the second period, employees live off savings and an allowance from their children, while entrepreneurs live off the profits of the firm.

1.2.1 Preferences

Agents maximize the time separable utility function:

$$U_t = \sum_{t=1}^{2} \beta^{t-1} \frac{c_t^{(1-\gamma)} - 1}{(1-\gamma)} + G(n^k) \tag{1.1}$$

where n^k is the number of kids. $G(n^k)$ is the utility from having n^k children. It is assumed that $G'(n^k) > 0$ and $G''(n^k) < 0$

1.2.2 Workers

Consider an agent who was born at t=0. At t=1, he is a young worker and starts to make economic decisions. His budget constraint is

$$c_1 + s_1 + Q(n^k) + \frac{P(n^s)}{n^s} = w_1$$

where $Q(n^k)$ is the cost of having n^k children. $\frac{P(n^s)}{n^s}$ is the allowance that each worker must give to his parents, where n^s is the number of siblings, including himself. Assume $\frac{\Delta P(n^s)}{\Delta n^s} > 0$.

This agent retires at t=2. He lives off his savings and his children's support.

$$c_2 = Rs_1 + P(n^k)$$

where similarly $\frac{\Delta P(n^k)}{\Delta n^k} > 0$

1.2.3 Entrepreneurs

As in Song, Storesletten and Zilibotti(2011), I assume there are two types of firms. One is government-owned firms (G), and the other is entrepreneur-owned firms (E). The G firms have lower productivity while having perfect access to the financial market; the E firms have higher productivity, but face a credit constraint. Both production functions are Cobb-Douglas

$$Y_{Gt} = K_{Gt}^{\alpha}(A_t N_{Gt})^{1-\alpha}$$
$$Y_{Et} = K_{Et}^{\alpha}(\chi A_t N_{Et})^{1-\alpha}$$

Note: $\chi > 1$

The labor market is competitive, and wages equal the marginal product of labor:

$$w_E = w_G = (1-\alpha)(\frac{\alpha}{R})^{\frac{\alpha}{1-\alpha}} A_t \tag{1.2}$$

The value of the E firm is then:

$$Max_{N_{Et}} \qquad [K_{Et}^{\alpha}(\chi A_t N_{Et})^{1-\alpha} - M_t - W_t N_{Et}]$$

where M_t is the payment to managers, who are the children of the owner. Assume owners favor their own kids, and pay them a share ϕ of output as wage:

$$M_t = \phi K_{Et}^{\alpha}(\chi A_t N_E t)^{1-\alpha} \tag{1.3}$$

From the wage equation,

$$N_{Et} = ((1-\phi)\chi)^{\frac{1}{\alpha}} (\frac{R}{\alpha})^{\frac{1}{1-\alpha}} \frac{K_{Et}}{\chi A_t} \tag{1.4}$$

Taking the first-order condition and plugging it back into the equation yields the value of the firm:

$$\Pi_t(K_{Et}) = (1-\phi)^{\frac{1}{\alpha}} \chi^{\frac{1-\alpha}{\alpha}} R K_{Et} = \rho_E K_{Et} \tag{1.5}$$

Firms will only produce if $\rho_E > R$. Thus, we need $\chi > (1-\phi)^{\frac{1}{1-\alpha}}$. As in Song, Storesletten and Zilibotti(2011), assume E firms can only pledge to pay back to the bank a share η of net profit. Thus, the credit constraint that E firms face is $Rl^E \leq \eta \rho_E (s^E + l^E)$, where l^E is the bank loan.

At t=1, young entrepreneurs work at their parents' firm as manager. Assuming they get a share ϕ of output as wage, their budget constraint is,

$$c_1^E + s_E + Q^E(n^k) = \frac{m}{n^s}$$

At t=2, they become the owner of the firm. The capital available to them is their previous period saving and bank loans.

$$c_2^E = \rho_E(l_E + s_E) - R l_E$$

In equilibrium the credit constraint is binding:

$$\frac{l_E}{l_E + s_E} = \frac{\eta \rho_E}{R} \tag{1.6}$$

Note that there is no allowance function, $P(n)$, entering the entrepreneurâĂŹs budget constraint. Entrepreneurs do not get an allowance from their children because they can live off the firm's profit in the second period, while their children are working for them as managers. Thus, young entrepreneurs simply save in the first period to accumulate capital for the second period's production.

1.2.4 Equilibrium

This section analyzes the equilibrium dynamics for workers and firms during a transition in which both G and E firms have positive employment.

Workers:

The representative worker maximizes the welfare fuction (1) under the budget constraints in section 1.2.2.

The utility maximizing number of kids is characterized by:

$$G'(n^k) = \pi^{-\gamma}(w_1 - Q(n^k) - \frac{P(n^s)}{n^s} + \frac{P(n^k)}{R})^{-\gamma}(Q'(n^k) - \frac{P'(n^k)}{R}) \tag{1.7}$$

where $\pi = 1 + \beta^{\frac{1}{\gamma}} R^{\frac{1}{\gamma}-1}$

The Euler equation for the representative worker is,

$$c_t^{-\gamma} = \beta R c_{t+1}^{-\gamma}$$

Proposition 1. *As the number of children decreases, a worker's total saving increases.*

Proof. Plugging the Euler equation into the budget constraint gives,

$$\begin{aligned} s_1 &= w_1 - c_1 - Q(n^k) \\ &= w_1(1 - \frac{1}{\pi}) - (1 - \frac{1}{\pi})Q(n^k) - (1 - \frac{1}{\pi})\frac{P(n^s)}{n^s} - \frac{1}{\pi}\frac{P(n^k)}{R} \end{aligned}$$

$$\frac{\Delta s_1}{\Delta n^k} = -(1 - \frac{1}{\pi})Q'(n^k) - \frac{1}{\pi R}P'(n^k) < 0$$

The intuition is that a reduction in the number of children leads to a reduction in expenditures, which increases their available resources for savings. Also, as the number of children decreases, there is a decrease in support from the children during retirement. Thus they need to save more to finance their consumption during the retirement period.

Entrepreneurs:

The representative Entrepreneur maximizes the welfare function (1) subject to their budget constraints in section 1.2.3 .

The utility maximizing number of kids is characterized by:

$$G'(n_E^k) = (c_E^1)^{-\gamma} \frac{R - \eta\rho_E}{\rho_E R(1-\eta)} \tag{1.8}$$

The Euler equation for the entrepreneur is,

$$c_t^{-\gamma} = \beta \frac{\rho_E R(1-\eta)}{R - \eta\rho_E} c_{t+1}^{-\gamma}$$

Proposition 2. *As the number of children decreases, an entrepreneurâĂŹs total saving increases.*

Proof. Plugging the Euler equation into the budget constraint, Entrepreneur's saving becomes,

$$\begin{aligned} s_E^1 &= \frac{m}{n^s} - c_E^1 - Q^E(n_E^k) \\ &= (\frac{m}{n^s} - Q^E(n^k))(1 - (\beta^{\frac{1}{\gamma}}(\frac{\rho_E R(1-\eta)}{R-\eta\rho_E})^{\frac{1-\gamma}{\gamma}} + 1)^{-1}) \end{aligned}$$

$$\frac{\Delta s_E^1}{\Delta n_E^k} = -Q'(n^k) < 0$$

Entrepreneurs save in order to accumulate capital for the next period, not for allowance purposes, so saving increases when the number of children decreases, because the cost decreases.

In a competitive equilibrium, the interest rate equals the marginal product of capital of G firms. Thus, for G firms:

$$K_{Gt} = (\frac{R}{\alpha})^{\frac{1}{\alpha-1}} A_t N_{Gt} \tag{1.9}$$

From E firms optimal employment equation:

$$K_{Et} = (1-\phi)^{-\frac{1}{\alpha}} \chi^{\frac{\alpha-1}{\alpha}} (\frac{R}{\alpha})^{\frac{1}{\alpha-1}} A_t N_{Et} \tag{1.10}$$

where full-employment implies $N_{Et} + N_{Gt} = N_t$

Proposition 3. *As the number of children and siblings decreases, capital accumulated by private owned firms grows faster.*

Proof. From (6)

$$K_{Et} = S^1_{E(t-1)}(\frac{R}{R-\eta\rho_E})$$

Thus,

$$k_{Et} = [k_{E(t-1)}\frac{\phi}{1-\phi}\frac{\rho_E}{\alpha n n^s} - Q(n^k)][1-(\beta^{\frac{1}{\gamma}}(\frac{\rho_E R(1-\eta)}{R-\eta\rho_E})^{\frac{1-\gamma}{\gamma}}+1)^{-1}](\frac{R}{R-\eta\rho_E})$$

where $k_{Et} = \frac{K_{Et}}{\mu N_t}$

As the number of children (n^k) decreases, capital grows faster. This is because entrepreneurs save more in the first period since there are fewer people to feed. Another thing that is worth noticing is that as number of siblings (n^s) decreases, wages of managers increase, as there are fewer siblings to share the profit with. This increases savings and capital accumulation as well.

Saving, Investment and Foreign surplus:

Banks' balance sheet

$$K_{Gt} + \frac{\eta\rho_E}{R}K_{Et} + B_t = s_{t-1}N_{t-1} \tag{1.11}$$

At the beginning of t, individuals work or borrow to produce. At the end of period t, they make consumption and saving decisions.

The right hand side consists of bank liabilities. The left hand side consists of bank assets: loans to the government-owned firms, loans to private firms, and foreign bonds.

Thus, for an economy in which all individuals only live for three periods, the country's net foreign assets are given by,

$$B_t = [\tau_t\frac{(1-\alpha)\frac{R}{\alpha}}{(1+g)(1+n)} - 1 + (1-\eta)\frac{N_{Et}}{N_t}](\frac{R}{\alpha})^{\frac{1}{\alpha-1}}A_t N_t \tag{1.12}$$

where g is the growth rate of technology, n is the population growth rate, $\tau = \frac{S}{w}$ is the saving rate of workers, and $\frac{N_{Et}}{N_t}$ is the E firm employment share. So far, the predictions of the model are similar to Song, Storesletten and Zilibotti(2011). However, in Song, Storesletten and Zilibotti(2011), a worker's saving rate is constant because households' saving behavior does not change over time. Here, τ changes over time because it is determined by changes in n^k and n^s. In addition, the growth rate of $\frac{N_{Et}}{N_t}$ is also constant in Song, Storesletten and Zilibotti(2011)'s model, because growth in the E firm labor share is determined by the managers' saving behavior, which doesn't change over time. In my model, changes in the fertility rate has an impact on managers' saving behavior, and thus the growth rate of $\frac{N_{Et}}{N_t}$ is also changing over time.

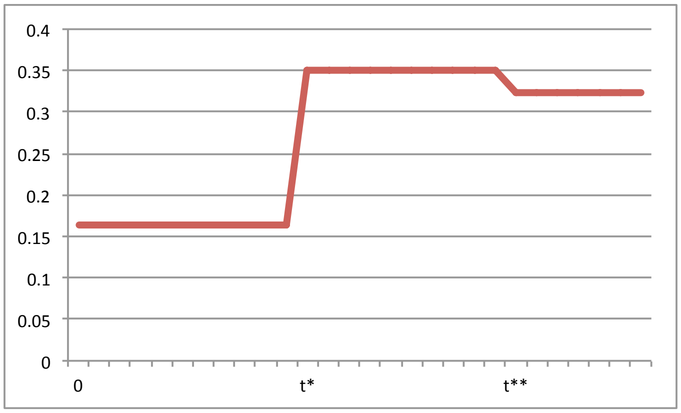


Figure 1.1: Saving Rate in the 3-Period Model

1.2.5 Discussion of τ_t and $\frac{N_{Et}}{N_t}$ in the 3-Period Model

From section 2.4, a worker's saving rate in terms of income, τ_t, is given by

$$\tau(n^k, n^s) = (1 - \frac{1}{\pi})(1 - q(log(n^k) + 1) - \frac{p(n^s)}{n^s}) - \frac{g}{\pi}\frac{p(n^k)}{R}$$

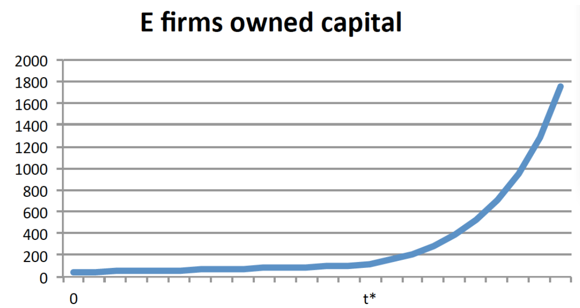
An individual's saving behavior depends on both the number of children and the number of siblings they have. Figure 1.1 depicts the saving rate over time in the 3-period model. Here, I assume that the individuals who are only allowed to have one child enter the labor market at time t^*, while their children, the "only-child" cohort, enter the labor market at time t^{**}. Proposition 1 predicts that changes in the number of children and siblings produce changes in the saving rate. Therefore, there are changes in saving rate at both t^* and t^{**}. In this simple 3-period model, one cannot capture the gradual impacts of the policy on the age structure and savings rate. In section 1.4, I therefore extend the 3-period model to a demographically realistic multi-period model. This will allow me to exam how the one-child policy gradually alters the demographic composition and the aggregage saving rate.

Another determinant of B_t, besides τ, is the growth rate of $\frac{N_{Et}}{N_t}$, the E firm empolyment share. It is determined by both technology growth and the saving of entrepreneurs

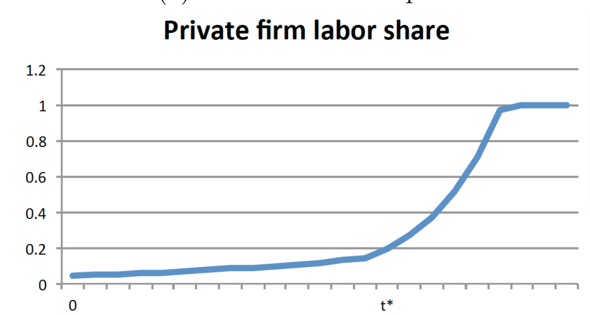
$$\frac{N_{Et+1}}{N_{Et}} = \frac{K_{Et+1}}{K_{Et}} / \frac{A_{t+1}}{A_t}$$

Note: $\frac{A_{t+1}}{A_t}$ is assumed to be a constant.

Proposition 4 shows that as n^k decreases, the total cost decreases. In addition, as n^s decreases, a young entrepreneur's disposable income increases because there are no siblings to split the profit with. Thus, as the number of children and siblings decreases, capital accumulation increases. The growth rate of E firms' employment share therefore increases over time. Figure 1.2(a) shows the time path of capital accumulated by E firms. Based on the theory, private capital increases at a constant rate over time, and it starts to increase



(a) Privated Firm Capital



(b) Private firm Labor Share

Figure 1.2: Transition in the Analytical Model

at a faster rate at t^*, where t^* is when the entrepreneurs who are affected by the policy start to enter the market. Song, Storesletten and Zilibotti(2011) also features a significant increase in E firms' employment share in early 2000. However, in their model this increase is caused by an exogenous relaxation of a credit constraint in early 2000. Here, I endogenize this increase. It is caused by a decrease in number of children. Figure 1.2(b) depicts the time path of E firms labor share.

As capital accumulates at a faster rate after t^*, the labor share of E firms starts to increase at a faster rate as well. The labor share of E firms keeps increasing until all labor is reallocated to the E firms. In the steady state, $\frac{N_{Et}}{N_t} = 1$, $n^k = n^s = 1$ and $n = 1$. Thus foreign net assets are given by,

$$\frac{B_T}{N_T} = [\tau^* \frac{(1-\alpha)\frac{R}{\alpha}}{g} - \eta(1 - \frac{(1-\delta)}{g})](\frac{R}{\alpha})^{\frac{1}{\alpha-1}} A_T$$

1.3 The Multi-period Model

In the previous section, I assumed that agents only live for three periods, with each period corresponding to about 25 years. In order to quantitatively match the theory with the data, I now extend the model to a multi-period model, in which agents live for 72 years, and so now a period corresponds to a single year. Clearly, the model must now be solved numerically.

1.3.1 Demographic Structure in 1988

China's one-child policy was suddenly announced at the end of 1979, and formally implemented in 1980. Given such short notice, the one-child policy is treated as an exogenous fertility shock in this paper. When the policy was first implemented, it was stricter in urban areas. Each couple could only have one child; otherwise they could face a large fine, or even lose their jobs, unless the first child was disabled. On the other hand, it was less strictly enforced in rural areas, where each couple might be allowed to have a second child if certain requirements were met. In this paper, I focus on the urban areas, where the policy was stricter. This policy was supposed to alleviate social, economic and environmental problems that are associated with a large population. However, over time a series of problems started to appear. For example, sex imbalance and population aging. Thus, starting in the 1990s, the policy was relaxed in a few provinces. Those provinces allowed each couple to have a maximum of two children if both parents are the only-child in their families. In 2000s, the policy was relaxed national wide. However, this policy relaxation only affects the "only-child" generation, who are the only-child in their families.

The year 1988 was chosen as the initial year for the analysis. In 1988, the policy had been implemented for 8 years. People who had all their children before 1980 were not affected by the policy. On the other hand, younger adults who had their children after 1980 were now only allowed to have one child. China Households' Survey shows that the average number of children born and survived by women aged 50 and above in 1988 was around 4. For women aged 40 to 49 it was 3, for women aged 35 to 39 it was 2, and for women younger than age 34 it was 1. Given this data, I assume that agents aged 50 and older in 1988 were not affected by the policy, agents aged between 35 and 49 were partially affected, while agents aged 34 and younger were fully affected.

The model regards each couple as a single household. In other words, each couple is viewed as one agent. From the above data, before the policy was introduced it is optimal for each couple to choose to have 4 children. Therefore, each (composite) agent chooses to have an optimal $4/2 = 2$ offspring before 1980. After the one child policy is implemented, each (composite) fully affected agent can only have $1/2$ offspring.

In reality, since time and age are continuous, the effects of the policy were gradual. To illustrate the gradual effects of the policy, I divide the working age population into five cohorts in 1988. The cohort aged 50 and older is not affected by the one-child policy. They have 4 children and 3 siblings on average. This cohort is indexed as $Cohort_{(2,2)}$, where $(2, 2)$ means the agents of this cohort have 2 offspring and their parents also have 2 offspring (including this agent). The second cohort, who is aged from 40 to 49, is partially affected by the policy. They had three children when the policy was introduced, but they couldn't have the fourth one. However, their parents were not affected. Thus, this cohort is indexed as $cohort_{(3/2,2)}$, where $(3/2, 2)$ means this cohort has $3/2$ offspring and their parents have

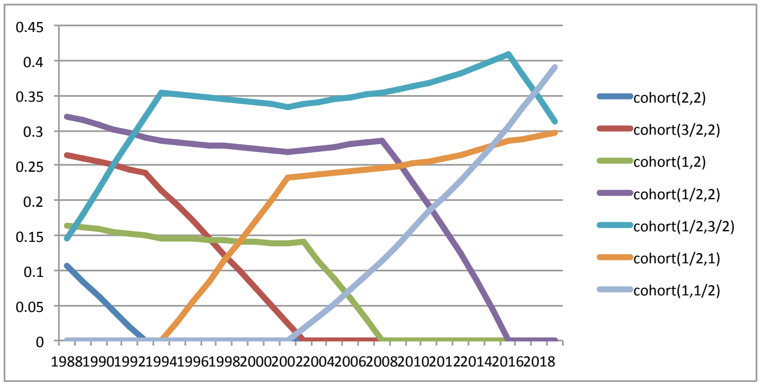


Figure 1.3: Population Structure Transition

2 offspring. The third cohort, agents aged 35 to 39, had two children when the policy was introduced. Those agents are called the $cohort_{(1,2)}$, which means they have 1 offspring and their parents have 2. The fourth cohort, agents aged from 27 to 34, are fully affected by the one-child policy. Thus, they can only have one child. However, their parents were not affected, which means their parents have 4 children. Thus, they are indexed as $cohort_{(1/2,2)}$. Finally, the last cohort in 1988 includes agents aged 26 and younger. They are fully affected by the policy, and their parents were partially affected. They are indexed as $cohort_{(1/2,3/2)}$.

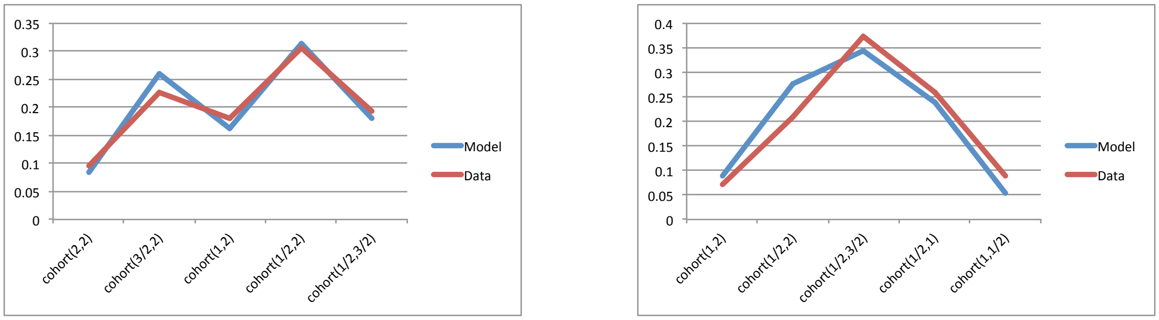
In 1995, a sixth cohort enters the labor market. Similar to $cohort_{(1/2,3/2)}$, they are fully affected by the policy, and their parents were partially affected. This cohort is indexed as $cohort_{(1/2,1)}$, which means they only have 1/2 offspring while their parents have 1.

In 2003, the first only child generation starts to enter the economy. These people are the only child in their family, and they are allowed to have two children. This cohort is the seventh cohort, and is indexed as $Cohort(1, 1/2)$, where (1,1/2) means this agent/couple has 1 offspring and their parents only had 1/2. [1]

I construct population shares using the population growth rate. The average labor growth rate in China was about 1.03 before the policy. After the policy, the size of younger generation declines. The population growth rate increases at a decreasing rate due to the change in population structure. In 2003, as the only-child generation enters the labor market, the labor growth rate starts to decrease. Figure 1.3 depicts the model estimated demographic structure from 1988 to 2018. It shows the changes in the population share of labor force for different cohorts over time.

In the initial years, cohorts that are not affected, partially affected, or fully affected by the one-child policy co-exist. The graph shows that during the transition, the population of agents who were not affected or only partially affected by the policy, $Cohort_{(2,2)}$, $Cohort_{(3/2,2)}$ and $Cohort_{(1,2)}$, decrease as they grow old and exit the labor market. On

[1] When the "only-child" generation enters the labor market, the one-child policy was already relaxed, so they are aware of the fertility control when they start making economic decisions. Thus, the two-child policy is treated as a fertility constraint in the model other than change in expectations



(a) Population Structure in 1989

(b) Population Structure in 2005

Figure 1.4: Cohort-Distribution of Population

the other hand, the younger cohorts in 1988, $Cohort_{(1/2,2)}$ and $cohort_{(1/2,3/2)}$, are relatively larger in population share during the transition. $Cohort_{(1/2,2)}$, remains relatively constant in population share and starts to decrease after 2008. In addition, the share of another younger cohort, $cohort_{(1/2,3/2)}$, increases and becomes the largest population share cohort in 1993.

In 1995, the sixth cohort, $cohort_{(1/2,3/2)}$, enters the market, and its share increases over time. The last cohort, $Cohort(1, 1/2)$, which is the only-child generation, starts to enter the labor force in 2003. As the older cohorts retire and exit the labor market, the younger cohorts who are fully affected by the one-child policy enter the market. In 2008, all cohorts that were not affected or just partially affected by the one-child policy are out of the labor market. The population consists entirely of agents who were fully affected by the policy.

In addition, the cohort-distribution of the population has a very important impact on aggregate level effects. Figure 1.4 compares the model predicted population share of different cohorts with the data provided by the China Census Survey for the years 1989 and 2005. Although a continuous comparison over the full sample would be ideal, the surveys are only available in 1989, 2000 and 2005. Still, the results show that the model predicted population structure is very close to the observed data in both the initial year and towards the end of the sample period. This suggests the model predicted change in the composition of the population should be close to the data in terms of long-term trends.

subsection Discussion of τ_t in a Multi-Period Model

As mentioned in section 1.2, the one-child policy will affect τ_t at the both the individual level and the aggregate level. At the individual level, different numbers of children and siblings leads to different saving rates. Thus, for the different cohorts, we have:

Cohorts that are not affected by the one-child policy

1.$Cohort_{(2,2)}$: They are not affected by the one-child policy. Each household representative (one couple) has 2 offspring and their parents also have 2 offspring.

$$\tau_{(2,2)} = (1 - \frac{1}{\pi})(1 - q(log(2) + 1) - \frac{p(2)}{2}) - \frac{g}{\pi}\frac{p(2)}{R}$$

Cohorts that are partially affected by the one-child policy:

2. $Cohort_{(3/2,2)}$: This cohort had 3 children when the policy was introduced. Recall that each couple is treated as one representative household. Thus each household has 3/2 offspring. The parents of $cohort_{(3/2,2)}$ are $cohort_{(2,2)}$ which are not affected by the policy.

$$\tau_{(3/2,2)} = (1 - \frac{1}{\pi})(1 - q(log(3/2) + 1) - \frac{p(2)}{2}) - \frac{g}{\pi}\frac{p(3/2)}{R}$$

3. $Cohort_{(1,2)}$: This agent/couple had 2 children when the policy was introduced and their parents were not affected.

$$\tau_{(1,2)} = (1 - \frac{1}{\pi})(1 - q(log(1) + 1) - \frac{p(2)}{2}) - \frac{g}{\pi}\frac{p(1)}{R}$$

Cohorts that are fully affected by the one-child policy:

4. $Cohort_{(1/2,2)}$:

This cohort is fully affected by the one child policy. They can only have one child. Thus each agent/couple has 1/2 offspring. The parents of $cohort_{(1/2,2)}$ are $cohort_{(2,2)}$ which are not affected by the policy.

$$\tau_{(1/2,2)} = (1 - \frac{1}{\pi})(1 - q(log(1/2) + 1) - \frac{p(2)}{2}) - \frac{g}{\pi}\frac{p(1/2)}{R}$$

5. $Cohort_{(1/2,3/2)}$:

This cohort is fully affected by the one child policy. Each agent/couple has 1/2 offspring. The parents of $cohort_{(1/2,3/2)}$ are $cohort_{(3/2,2)}$ which are partially affected by the policy.

$$\tau_{(1/2,3/2)} = (1 - \frac{1}{\pi})(1 - q(log(1/2) + 1) - \frac{p(3/2)}{3/2}) - \frac{g}{\pi}\frac{p(1/2)}{R}$$

6. $Cohort_{(1/2,1)}$:

This cohort is fully affected by the one child policy, and their parents were partially affected.

$$\tau_{(1/2,1)} = (1 - \frac{1}{\pi})(1 - q(log(1/2) + 1) - p(1)) - \frac{g}{\pi}\frac{p(1/2)}{R}$$

The only-child generation

7. $Cohort_{(1,1/2)}$:

They are the only-child in their family, and they are allowed to have 2 children. Thus, each household will have 1 offspring (two children). In addition, each household must support 2 older households (4 parents). Thus the cost of taking care of the parents $p(1/2)$ doubles.

$$\tau_{(1,1/2)} = (1 - \frac{1}{\pi})(1 - q - \frac{p(1/2)}{1/2}) - \frac{g}{\pi}\frac{p(1)}{R}$$

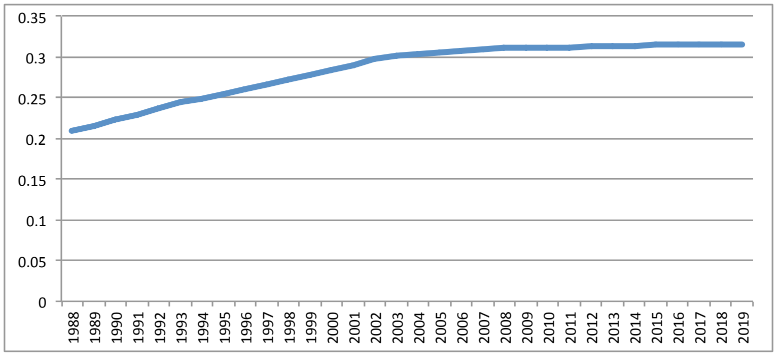


Figure 1.5: Population Weighted Average Saving Rate

These results show that cohorts that are not affected, or just partially affected by the policy, save the least ($Cohort_{(2,2)}$, $Cohort_{(3/2,2)}$ and $Cohort_{(1,2)}$). Cohorts that are fully affected by the policy save the most ($Cohort_{(1/2,2)}$, $Cohort_{(1/2,3/2)}$ and $Cohort_{(1/2,1)}$), and the cohort that is the only-child generation ($Cohort_{(1,1/2)}$) lies in between.

The saving rate equations above have shown that different cohorts have different saving rates because of different numbers of children and siblings. Thus, τ_t in equation (20) is a share-weighted average of all cohorts' saving rates in each year.

$$\tau_t = \sum \tau_{cohort_i} (\frac{N_{cohort_i}}{N})_t$$

Figure 1.5 shows how the model predicted average saving rate changes over time. Cohorts that are fully affected by the one-child policy are the ones who save the most compared to the other cohorts. Thus, it is not surprising to see that as the share of these cohorts increases, the average saving rate increases. The population share of the fully affected cohorts increases until the year 2009. Thus, the average saving rate increases until 2009 as well. As the only-child generation begins to enter the labor market and grows in size, the average saving rate starts to decrease because the only-child generation saves relatively less than the fully affected cohorts. Notice here that saving rate is not the total saving of workers, it is the percentage of income. Total worker savings is $\tau_t W_t N_t$, which depends on a workers' wage. As in Song, Storesletten and Zilibotti(2011), I assume there is a unique wage which is determined by the marginal product of labor in G firms. Thus, it increases at the same constant rate as technology. As a result, per capita household saving for workers only depends on the saving rate τ and the constant technology growth rate g.

1.3.2 Quantitative Analysis

In previous sections, I have extended Song, Storesletten, and Zilibotti (2011) by including children and siblings into the model. In this section, I present calibrated numerical results. Following Song, Storesletten, and Zilibotti (2011), I now extend the 3-period model to an

Auerbach-Kotlikoff OLG model. This model allows agents to live multiple periods. I assume workers start making economic decision at age 23, retire at 55, then die at 72., so ($T = 50$) and they work $J = 32$ years. Entrepreneurs work as manager at their parents' firms at age 23 and then become entrepreneurs at 48. They also live until 72.

Household preferences are the same as in the two period model. They now become:

$$U_t = \sum_{t=0}^{T} \beta^t \frac{c_t^{(1-\gamma)} - 1}{(1-\gamma)} + G(n^k)$$

Workers:

Their lifetime budget constraint is now: [2]

$$\sum_{t=0}^{T} R^{-t} c_t + (Q(n^k) + \frac{P(n^s)}{n^s} \sum_{t=0}^{J} R^{-t} = \sum_{t=0}^{J} R^{-t} W_t + \sum_{t=J+1}^{T} R^{-t} P(n^k)$$

The Euler Equation for workers is thus given by,

$$c_t^{-\gamma} = \beta R c_{t+1}^{-\gamma}$$

Plug the Euler equation into the lifetime budget constraint,

$$c_0 = [1 - (R^{-\frac{-\gamma-1}{\gamma}} \beta^{\frac{1}{\gamma}})] R^{-J} \sum_{t=0}^{J} (\frac{1}{R})^{t-J} (w_t - Q(n^k) - \frac{P(n^s)}{n^s}) + \sum_{t=J+1}^{T} \frac{1}{R}^{T-t} P(n^k)$$

Entrepreneurs:

When young entrepreneurs work as managers in their parent's firms, they earn income given by equation(1.4), and deposit their savings into banks. When they become new entrepreneurs and start up their own firms, they invest the accumulated savings into their firms. An entrepreneur's lifetime budget constraint is thus:

$$\sum_{t=0}^{J} R^{t-J} c_t + \sum_{t=J+1}^{T} (R^*)^{t-J} c_t = \sum_{t=0}^{J} R^{t-J} [\frac{m_t}{n^s} - Q^E(n^k)]$$

where $R^* = [(1-\delta) + (1-\eta)\rho_E] \frac{R}{R - \eta\rho_E}$.

The Euler Equation for workers is, For t=[0, J],

$$c_t^{-\gamma} = \beta R c_{t+1}^{-\gamma}$$

[2] In my model, the rate of technological progress is calibrated to match the output growth rate. Given this calibrated rate of technological progress, the saving constraint will never bind, s_t is always positive. However, this constraint could bind if the rate of technological progress was high enough.

On the other hand, for $\tilde{t}$=[J+1, T],

$$c_{\tilde{t}}^{-\gamma} = \beta R^* c_{\tilde{t}+1}^{-\gamma}$$

In addition,

$$c_0^{-\gamma} = (\beta^{1+J} R^J R^*) c_{\tilde{t}}^{-\gamma}$$

Plugging the Euler equations into the lifetime budget constraint yields,

$$c_0^E = [\sum_{t=0}^{J} R^{t-J} (\beta R)^{\frac{t}{\gamma}} + [(\beta^{1+J} R^J R^*)^{\frac{1}{\gamma}}] \sum_{t=J+1}^{T} (\frac{1}{R^*})^{T-J} (\beta R^*)^{\frac{t-J}{\gamma}}]^{-1} \sum_{t=0}^{J} R^{t-J} [\frac{m_t}{n^s} - Q^E(n^k)]$$

The entrepreneurs will be facing the credit constraint, so they can only borrow part of their capital from the bank. I assume that capital depreciates at a constant rate $\delta < 1$. Thus the law of motion for aggregate capital is $K_{t+1} = (1-\delta)K_t + I_t$ for the entrepreneurs. Recall that the share of investment that can be financed through bank loans is $\frac{\eta\rho}{R}$. Bank loans to entrepreneurs are,

$$L_E^{t-1} = \frac{\eta\rho}{R}[K_E^t - (1-\delta)K_E^{t-1}] \tag{1.13}$$

$$= (\frac{R}{\alpha})^{\frac{1}{\alpha-1}} A_t N_t \eta [\frac{N_E^t}{N_t} - (1-\delta)\frac{N_E^{t-1}}{N_{t-1}}\frac{1}{ng}] \tag{1.14}$$

<u>Government Owned Firms:</u>

In contrast, G firms do not face a credit constraint. Capital depreciates at rate δ. Loans to G firms are given by,

$$L_G^{t-1} = K_G^t - (1-\delta)K_G^{t-1}$$

$$= (\frac{R}{\alpha})^{\frac{1}{\alpha-1}} A_t N_t [\frac{N_G^t}{N_t} - (1-\delta)\frac{N_G^{t-1}}{N_{t-1}}\frac{1}{ng}]$$

Aggregate bank loans are the sum of loans to both G and E firms. On the other hand, aggregate bank deposits consist of the savings of young workers, retirees and managers. The initial distribution of wealth is the only state variable. Thus, the model is solved by standard iteration on the sequences of wages $\{w\}_t$ and profit shares $\{m\}_t$.

1.3.3 Data and Calibration

Lane and Milesi-Ferretti (2007)'s External Wealth of Nations Mark II, EWN, database provides data on the volume of accumulated foreign reserves (FX), which is used as the measurement of the central bank's net foreign asset holdings. China Statistical Yearbook, issued by the NBS, provides data on national level variables, for example, the annual investment rate and private firm employment share. In addition, the Urban Household Survey, also issued by the NBS, is the standard data source for household level variables. For example, household income, consumption, savings and number of children. In addition, China Health and Retirement Longitudinal Study (CHARLS) provides data on intergenerational transfers within families.

This paper focuses on the period 1988-2011. This choice is motivated by two considerations. First, the China Statistical Yearbook provides data for the E firm labor share, and the earliest year available is 1988. Second, it is better to have as long a sample as possible. The most recent data available is for 2011. Table 1.1 summarizes the calibration.

Table 1.1: Calibration of Model Parameters

Parameter	Value	Target (data)
Exogenous		
β	0.99	/
α	0.5	/
γ	0.5	/
δ	0.15	/
Endogenous		
R	1.041	Initial aggregate household saving rate(1987)
g	1.08	Average output growth rate per worker (1987-2011)
χ	1.27	Initial labor share growth rate(1988-1990)
ϕ	0.535	Rate of return to capital difference
η	0.46	$\frac{L_E}{S_E+L_E} = 50\%$ (assumption)
$n(pre-policy)$	1.03	Average population growth rate(1975-1978)
$n(post-policy)$	$(1.02, 1)$	Model predicted population structure
Transfers		
$p(2)$	27%	Obseved transfers with four children
$p(3/2)$	20%	Observed transfers with three children
$p(1)$	7%	Observed transfers with two children
$p(1/2)$	3.5%	Transfers with one child(Assumption)
q	25%	Observed cost of raising a child

Exogenous Parameters The parameters that were set exogenously in Song, Storesletten and Zilibotti(2011) are also treated exogenously here. The discount factor β is set to 0.99 on an annual basis. The capital share is assumed to be $\alpha = 0.5$. In addition, the intertemporal elasticity of substitution is set to be $\frac{1}{\gamma} = 2$. The annual depreciation rate is, $\delta = 0.15$.

Technology and Population The annual deposit rate $R = 1.041$, which is set to match the initial aggregate household saving rate in 1987. The rate of labor-augmenting technical progress is set to be 1.08 in order to match the average annual real income growth rate from 1988 to 2011 provided by NBS. As in Song, Storesletten and Zilibotti(2011), the parameters χ and ϕ are calibrated to match two moments: (1) initial labor share growth rate; (2) observed rate of return difference of 9 percent between E and G firms. I also assume that E firms can finance externally 50% of their investment, which leads to a value of $\eta = 0.46$. The pre-policy population growth rate is set to match the average population growth rate from 1975 to 1978. Thus, it is assumed that before the one-child policy was implemented, the population of each generation is increasing at a rate of 1.03. After the policy is implemented, the population of younger generations obviously decreases. This leads to a decrease in the growth rate of the overall population.

Intergenerational Transfers Parameters China Health and Retirement Longitudinal Study (CHARLS) provides data on transfers to the elderly. It examines a restricted sample of urban households with a respondent at least 60 years of age with at least one surviving adult child aged 25 or older. The database provides data on net transfers for households with different numbers of children. The data suggests that as number of children increases, total transfer from children to parents increases, which is consistent with the assumption of the model. [3] Children provide a crucial resource for elderly support in China. Children financially supporting their retired parents is not just culture norm but also stipulated by the Constitutional law. Therefore, I set the value of transfers per income from children to parents exogenously to match with the data. In addition, I report a robustness check in section 1.3.4, the results suggests that as long as transfer increases when number children increases, with an adjusted interest rate, different value of P (transfer form children to parents) will not change the results significantly. CHARLS also provides data on the cost of raising children. However, the only data available is the cost of a child's education. Since the cost of education comprises about 50% of the total cost, it is treated as an index for the total cost of raising children. The results from robustness check also suggest that with an adjusted interest rate, the estimated results are pretty robust to different values of Q (cost of raising children), as long as cost increases in number of children.

1.3.4 Results

Figures 1.6-1.9 illustrate, respectively, the transition of E firm employment share, the aggregate saving rate, the investment rate, and the foreign reserves/GDP ratio generated by the calibrated multi-period economy. The dashed line in Figure 1.6 shows the private employment share in the NBS data, $\frac{E}{E+G}$, where E is employment in private enterprises and self employed workers, and G is state-owned enterprises employment. It shows an increase from about 6 percent in 1988 to about 60 percent in 2010. The model's calibrated employment share matches very closely with the NBS data. The E firm employment share increases significantly twice during the sample period, in the years 1998 and 2003. This result is consistent with the theory. Recall that $cohort_{(1,2)}$ and $cohort_{(1/2,2)}$ were partially affected by the one-child policy. Those two cohorts accumulate more savings from previous years

[3] In the database, families with two children and one child are not distinguished. In order to differentiate cohorts, I assume net transfers to the elderly for households with two children are double those with only one child.

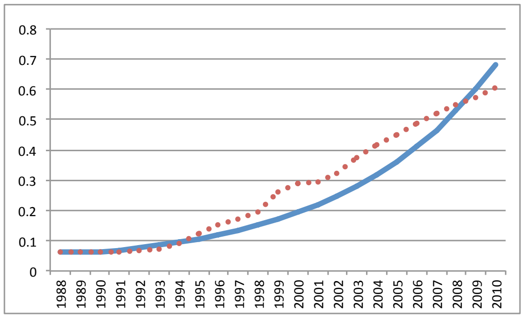


Figure 1.6: Private employment share

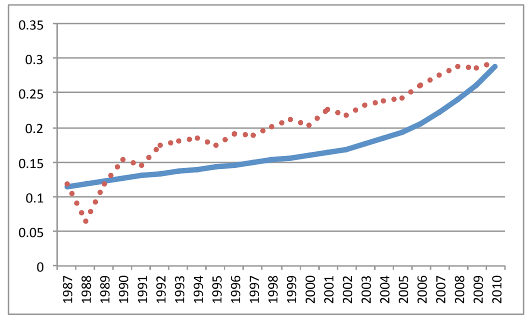


Figure 1.7: Household saving rate

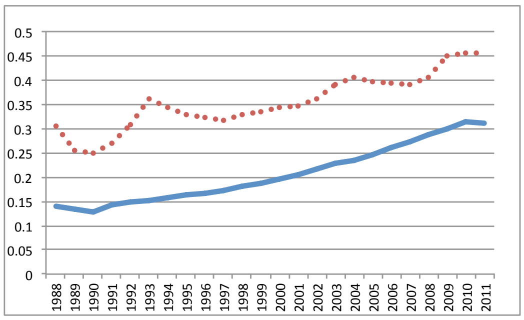


Figure 1.8: Aggregate investment rate

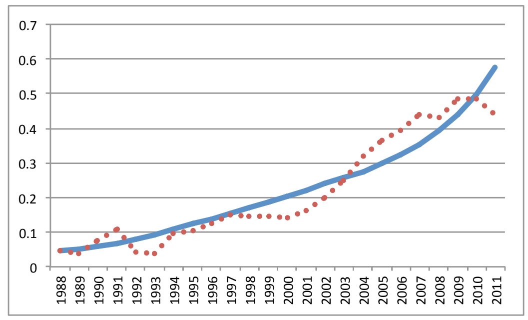


Figure 1.9: Foreign reserves/GDP

Note: the solid line refers to the estimated results from the model while the dashed line refers to the data.

working as managers due to fewer children to feed. Thus, they accumulate more capital, and hire more labor. As $cohort_{(1,2)}$ and $cohort_{(1/2,2)}$ become entrepreneurs in 1998 and 2003 respectively, the E firm employment share growth rate shows a significant increase. This result is very close to Song, Storesletten and Zilibotti (2011). They also show a significant increase in private employment growth. However the increase in their model is due to an exogenous relaxation in the credit constraint. Here it is caused by an endogenous increase in saving due to the one-child policy.

Figure 1.7 depicts the aggregate household saving rate, which is the total savings of workers, retirees and managers. The calibrated model matches the data closely in terms of long-term trends, even though it is slightly lower on average. In Song, Storesletten and Zilibotti's(2011)s' model, the workers' saving rate is treated as constant over time. In this paper, I am able to explain the changes in workers' saving behavior and the overall saving rate. Indeed, workers' saving rate explains more than 50% of the increase in overall saving rate on average. The calibrated household saving rate increases at a decreasing rate until year 2003, which is consistent with the model's prediction. Recall that cohorts that are partially or fully affected by the one-child policy are the ones that save the most, because they expect a reduction in the future transfers form their children. When their population share increases, the saving rate increases. On the other hand, the aggregate household saving rate shows a significant increase in 2003. This is caused by a significant increase in managers' savings. Song, Storesletten and Zilibotti's(2011)s' estimated results show an increase in the aggregate saving rate in 2001. This increase is driven by the high saving rate of managers as well. The credit constraint was assumed to be relaxed in 2001, which causes a faster labor reallocation towards E firms. Thus, the managers' income increase leads to an increase in saving. In this paper, an increase in manager's saving arises for two reasons. First, in 2003 the first generation of the fully affected cohorts, $cohort_{(1/2,2)}$, has started having their own firms and becoming entrepreneurs. As discussed before, they accumulate more savings than the previous entrepreneurs due to lower costs for raising children. Thus they hire more labor and generate higher profits. Their offspring, $cohort_{(1,1/2)}$, who get a share of the profits as managers, therefore gets higher pay. Second, $cohort_{(1,1/2)}$ starts entering the market in 2003. Because the managers of $cohort_{(1,1/2)}$ do not have siblings to split the profit with, they save more than the other cohorts. This produces a significant increase in managers' savings in 2003, and thus an increase in aggregate household saving.

Figure 1.8 depicts results for the aggregate investment rate. The calibrated result is lower than the observed data on average, especially during the initial years. This is because at the given parameters, the investment rate is determined by the E firm labor share. The initial E firm labor share was calibrated to match the data, which is about 6.2%. Given this growth rate and other parameters, the predicted initial investment rate was much lower than in the data. However, afterwards investment in the calibrated model increases due to the increase in private firms' labor share growth rate, which matches the data better in terms of long-run trend. Recall that there is a significant increase in the E firm labor share in 2003. This increase causes an increase in the investment growth rate in 2003 as well.

Figure 1.9 compares the predicted foreign reserve ratio with the NBS data. The initial ratio was set to match the data. As aggregate saving increases faster than loans, accumulated foreign reserves increase over time. Although it may seem puzzling that reserves increase when saving is less than investment, remember that with the borrowing constraint binding, entrepreneurial firms need to finance part of it's investment through internal savings. Entrepreneurial forms outgrow state owned firms, thus domestic demand for loans is smaller than investment. The difference between domestic saving and borrowing determines the foreign reserve accumulations. The model prediction matches the data very closely until 2009. The model predicts a significant increase in the foreign reserve ratio around year 2004, which is consistent with the observed data. This predicted increase is not surprising, because as seen in Figure 1.6, the growth rate of the aggregate household saving rate increases in 2003. Recall the economy was calibrated to match the initial value, not the time path. The model is thus able to replicate the long run increase in foreign reserves.

1.3.5 Robustness

In this paper, the value of transfers from children and the cost of raising children, $P(n^k)$ and Qn^k respectively, are essential for the calibrated results. In this section, I check the

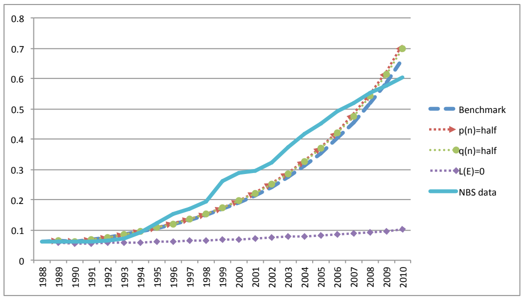


Figure 1.10: Private employment share

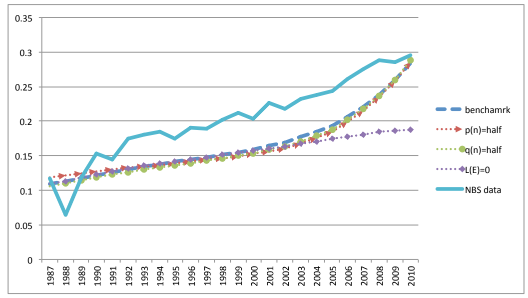


Figure 1.11: Household saving rate

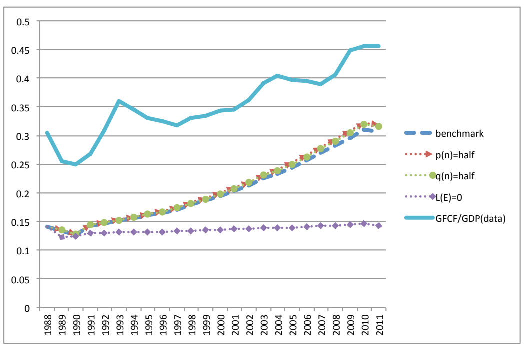


Figure 1.12: Aggregate investment rate

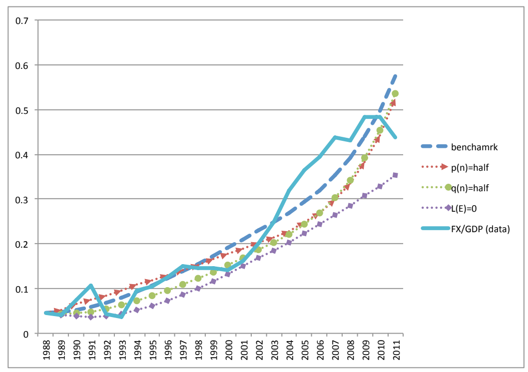


Figure 1.13: Foreign reserve/GDP

Note: the dashed line refers to the estimated results from the model while the solid line refers to the data.

robustness of the model by examining alternative assumptions about $P(n^k)$ and $Q(n^k)$: (1) the value of transfers from children are assumed to be half of the benchmark model, (2) the cost of raising children is assumed to be half of the benchmark model. In addition, I examine the behavior of the model when entrepreneurs cannot borrow at all. Thus, in the third experiment: (3) $\eta = 0$. As in the benchmark model, $R\%$ will be adjusted to match the initial aggregate saving rate.

Figure 1.10 shows that the change in $P(n^k)$ and $Q(n^k)$ does not affect the trend of the E firm labor share. On the other hand, when E firms are not allowed to borrow at all, the E firm labor share only increases by about 4% over 22 years. Thus, the predicted transition would be very slow if banks did not lend at all to private firms.

Figure 1.11 shows the comparison of the saving rate under the three experiments with the benchmark model. The results suggest that changing the value of $p(n^k)$ or $q(n^k)$ does not change the long-run trend of aggregate saving. On the other hand, in the third experiment, when entrepreneurs cannot borrow at all, the estimated aggregate saving rate still increases, but it increases at a slower rate after 2003. When banks do not lend to E firms at all, managers' saving rate is predicted to be very low, close to 2% on average. Thus, the increase in the aggregate household saving rate is mainly driven by workers' saving. Song, Storesletten and Zilibotti(2011) also run this robustness experiment. The estimated saving rate stays constant when they set $\eta = 0$, which is not surprising since in their model workers' saving rate is treated as a constant.

The changes in investment under the three experiments are shown in Figure 1.12. As with the E firm labor share, changing $p(n^k)$ or $q(n^k)$ does not change much the predicted investment rate, while an extremely tight credit constraint makes the investment rate stay relatively stable.

Finally, Figure 1.13 depicts the value of the foreign reserve ratio under different experiments. Given that the estimated results of aggregate saving rate and investment ratio are robust to the first two experiments, changes in $p(n^k)$ or $q(n^k)$, the result for the foreign reserve ratio is also robust. In the third experiment, when E firms are not allowed to borrow, the estimated foreign reserve ratio is significantly lower. Recall that the estimated investment rate stays constant in the third experiment, and the model is calibrated to match the initial value, thus the increase in the foreign reserve ratio is driven by the increase in workers' savings.

1.4 Conclusion

In this paper, I studied the effects of China's one-child policy on domestic savings and foreign reserve accumulation. The model features two key elements: (1) contractual and financial market imperfections, which was borrowed from Song, Storesletten and Zilibotti's (2011) model, and (2) within family intergenerational transfers. I showed that an exogenously imposed fertility restriction affects economic decisions at the household level, and the demographic composition at the aggregate level. A quantitative framework was used to study the effects of the one-child-policy on labor reallocation, savings, investment, and foreign reserve accumulation. These effects were shown to be close to those in the data for reasonable parameter values.

A country like China, which grows so rapidly while increasing its foreign reserves at the same time, is one of the major puzzles of the recent growth experience. Some commentators have argued that the build-up of the large foreign surplus in China is prima facie evidence of government exchange rate manipulation. This paper offers an alternative explanation of China's large foreign reserves. It suggests that the increase in foreign reserves is an outcome of domestic financial and contractual imperfections. I argue that the acceleration after the year 2000 was caused by a demographic transition, which is solely an internal economic adjustment.

It is noteworthy that the one-child-policy was relaxed in 2000. Each couple is now allowed to have two children. My model predicts that the saving rate will start to decrease once the new generation becomes economically active. We should also expect to see that foreign reserves will eventually decrease within a couple of decades. Finally, it is interesting to observe that population growth in China has not increased much following the policy relaxation. In chapter 2, I extend the model to include a classic Beckerian quantity/quality trade-off in the number of children. With fewer children, parents optimally choose to invest more in their child's education. Higher education produces higher incomes, which raises the cost of children. I show that this can potentially explain why population growth hasn't increased much recently.

Chapter 2

Population Control, Technology and Economic Growth

2.1 Introduction

The evolution of population and income levels has been an important topic in economic growth. Malthus (1798) first proposed the most basic description of this relationship. The Malthusian model posits a positive effect of income per capita on population growth. The Malthusian model successfully explained a long period of observed population and income data. However, most empirical studies now find that fertility rates *fall* as income grows. For example, Barlow (1994), which draws on data from 86 countries and several different time periods, shows that per capita income growth is negatively related to population growth. Other empirical analyses find no significant relationship, including Simon(1989) and Kelly(1988). Becker, Murphy and Tamura(1990) argue that the failure of the Malthusian model stems from its neglect of human capital investment. Denison(1985) provides evidence showing that 25 percent of the increase in GDP per capita in the US between 1929 to 1982 is explained by increased schooling.

Figure 2.1 depicts the growth rates of population and income per-capita in western Europe from AD600 to the 1900s (Lagerlöf (2006)). Galor and Weil (2000) develop a single, unified growth model that captures this historical evolution between population growth and income per capita. Based on the behavior of per-capita income, and the relationship between the level of income per capita and the growth rate of population, they separate the evolution of population and income into three regimes. The first regime is called the "Malthusian" regime. In this stage, income and population growth are positively correlated, which is consistent with the Malthusian model's prediction. In the absence of changes in technology, and when the population is small, income per capita is high, and population grows naturally. When population is large, income per capita will be low, thus reducing

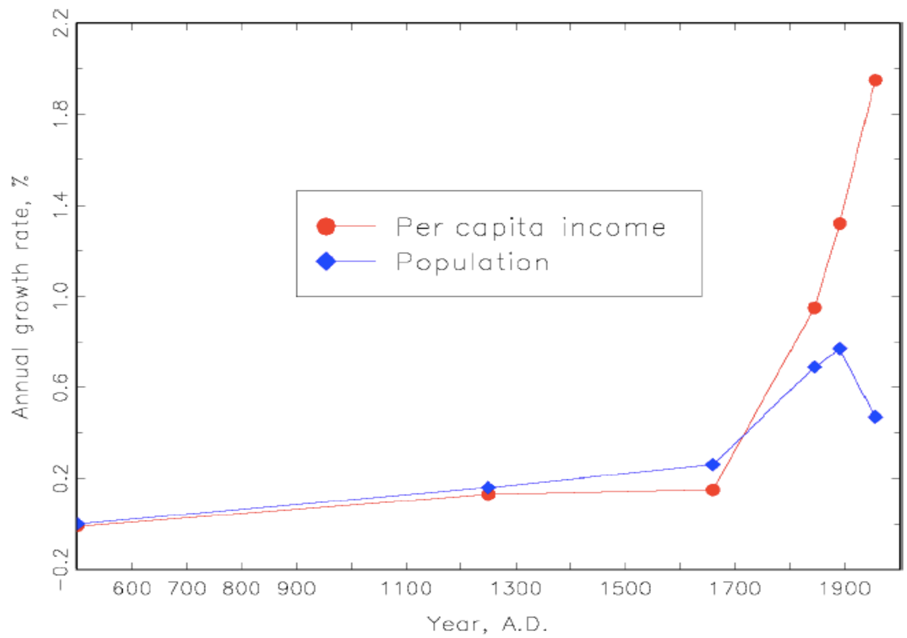


Figure 2.1: Growth Rates in Western Europe

population growth. Hence, population growth will be stable around a slowly evolving level of technological progress.

As population gradually rises, technological progress speeds up because countries with denser population should have superior technology. According to Kuznets (1960), Simon (1977, 1981) and Aghion and Howitte(1992), a larger population means more potential inventors and higher chances of technological breakthrough. The resulting increase in technological progress allows the economy to transition to a second regime, which is called the "post-Malthusian" regime. During this regime, income and population growth are still positively correlated, but both grow at a faster rate due to the effect of more rapid technological progress.

As population and technological progress continue, the economy eventually transitions to a third regime, called the "Modern Growth" regime. This regime differs from the previous two because income and population growth now become negatively correlated. This negative relation is due to the demographic transition, in which parents switch to having fewer, higher quality children. As Schultz(1964) argued, technological progress raises the return to human capital because new technology requires the ability to analyze and work with new production techniques. Thus, an advance in technology increases the level of resources invested in each child, and decreases the total number of children each family has.

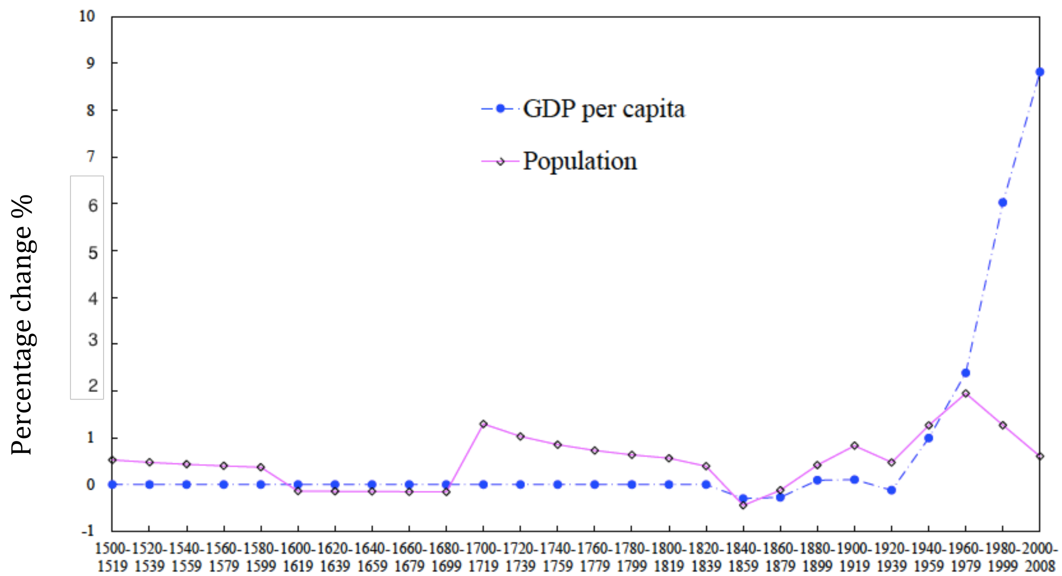


Figure 2.2: Growth Rates in China

Although Galor and Weil's (2000) model can be used to explain the three stages of the historical evolution of population and economic growth in Western Europe, a natural question arises - Can the Galor-Weil model also explain the evolution in China? Figure 2.2 shows the growth rate of population and GDP per capita in China from 1500 to 2008, based on Maddison's (2007) estimates. As the graph shows, the historical evolution of population and economic growth appears to be consistent with the three stages of the Galor-Weil model. However, one thing that is worth of noticing is that population growth drops around 1980. This was *not* due to a natural transition between regimes. Instead, it was caused by the imposition of a government policy. In 1979, China introduced a population control policy, the so-called "One-Child Policy", in order to reduce population growth and alleviate social, economic and environmental pressures. The policy stated that each couple could have only one child. However, some exceptions were allowed. For example, ethnic minorities and some families in rural areas were exempted. This policy reduced the fertility rate significantly in China, especially in urban areas. According to China Census, the average urban fertility rate was around 3 per woman in 1970s. It decreased to very close to 1 by the mid-1980s. As the fertility rate kept falling, declining population growth was accompanied by several serious problems. For example, sex imbalance, population aging and other potential social problems. In 2013, China announced the decision to relax the one-child policy. Under the new policy, families can now have two children if one parent is an only child.

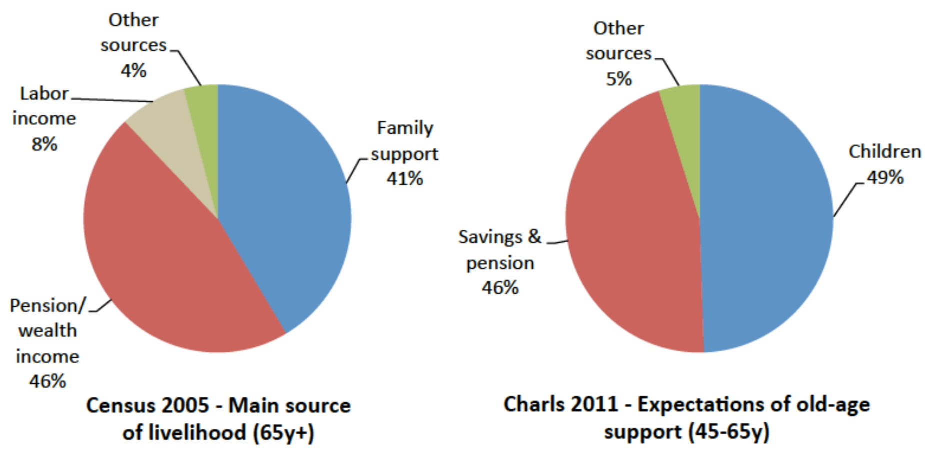


Figure 2.3: Main Source of Livelihood for the Elderly (65+) in urban areas

China's one-child policy is a very unique population control scheme. It has recently attracted the attention of economic researchers. Choukhmane, Coeurdacier and Jin (2014) investigate the effect of the one-child policy on China's household saving rate and human capital. Song, Storesletten, Wang and Zilibotti(2015) analyze the welfare effects of alternative pension systems, taking the one-child policy into consideration. Li and Zhang (2007) provide an empirical analysis of the impact of the birth rate on economic growth. They find that the birth rate has a negative impact on economic growth. Chen (2015) argues that exogenous fertility restrictions affect economic decisions at the household level, and demographic composition at the aggregate level. The demographic transition combined with domestic financial and contractual imperfections can explain the recent increase in China's foreign reserves.

Xue, Yip and Tou (2013) analyze the effect of exogenous population control on China's long run economic development in the Galor-Weil model. They extend Galor-Weil model by introducing a policy variable on population growth. According to Galor and Weil (2000), lower population density leads to slower technological progress. Thus, they find that in the long run, population control results in a steady state of lower education, and slower technological progress and economic growth. Following Galor and Weil (2000), Xue, Yip and Tou (2013) also considered the substitution between the quality and quantity in their model. Rapid technological progress results in high return to education. Thus it triggers a demographic transition in which fertility rates permanently decrease. However, they didn't study the effect of the quantity of children on quality.

Number of households	321
Average number of adult children (25+)	3.4
Share living with adult children	45%
Incidence of positive net transfers	
- from adult children to parents	65%
- from parents to adult children	4%
Net transfers in % of parent's pre-transfer income	
- All parents	28%
- Transfer receivers only	47%
Of which households with:	
- One or two children	10.5%
- Three children	34.6%
- Four children	45.9%
- Above Five children	69.7%

Notes: Data source: CHARLS (2008). Restricted sample of urban households with a respondent/spouse of at least 60 years of age with at least one surviving adult children aged 25 or older. Transfers is defined as the sum of regular and non-regular financial transfers in yuan. Net Transfers are transfers from children to parents less the transfers received by children.

Figure 2.4: Transfers towards elderly: Descriptive Statistics

In countries like China, where the social pension system is not so well established, within-family intergenerational transfers are very important. Parents raise and educate their children when they are young, and children financially support their parents when their parents are retired. Intergenerational transfers are not just based on cultural norms, but also stipulated by Constitutional Law. Children provide a very important source of old age support in China. Figure 2.3 shows the main sources of livelihood for the elderly in urban areas (Choukhmane, Coeurdacier and Jin (2014)). According to Census 2005 (left panel), family support is 41% of the total for the elderly. From the China Health and Retirement Longitudinal Study (CHARLS), this pattern is expected to continue in the future (right panel). In addition, Figure 2.4 shows more detailed data on intergenerational transfers (choukhmane, Coeurdacier and Jin (2014)). The data show that there are positive net transfers from children to parents in 65% of families. More importantly, average transfers, as a percentage of pre-transfer income, are increasing in the number of children. When the one-child policy was implemented, parental expected future income decreases as the number of children they have decreases. To compensate for this loss, parents can substitute quantity for quality. That is, parents will increase investment in their children's education in order to accumulate financial wealth in expectation of lower support from their children. Choukhmane, Coeurdacier and Jin (2014) argue that the policy significantly increased the human capital of the only child generation due to the quantity and quality trade-off effect. They also provide an empirical check by using the birth of twins as an exogenous deviation from the policy. The results show that the per-capita education expenditure on a twin is significantly lower than on an only child.

In this paper, I extend and modify the Galor and Weil (2000) model to examine the long run effects of the one-child policy on economic growth. My theoretical framework incorporates one new element into the model: intra-family transfers. Agents make decisions about how many children to have, *and* their level of education. When they retire, they live off their children's transfer and savings. Bearing children is not simply for utility purposes, but is also an investment. This model thus allows the one-child policy to impact both long run technological progress and the level of education. On one hand, according to Galor and Weil (2000), lower population density leads to a slower technological progress, thus slowing down economic growth in long run. On the other hand, fertility restrictions provide incentives for households to increase their offspring's education, which increases human capital accumulation, which then accelerates economic growth.

2.2 Model

Consider a small, open, overlapping-generations economy. In each period, the economy produces a single homogeneous good. The output produced at time t, Y_t, is:

$$Y_t = A_t H_t^{\alpha} K_t^{1-\alpha} \tag{2.1}$$

where K_t is physical capital, which is accumulated through aggregate saving and international borrowing, H_t is efficiency units of labor, and A_t represents the endogenously determined technology level. Assume this economy operates in a perfectly competitive world capital market, and the world interest rate is constant at a level of R. The marginal product of capital therefore equals R. Substituting the level of capital into the production function yields output per worker

$$y_t = (1-\alpha)^{\frac{1-\alpha}{\alpha}} R^{\frac{\alpha-1}{\alpha}} A_t^{\frac{1}{\alpha}} h_t \tag{2.2}$$

where $y_t = Y_t/L_t$ and $h_t = H_t/L_t$. Income per wroker at time t, is

$$z_t = w_t h_t = \gamma R^{\frac{\alpha-1}{\alpha}} A_t^{\frac{1}{\alpha}} h_t \tag{2.3}$$

where $\gamma = \alpha(1-\alpha)^{\frac{\alpha-1}{\alpha}}$.

2.2.1 Individuals

Each individual lives for three periods. They are children in the first period, and do not make economic decisions. They simply consume a fraction of their parents' income. In the second period, they become adults and start making decisions. They supply labor and earn wage w_t per efficiency unit of labor, which is used for consumption, transfers, and savings. In this period, they also need to decide the amount of human capital to endow each of their children. In the third period, individuals do not work, and live off their savings and transfers from their children.

Preferences:

$$U_t = ln(c_t) + \beta ln(c_{t+1}) + \nu ln(n_t)$$

where n_t^k is the number of children of individual t.

Budget constraint:

$$c_t + s_t = z_t - (\tau^q + \tau^e e_{t+1}) n_t z_t - \phi \frac{n_{t-1}^{\omega-1}}{\omega} z_t$$
$$c_{t+1} = R s_t + \phi \frac{n_t^{\omega}}{\omega} z_{t+1}$$

An individual born in time $t-1$ starts making economic decisions in time t. Individuals are endowed with one unit of time. The time cost of raising n_t children,$(\tau^q + \tau^e e_{t+1}) n_t z_t$, is propotional to current income, where τ^q is the time cost regardless of the level of education; τ^e is the cost per each unit of education. $\phi \frac{n_{t-1}^{\omega-1}}{\omega} z_t$ is the transfer made to parents, where n_{t-1} is the number of the agent's siblings, with $\phi > 0$ and $0 < \omega < 1$. Thus, an agent's transfer to his parents is decreasing as the number of siblings increases. In period $t-1$, the agent lives off his savings from period t, and the transfers from his own children: $\phi \frac{n_t^{\omega}}{\omega} z_{t+1}$. The transfer increases as the number of children increases, and as his the wage of his children increases.

Human Capital

An individual's level of human capital is determined by education and technology. I assume that education and technological progress, $g_{t+1} = (A_{t+1} - A_t)/A_t$, increases human capital. In addition, according to Schultz(1964), technological progress raises the return to education in producing human capital.

Assumption 1(A1):

$$h_{t+1} = h(e_{t+1}, g_{t+1}) \tag{2.4}$$

where for all $h(e_{t+1}, g_{t+1}) \geq 0$

$$h_e(e_{t+1}, g_{t+1}) > 0; h_{ee}(e_{t+1}, g_{t+1}) < 0$$
$$h_g(e_{t+1}, g_{t+1}) > 0; h_{gg}(e_{t+1}, g_{t+1}) < 0; h_{eg}(e_{t+1}, g_{t+1}) > 0$$
$$h(e_{t+1}, g_{t+1}) > 0; lim_{g_{t+1} \to \infty} h(0, g_{t+1}) = 0;$$

Thus individual human capital is an increasing, concave function of education and the rate of technological progress. In addition, technological progress increases the rate of return to education.

Optimization

Log utility implies that optimal consumption is a constant fraction of the present value of lifetime income, thus

$$c_t = \frac{1}{1+\beta}[(1-(\tau^q+\tau^e e_{t+1})n_t - \phi\frac{n_{t-1}^{\omega-1}}{\omega})z_t + \frac{1}{R}\phi\frac{n_t^{\omega}}{\omega}z_{t+1}] \tag{2.5}$$

Therefore, from the budget constraint,

$$s_t = \frac{\beta}{1+\beta}[(1-(\tau^q+\tau^e e_{t+1})n_t - \phi\frac{n_{t-1}^{\omega-1}}{\omega})z_t - \frac{1}{\beta R}\phi\frac{n_t^{\omega}}{\omega}z_{t+1}] \tag{2.6}$$

Saving increases as the number of children decreases due to the decrease in the cost of raising children and the prospect of lower future transfers.

Number of children:

$$\frac{\nu}{n_t} = \frac{\beta}{c_t}[(\tau^q+\tau^e e_{t+1})z_t - \frac{1}{R}\phi n_t^{\omega-1}z_{t+1}] \tag{2.7}$$

Education influences the optimal number of children through two channels. First, higher education raises the cost per child, thus reducing the incentive to have more children. Second, higher education raises future transfers from each child, thus motivating parents to have more children. If the second effect dominates, the marginal benefit from future transfers is greater than marginal cost, in which case as e_{t+1} increases, the number of children n_t increases. On the other hand, if the first effect dominates, n_t is decreasing in e_{t+1}. In addition,

$$MC = \tau^e h(e_t, g_t)$$
$$MB = \frac{\phi}{\alpha R}n_t^{\omega-1}g_{t+1}^{\frac{1}{\alpha}}h_e(e_{t+1}, g_{t+1})$$

Note marginal cost is independent of e_{t+1}, while the marginal benefit is decreasing in e_{t+1}. In this paper, I assume that there exists an education level $\hat{e}$, such that when $e_{t+1} < \hat{e}$, the marginal benefit is bigger than the marginal cost, so n_t is increasing in e_{t+1}. On the other hand, when $e_{t+1} > \hat{e}$, the marginal benefit is lower than marginal cost. Therefore, n_t decreases in e_{t+1}.

Education:

$$\tau^e n_t^k z_t = \frac{1}{R}\phi\frac{n_t^{\omega}}{\omega}\frac{\delta z_{t+1}}{\delta e_{t+1}} \tag{2.8}$$

Define $G(e_{t+1}, g_{t+1})$ as the difference between MB and MC. For all $e_{t+1} > 0$ and $g_{t+1} \geq 0$,

$$G(e_{t+1}, g_{t+1}) = \frac{1}{R}\phi\frac{n_t^{\omega-1}}{\omega}g_{t+1}^{\frac{1}{\alpha}}h_e(e_{t+1}, g_{t+1}) - \tau^e h(e_t, g_t) = 0 \quad if \quad e_{t+1} > 0 \tag{2.9}$$

$$\leq 0 \quad if \quad e_{t+1} = 0 \tag{2.10}$$

Following from Assumption 1,

$$G_g(e_{t+1}, g_{t+1}) = \frac{\phi}{R\omega}n_t^{\omega-1}g_{t+1}^{\frac{1}{\alpha}}(h_{eg} + \frac{1}{\alpha}\frac{h_e(e_{t+1}, g_{t+1})}{g_{t+1}}) > 0 \tag{2.11}$$

$$G_e(e_{t+1}, g_{t+1}) = \frac{\phi}{R\omega}n_t^{\omega-1}g_{t+1}^{\frac{1}{\alpha}}h_{ee}(e_{t+1}, g_{t+1}) < 0 \tag{2.12}$$

$$G_n(e_{t+1}, n_t) = (\omega - 1)\frac{\phi}{R}\frac{n_t^{\omega-2}}{\omega}g_{t+1}^{\frac{1}{\alpha}}h_e < 0 \tag{2.13}$$

$$G_e(e_{t+1}, n_t) = \frac{\phi}{R\omega}n_t^{\omega-1}g_{t+1}^{\frac{1}{\alpha}}((\omega - 1)n_t^{-1}\frac{\delta n_t}{\delta e_{t+1}} + h_{ee}) < 0 \tag{2.14}$$

In addition, $G(0, 0) = -\tau^e h(e_t, g_t) < 0$. Thus, there exists a positive level of g_{t+1}, such that the optimal choice of e_{t+1} is 0.

Lemma 1. Education e_{t+1} is a concave function of the rate of technological progress g_{t+1}.

$$e_{t+1} = e(g_{t+1}) = 0 \quad if \quad g_{t+1} \leq \hat{g}$$
$$> 0 \quad if \quad g_{t+1} = \hat{g}$$

where $\hat{g} > 0$. $e'_{t+1}(g_{t+1}) = -\frac{h_{eg} + \frac{1}{\alpha}\frac{h_e}{g_{t+1}}}{h_{ee}}$. Following from (2.11) and (2.12), thus

$$e'(g_{g+1}) > 0 \quad \forall g_{t+1} > \hat{g} \tag{2.15}$$

In addition, assume that

$$e"(g_{t+1}) < 0 \quad \forall g_{t+1} > \hat{g} \tag{2.16}$$

Lemma 2 Education e_{t+1} is a decreasing, convex function of the fertility rate n_t, holding g_{t+1}constant. $e'_{t+1}(n_t) = -\frac{G_n(e_{t+1}, n_t)}{G_e(e_{t+1}, n_t)} = -\frac{(\omega-1)\frac{h_e}{n_t}}{(\omega-1)n_t^{-1}\frac{\delta n_t}{\delta e_{t+1}} + h_{ee}}$. Following from (2.13) and (2.14), assume when $e_{t+1} > \hat{e}$, $|h_{ee}| > |(\omega - 1)n_t^{-1}\frac{\delta n_t}{\delta e_{t+1}}|$

$$e'_{t+1}(n_t) < 0$$
$$e_{t+1}"(n_t) > 0$$

Furthermore, substituting $e_{t+1} = e(g_{t+1})$ into (7),

$$\frac{\nu}{n_t} = \frac{\beta}{c_t}[(\tau^q + \tau^e e(g_{t+1}))z_t - \frac{1}{R}\phi n_t^{\omega-1}z_{t+1}]$$

where

$$z_t = w_t h_t = \gamma R^{\frac{\alpha-1}{\alpha}} A_t^{\frac{1}{\alpha}} h(e_t, g_t) = z(e_t, g_t)$$

$$z_e(e_t, g_t) > 0; z_g(e_t, g_t) > 0 \tag{2.17}$$

2.2.2 Comparative Statics

The effect of technological progress on quantity and quality of children:

$$\frac{\delta n_t}{\delta g_{t+1}} > 0 \tag{2.18}$$

$$\frac{\delta e_{t+1}}{\delta g_{t+1}} > 0 \tag{2.19}$$

The quantity and quality trade-off effect:

$$\frac{\delta n_t}{\delta e_{t+1}} > 0 \quad if \quad e < \hat{e} \tag{2.20}$$

$$\frac{\delta n_t}{\delta e_{t+1}} < 0 \quad if \quad e > \hat{e} \tag{2.21}$$

$$\frac{\delta e_{t+1}}{\delta n_t} < 0 \tag{2.22}$$

2.2.3 Technological progress

Technological progress g_{t+1} depends on the education level of generation t, e_t, and the population size in period t, L_t.

$$g_{t+1} = \frac{A_{t+1}}{A_t} = g(e_t) f(L_t) \tag{2.23}$$

where for all $e_t > 0$ and $L_t > 0$

$$g(0) > 0, g'(e_t) > 0, g''(e_t) < 0$$
$$f(L_t) > 0, f'(L_t) > 0, f''(L_t) < 0$$

Thus, g_{t+1} is an increasing and concave function of e_t and L_t. In addition, when the education level of generation t is zero, $g_{t+1} > 0$.

2.3 The Dynamical System

The evolution of the economy is fully determined by the following system

$$e_{t+1} = e(g(e_t, L_t), n_t)$$
$$g_{t+1} = g(e_t, L_t)$$
$$L_{t+1} = n_t(g(e_t, L_t), e_{t+1})L_t$$

This system governs the co-evolution of output per worker, population, technology, education, and human capital per worker.

2.3.1 The Evolution of Quantity and Quality

The dynamical sub-system of childrens' quantity and quality consists of:

$$QQ : e_{t+1} = e(n_t)$$
$$NN : n_t = n(e_{t+1})$$

QQ represents the response of education to fertility while NN represents the response of the quantity of children to education, holding technology constant. From equation (2.7) and lemma 2, the QQ curve is decreasing and convex in n_t. NN is increasing in e_{t+1} when $e_{t+1} < \hat{e}$ and decreasing in e_{t+1} when $e_{t+1} > \hat{e}$.

Figure 2.5a depicts the evolution of the fertility rate and education level when $e_{t+1} < \hat{e}$. I assume that NN is convex in e (Note: convexity is not essential. Alternative assumption will not change the result). Given the rate of technological progress, the intersection of the NN and QQ curves determines the temporary stable equilibrium (e_1, n_1). From lemma 2 and equation 7, the NN and QQ curves shift to the right in response to an increase in g_t. In response, fertility rate increases. The effects on education work through two channels.

On one hand, as the rate of technological progress increases, the rate of return to education increases, which increases the chosen level of education. On the other hand, as the number of children increases, the cost increases, which decreases the incentive to invest in children's education. From Lemma 1 and Lemma 2, the positive effect always dominates when $\frac{\delta n_t}{\delta e_{t+1}} > 0$. Thus, as the rate of technological progress increases, the education level and fertility rate increase.

Figure 2.5b on the other hand shows the evolution of fertility and education when $e_{t+1} > \hat{e}$. I assume that NN is flatter (This assumption is made to ensure a unique intersection. Alternative assumption will not change the result). As before, when the rate of technological progress, g_{t+1}, increases, the NN and QQ curves shift to the right. Thus, the fertility rate again increases. Recall that $\frac{\delta n_t}{\delta e_{t+1}} < 0$ if $e_{t+1} > \hat{e}$. Thus, in contrast to the previous case, now the change in education is ambiguous. China yearbook provides data on the percentage of graduates entering higher education. In this paper, I use the percentage of

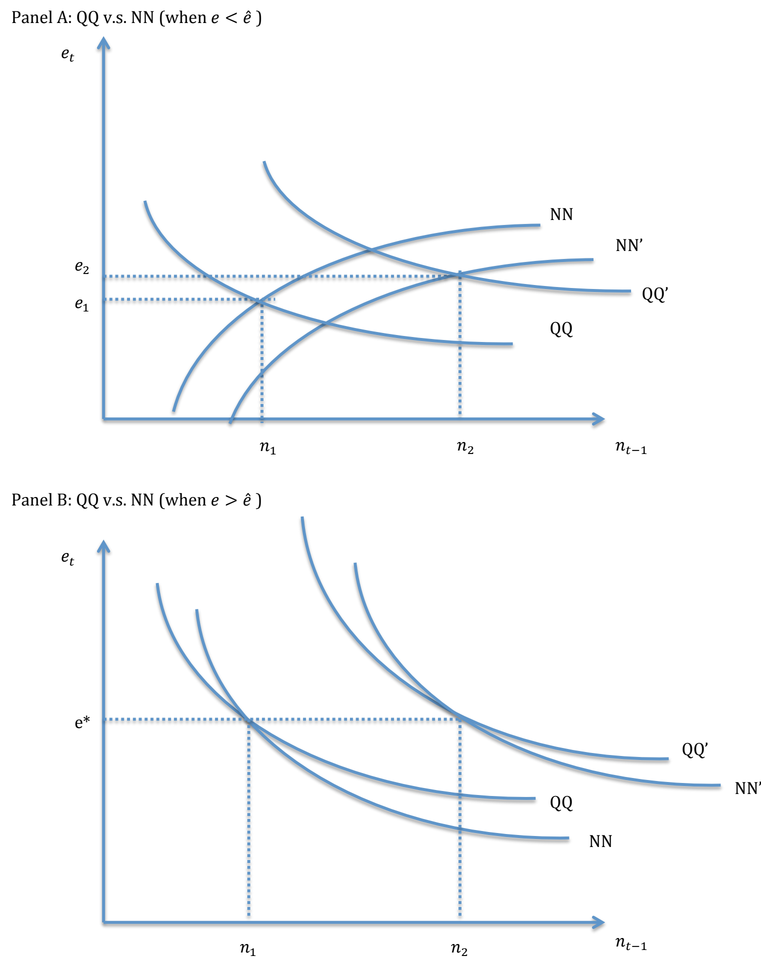


Figure 2.5: QQ vs. NN

graduates of junior middle school entering senior middle school as a proxy for the average education level. (Note: data for the percentage of graduates of senior middle school entering college is not available until year 1990). In 1966, China's Communist leader Mao Zedong launched the Cultural Revolution. This revolution had a massive impact on education. In the early months of the Cultural Revolution, schools and universities were closed. Even though primary and middle schools later gradually reopened, the youth in urban areas were sent to live and work in agrarian areas in order to obtain a better understanding of the role of manual agrarian labor in Chinese society. In addition, most universities did not reopen until 1972. The university entrance exams were not restored until 1977 under Deng Xiaoping. Thus 1977 is often considered as the end of the Cultural Revolution. Thus, the Cultural Revolution severely damaged China's education system. In this research, in order to eliminate this exogenous impact on education, I focus on the period after the Culture

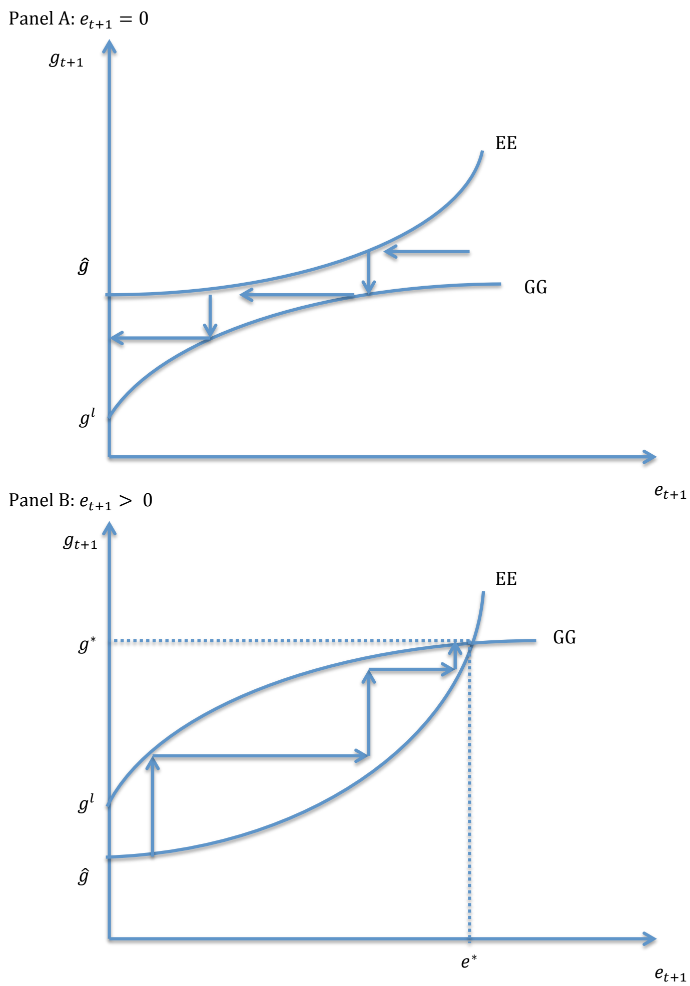


Figure 2.6: EE vs. GG

Revolution. Data shows that the percentage of graduates of junior middle school entering senior middle school was 45.9% in 1980. Thereafter, it was pretty stable around 40% to 45% until 1994 (see Figure 8). In order to be consistent with the data, I assume that the cut-off education level $\hat{e}$ occurs when the percentage of graduates of junior middle school entering senior middle school is 45%. When $e_{t+1} > \hat{e}$, as the rate of technological progress increases, the education level stays constant and the fertility rate increases.

2.3.2 The Evolution of Technology and Education

The dynamical sub-system of Technology and Education consists of:

$$EE : e_{t+1} = e(g(e_t))$$
$$GG : g_{t+1} = g(e(g_t))$$

From equation (2.21) and lemma 1, the EE curve is concave while the GG curve is convex. In the graph above, $g^l = g(0, L)$, is the technology growth rate when education is zero. $\hat{g}$ is such that, when $g \leq \hat{g}$, the optimal level of education is 0.

As in Galor and Weil(1998), I separate the analysis into two regimes, depending on whether the optimal level of education is zero or positive. When the population size is small enough, there is a temporary steady state where $(\bar{e}, \bar{g}) = (0, g^l)$ for a given population size. As shown in Figure 2.6a, the rate of technological progress increases monotonically with the size of population, while the education level remains at zero. This is because technological progress is too low to invest in education.

As population gradually increases, the rate of technological progress increases. At a certain level of population, g^l is high enough, such that $g^l > \hat{g}$. For a given population size, there exists a stable steady state equilibrium: $(\bar{e}, \bar{g}) = (e^*, g^*)$. As discussed in section 2.1, an increase in the rate of technological progress increases the fertility rate and education level at the beginning when $e_{t+1} < \hat{e}$. As n_t increases, the GG and QQ curves shift upwards. Thus, technological progress and education increase over time, as well as the fertility rate. The positive impact of technological progress on education only operates when $e_{t+1} < \hat{e}$. As education level increases, once $e_{t+1} > \hat{e}$, further increase in technological progress rate no longer increases the education level. Thus, once the economy crosses the threshold where $e_{t+1} < \hat{e}$, education stays constant. As education stays constant, equation (2.23) then implies the population size converges to a constant level L^* (population growth rate is zero). Figure 2.6b shows that in the steady state, the education level and the rate of technological progress will be constant.

2.4 The Impact of the One Child Policy

Now assume the government imposes an exogenous fertility control policy, such that each individual can only have one child. Thus, $n_t = 1$. The fixed fertility rate affects the GG curve through the change in L_t. In addition, it also shifts the EE curve due to quantity and quality trade-off effects. As the number of children decreases, parents' future transfers decrease. Thus, according to lemma 2, reducing the fertility rate increases the incentive for parents to invest more in their children's education.

First, suppose the economy is in the Malthusian regime when the policy is implemented. In this regime, the optimal level of education is 0. If the fertility rate is fixed at $n_t = 1$, the

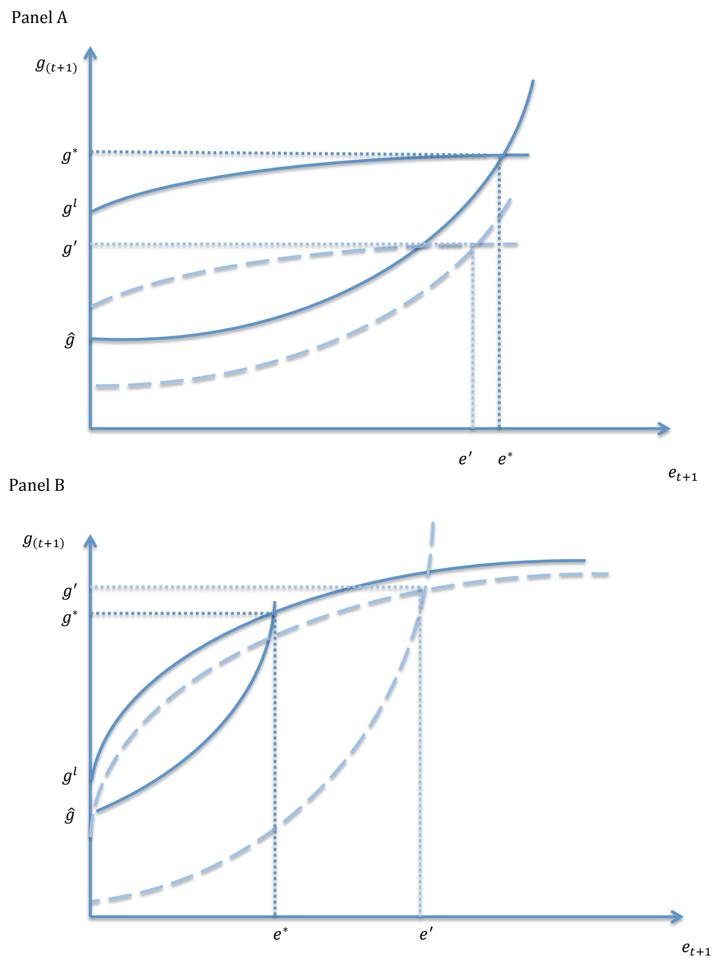


Figure 2.7: Impact of One-Child-Policy

rate of technological progress remains constant and the education level stays at zero. The economy will never be able to move to the second regime.

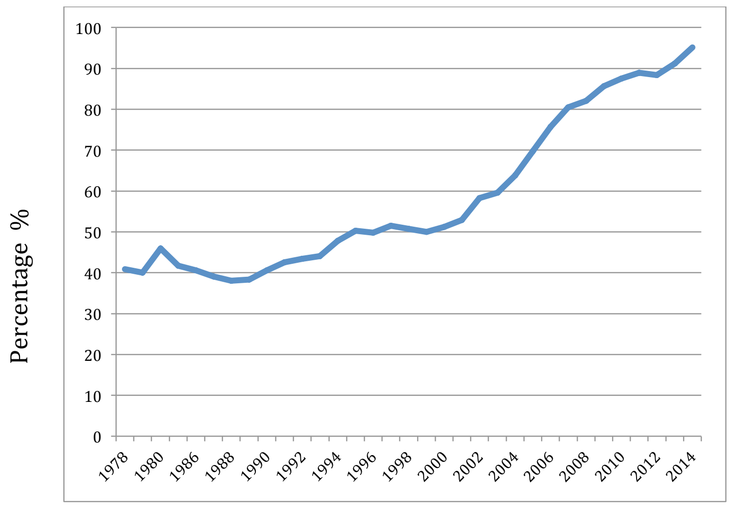
As the benchmark model is section 2.2 revealed, there exists a threshold level of education. When education is above this level, the effect of technological progress on education vanishes in the absence of exogenous shocks. Given the concavity of technological progress in population, as assumed in equation (2.23), the population will be stable around a constant level in the long run equilibrium. In other words, each family will eventually choose to voluntarily have only "one-child" in the long run equilibrium, even without any policy restriction. Thus, when considering the timing of the policy, it is only binding *before* the long run equilibrium is reached. Technological progress and education level instead of moving between steady states, they will jump to their new saddle path.

Now assume the policy is introduced during the second regime, in which $g^l > \hat{g}$. In this case, as n_t is decreased to 1, the GG curve shifts to the right. From lemma 2, the EE curve also shifts to the right. Introducing the one-child-policy before the steady state is reached will not change the fertility rate in the long run. It only decreases the total population. This decreases the long-run technological growth rate. On the other hand, given the quantity/quality trade-off effect, as number of children decreases, the chosen level of education increases. A higher level of education advances technological progress. Thus, the change in the rate of technological progress depends on whether the negative effect from lower population dominates the positive effect from the higher education. Figure 2.7a depicts the case when the negative effect dominates. The new steady state that if one child policy was introduced is: $(\bar{e}, \bar{g}) = (e', g')$, where $g' < g^*$ and $e' < e^*$. Notice that the effect on education also works through two channels. First, the chosen level of education increases as the fertility rate decreases. Second, as technological progress decreases, the rate of return to education decreases thus reduce the incentive to educate the children. Following Lemma 1 and Lemma 2, when one child policy is introduced, $\frac{\delta n_t}{\delta e_{t+1}} = 0$, thus the technological effect always dominates, which means education decreases. In contrast, if the positive effect from higher education on technological progress rates dominates the negative effect from lower population. Long run technological progress rate and chosen education level increase. Figure 2.7b has shown the new steady state that if one child policy was introduced is: $(\bar{e}, \bar{g}) = (e', g')$, where $g' > g^*$ and $e' > e^*$.

Therefore, when we take the negative effect of fertility rate on the chosen level of education into consideration, the impact of the one-child policy on economic growth in China is ambiguous. Consider an economy with particular technological progress and human capital functions such that, when one-child policy was introduced, the quantity-quality effect was not large enough to compensate the negative population spill over effect on technological progress. This situation is represented in Figure 2.7a, in which both technological progress and education level merge to a lower level of long run equilibrium. In addition, the growth rate of output per capita is lower than the benchmark model predication. On the other hand, now consider an alterative human capital function such that, when number of children decreases, chosen level of education increases by a significant magnitude. In addition, the technological progress function allows the positive education effect dominates the negative population effect. Thus, the economy merges to a higher level of technological progress rate and education in the long run as shown in Figure 2.7b. Output per capita also grows at a higher rate compare to the benchmark model.

2.5 Conclusion

Motivated by Galor and Weil (2000), this paper examines the effects China's exogenous population control on economic growth. This paper adopts two key assumptions from the



Data Source: China year book(2015)

Figure 2.8: graduates of junior secondary schools entering senior secondary schools (%)

Galor-Weil model: (1) higher population leads to technological progress, and (2) technological progress raises the return to human capital. On the other hand, it incorporates one new element into the model, which is the negative effect of fertility on education. Taking within family intergenerational transfers into consideration, raising children is no longer just for pleasure, but it also becomes an investment.

The theoretical analysis shows that in response to exogenous population control intervention, total population decreases, which produces a negative effect on technological progress. However, transfers from children to parents decrease as number of children decreases. Thus, parents increase the education endowment in their only child in order to increase their child's future income to compensate the loss from reduced transfers. Higher education levels then trigger more rapid technological progress. Based on the theoretical framework in this paper, we are not able to conclude unambiguously whether the one-child policy will have a positive or negative effect on long run economic growth in China.

Figure 2.8 shows the time path of education index, which is the percentage of graduates of junior secondary schools entering senior secondary schools. The figure shows that the education level fluctuates around 40 to 45 % from 1978 to 1993. It starts rising after 1994. In 2014, the percentage of Graduates of junior secondary schools entering senior secondary schools is as high as 95%. Since the policy was implemented in 1980, the "only-child" will start entering senior high around 1995. Thus, the timing of the increase in education is coincident with the implementation of the one-child policy. The data suggested that education increases after the population control intervention, which is consistent with our quantity-quality trade off effect assumption. However, in order to understand the casual relationship, it requires further quantitative analysis. The forms for technological progress and human capital need to be specified in order to provide a quantitative estimation. Given that this paper has provided a theoretical framework for examining the impact of one-child policy on long run economic development, it allows me to extend the analysis by studying the quantitative effects in the future.

Chapter 3

Population Control and Long Run Economic Growth: A Quantitative Study of China's One-Child Policy

3.1 Introduction

The evolution of population and income per capita has been an important topic in economics. A number of papers have provided models to capture the historical evolution of these two variables. The "Malthus Model" (1798) suggested a positive relationship between income per capita and population growth. More recent studies have found that the relationship is negative, or at most non-significant. For example, Barlow (1994), Simon (1989) and Kelly (1988) support a negative or non-significant relationship. Becker, Murphy and Tamura (1990) argue that the failure of the Malthusian model to explain more recent data stems from its neglect of human capital investment.

Galor and Weil (2000) develop a unified growth model that captures the evolution of population growth and income per capita in the "very long" run. Figure 3.1 depicts the growth rates of population and income per-capita in Western Europe from AD 600 to the 1900s (Lagerlöf (2006)). The figure shows that the relationship between population and income per capita switched from positive to negative during the last couple of millennia. Galor and Weil (2000) model the evolution of population and income by separating it into three regimes. First, in the "Malthusian Regime", income and population growth are positively correlated, and the growth rates of population and per capita income are low. Then, in the "Post-Malthusian Regime", income and population growth are still positively correlated, but grow at a faster rate. Finally, the last regime is called the "Modern Growth Regime". This regime differs from the previous two because income and population growth now become negatively correlated. Lagerlöf (2009) provides a quantitative analysis of the

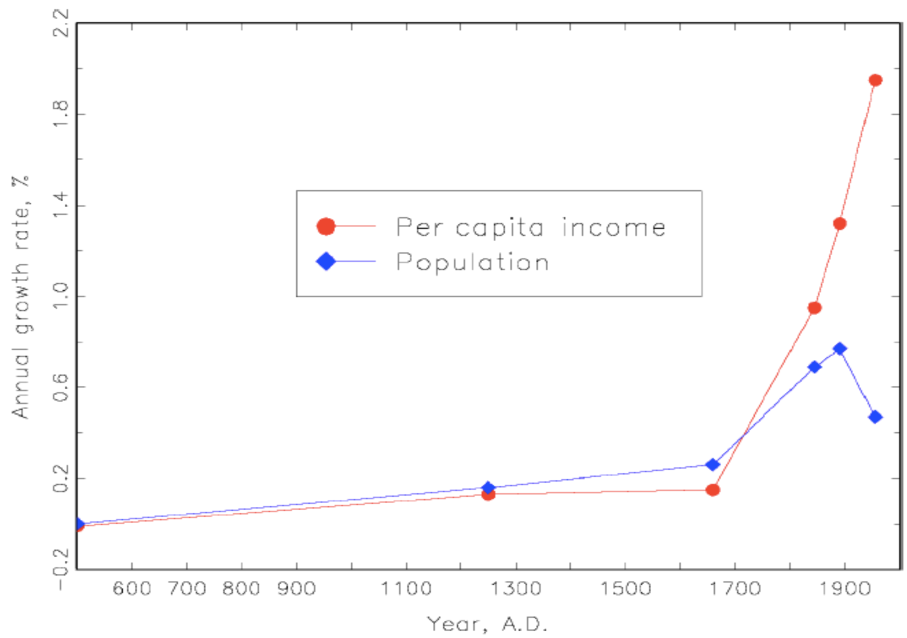


Figure 3.1: Growth Rates in Western Europe (Lagerl$\ddot{o}$f(2006))

Galor/Weil model. The estimated results replicate the growth paths that are observed in the data.

Interestingly, the evolution of population and income in China appears to follow a similar historical pattern as the one in Western Europe. Figure 3.2 shows the growth rates of population and GDP per capita in China from 1500 to 2008, based on Maddison's (2007) estimates. As the graph shows, the evolution of population and income replicates a three-stage process of development, which is consistent with the Galor-Weil model. The transit from the "Post-Malthusian Regime" to the "Modern Growth Regime" started in the 1980s, after which the population growth rate starts to drop significantly. However, it is important to note that this was not due to an endogenous fertility change; rather, it was caused by an exogenous fertility control policy, the so-called "One-Child Policy".

In 1979, China introduced a "One-Child Policy", in order to reduce population growth and alleviate social, economic, and environmental pressures. The policy stated that each couple could have only one child. However, some exceptions were allowed. For example, ethnic minorities and some families in rural areas were exempted. This policy reduced the fertility rate significantly, especially in urban areas. According to China Census, the average fertility rate in urban areas was around 3 births per woman in the 1970s. The birth rate decreased to almost 1 by the mid-1980s. China's one-child policy is a unique population control scheme, which has attracted the attention of economic researchers. Choukhmane,

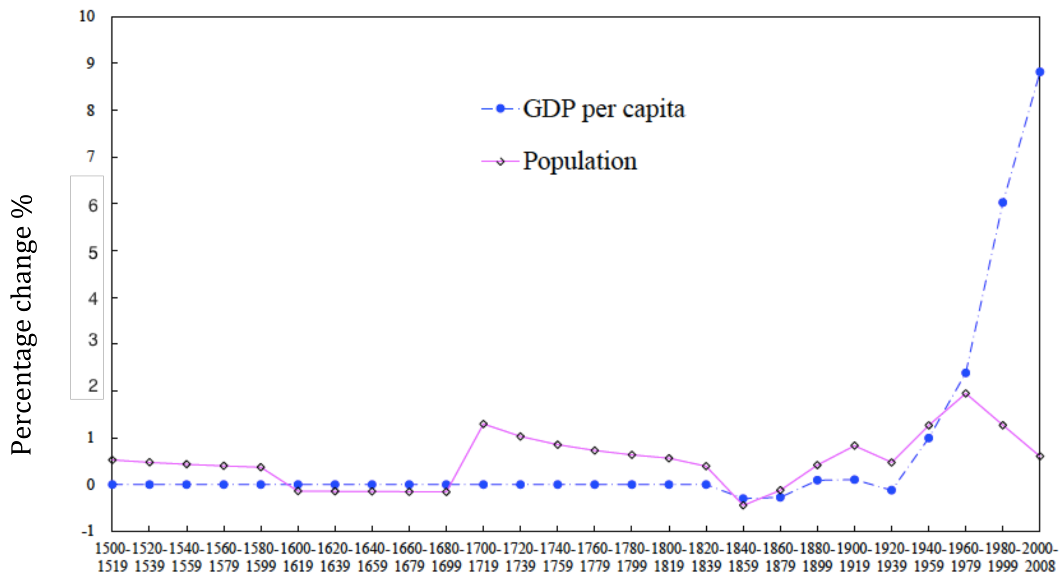


Figure 3.2: Growth Rates in China (Xue, Yip and Tou(2013))

Coeurdacier and Jin (2014) investigate the effect of the one-child policy on China's household saving rate and human capital. Song, Storesletten, Wang and Zilibotti (2015) analyze the welfare effects of alternative pension systems, taking the one-child policy into consideration. In chapter 1 I argue that exogenous fertility restrictions affected economic decisions at the household level, and demographic composition at the aggregate level. In that paper I show that the demographic transition combined with domestic financial market imperfections can explain the recent increase in China's foreign reserves. In addition, many of the past papers focus on examining the effect of the one-child policy on the economic growth. Li and Zhang (2007) provide an empirical analysis of the impact of the birth rate on economic growth. They find that the birth rate has a negative impact on economic growth. Xue, Yip and Tou (2013) use the Galor-Weil model to analyze the effect of exogenous population control on China's long run economic development. They extend the Galor-Weil model by introducing a policy variable on population growth. According to Galor and Weil (2000), lower population density leads to slower technological progress. Thus, they find that in the long run, population control results in a steady state of lower education, and slower technological progress and economic growth.

However, in chapter 1 I argue that within-family intergenerational transfers play a crucial role for old age support in China. Thus, raising children does not only provide utility, it also constitutes an investment. When the one-child policy was implemented, parents could expect lower future income, as the number of children they have decreases. To compensate for this loss, parents optimally substitute quality for quantity. That is, parents increase investment in their children's education in order to accumulate financial wealth in expectation of lower support from their children. Therefore, by incorporating a "quantity-quality" trade off into the model, the effect of the one-child policy on China's long-run economic growth becomes ambiguous without specifying explicit functional forms. The key ingredient in Chen's (2015) model is the "quantity-quality" trade off, which is supported by empirical evidence. Choukhmane, Coeurdacier and Jin (2014) provide an empirical check by using the birth of twins as an exogenous deviation from the policy. The results show that the per-capita education expenditure on a twin is significantly lower than on an only child in China. Rosenzweig and Zhang (2007) also find a significant contribution of the one-child policy in China to the development of its human capital.

In chapter 2 I provide a theoretical framework for examining the impact of the one-child policy on long run economic development. In this paper, I extend the model by taking into account the long-run relationship between population and per capita income. In addition, I specify explicit functional forms for relationships that were only described in general terms in Chen's (2015) model, and then use them to quantify the effects of China's one-child policy on its long run economic growth. The transition between the three stages of economic development in this paper differs from the Galor-Weil model in a few ways. First, in their model, one of the main forces driving the economy's transition from one regime to another is a subsistence consumption constraint. The fertility rate depends on the level of income when the constraint is binding, and remains constant when the constraint is not binding. In this paper, by incorporating within family intergenerational transfers, a household's optimal fertility rate always depends on children's income, while the fertility choice function remains constant across different regimes. Second, intergenerational transfers also extend the Galor -Weil's one period model to a three-period model. Third, the Galor-Weil model assumed a negative effect of technological progress on human capital to ensure parents trade children's quantity for quality. In this paper, since education is treated as an investment, technological progress is assumed to increase human capital. This is more consistent with previous literature.

In the next section, I describe the benchmark model without the one-child policy. In section 3.3, I specify the functional forms by using Lagerlöf's (2006) study of the Galor-Weil model as guidance. In section 3.4, I begin by providing intuition for the benchmark model's dynamics, and how it transitions from one regime to another. Then, I analyze the impact of the one-child policy. In section 3.5, I calibrate parameter values from the data, and provide a quantitative analysis.

3.2 Model

Consider a small, open, overlapping-generations economy. In each period, the economy produces a single homogeneous good. The income per unit of time of an agent at time t is:

$$z_t = h_t^{\alpha} x_t^{1-\alpha} == h_t^{\alpha} (\frac{A_t X}{L_t})^{1-\alpha} \tag{3.1}$$

where h_t is human capital accumulated for generation t. A_t indicates the endogenously determined technology level at time t. L_t is the total worker population. X represents a fixed factor, which is treated as a exogenous constant here. Thus, x_t is the effective resource per worker.

3.2.1 Individuals

Each individual lives for three periods. They are children in the first period, and do not make economic decisions. They simply consume a fraction of their parents' income. In the second period, they become adults and start making decisions. They supply labor and earn income z_t, which is used for consumption, parental transfers, and savings. In this period, they also need to decide the amount of human capital to endow each of their children with. In the third period, individuals do not work, and live off their savings and transfers from their children.

Preferences:

$$U_t = ln(c_t) + \beta ln(c_{t+1}) + \nu ln(n_t)$$

where n_t is the number of children of generation t.

Budget constraint:

$$c_t + s_t = z_t - (\tau^q + \tau^e e_{t+1}) n_t z_t - \phi \frac{n_{t-1}^{\omega-1}}{\omega} z_t$$
$$c_{t+1} = R s_t + \phi \frac{n_t^{\omega}}{\omega} z_{t+1}$$

In addition, I impose a non-negativity constraint on education:

$$e_{t+1} \geq 0$$

An individual born in period $t-1$ starts making economic decisions in period t. Individuals are endowed with one unit of time. The time cost of raising n_t children,$(\tau^q + \tau^e e_{t+1}) n_t z_t$, is proportional to current income, where τ^q is the time cost regardless of the level of education; τ^e is the cost per each unit of education. $\phi \frac{n_{t-1}^{\omega-1}}{\omega} z_t$ is the transfer made to parents, where n_{t-1} is the number of the agent's siblings, with $\phi > 0$ and $0 < \omega < 1$. Thus, an agent's transfer to his parents is decreasing as the number of siblings increases. In period $t-1$, the agent lives off his savings from period t, and the transfers from his own children:

$\phi\frac{n_t^\omega}{\omega}z_{t+1}$. The transfer increases as the number of children increases, and as the wage of his children increases.

Human Capital

An individual's level of human capital is determined by education and technology. I assume that education and technological progress, $g_{t+1} = \frac{A_{t+1}}{A_t}$, increases human capital. In addition, according to Schultz(1964), technological progress raises the return to education in producing human capital.

Assumption 1(A1):

$$h_{t+1} = h(e_{t+1}, g_{t+1}) \tag{3.2}$$

where for all $(e_{t+1}, g_{t+1}) \geq 0$

$$\begin{aligned} &h_e(e_{t+1}, g_{t+1}) > 0; h_{ee}(e_{t+1}, g_{t+1}) < 0 \\ &h_g(e_{t+1}, g_{t+1}) > 0; h_{gg}(e_{t+1}, g_{t+1}) < 0; h_{eg}(e_{t+1}, g_{t+1}) > 0 \\ &h(e_{t+1}, g_{t+1}) > 0; lim_{g_{t+1}\to\infty} h(0, g_{t+1}) = 0; \end{aligned}$$

Thus individual human capital is an increasing, concave function of education and the rate of technological progress. In addition, technological progress increases the rate of return to education.

Optimization

Log utility implies that optimal consumption is a constant fraction of the present value of lifetime income, thus

$$c_t = \frac{1}{1+\beta}[(1 - (\tau^q + \tau^e e_{t+1})n_t - \phi\frac{n_{t-1}^{\omega-1}}{\omega})z_t + \frac{1}{R}\phi\frac{n_t^\omega}{\omega}z_{t+1}] \tag{3.3}$$

The first order condition for e_{t+1} gives

$$G(n_t, e_{t+1}, g_{t+1}) = \begin{cases} 0 & \text{if } e_{t+1} > 0 \\ \leq 0 & \text{if } e_{t+1} = 0 \end{cases}$$

where $\forall e_{t+1} \geq 0$ and $\forall g_{t+1} > 0$.

$$G(n_t, e_{t+1}, g_{t+1}) = \frac{\alpha\phi}{R\omega}n_t^{\omega+\alpha-2}g_{t+1}^{1-\alpha}h^{\alpha-1}(e_{t+1}, g_{t+1})h_e(e_{t+1}, g_{t+1}) - \tau^e h^\alpha(e_t, g_t) \tag{3.4}$$

Thus, education invested in children (e_{t+1}) is an implicit function of the number of children (n_t) and technological progress (g_{t+1}).

In addition,

$$G(n_t, 0, 0) = -\tau^e h^\alpha(e_t, g_t) < 0$$

Thus, there exists a positive g_{t+1} such that the optimally chosen level of education is 0. It is written as,

$$e_{t+1} = e(g_{t+1}, n_t) = \begin{cases} 0 & \text{if } g_{t+1} \leq \hat{g} \\ > 0 & \text{if } g_{t+1} > \hat{g} \end{cases}$$

Lemma1. Following from Assumption 1(A1), $\forall g_{t+1} > \hat{g}$

$$\frac{\delta e_{t+1}}{\delta n_t} = -\frac{G_n(n_t, e_{t+1}, g_{t+1})}{G_e(n_t, e_{t+1}, g_{t+1})} < 0 \tag{3.5}$$

$$\frac{\delta e_{t+1}}{\delta g_{t+1}} = -\frac{G_g(n_t, e_{t+1}, g_{t+1})}{G_e(n_t, e_{t+1}, g_{t+1})} > 0 \tag{3.6}$$

In addition , I assume (A2):

$$\begin{cases} \frac{\delta^2 e_{t+1}}{\delta^2 n_t} & > 0 \\ \frac{\delta^2 e_{t+1}}{\delta^2 g_{t+1}} & < 0 \end{cases}$$

The first-order condition for n_t gives

$$F(n_t, e_{t+1}, g_{t+1}) = 0 \tag{3.7}$$

where

$$F(n_t, e_{t+1}, g_{t+1}) = \frac{\nu}{n_t} - \frac{\beta}{c_t}[(\tau^q + \tau^e e_{t+1})z_t - \frac{1}{R}\phi n_t^{\omega-1} z_{t+1}] \tag{3.8}$$

The optimal number of children is an implicit function of education invested in children (e_{t+1}) and technological progress (g_{t+1}).

Lemma2. Following from Assumption 1(A1):

$$\frac{\delta n_t}{\delta e_{t+1}} = -\frac{F_e(n_t, e_{t+1}, g_{t+1})}{F_n(n_t, e_{t+1}, g_{t+1})} < 0 \tag{3.9}$$

$$\frac{\delta n_t}{\delta g_{t+1}} = -\frac{F_g(n_t, e_{t+1}, g_{t+1})}{F_n(n_t, e_{t+1}, g_{t+1})} > 0 \tag{3.10}$$

In addition , I assume (A3):

$$\begin{cases} \frac{\delta^2 n_t}{\delta^2 e_{t+1}} & > 0 \\ \frac{\delta^2 n_t}{\delta^2 g_{t+1}} & < 0 \end{cases}$$

3.2.2 Technological progress

Technological progress g_{t+1} depends on the education level of generation t, e_t, and the population size in period t, L_t. For all $e_t > 0$ and $L_t > 0$,

$$g_{t+1} = \frac{A_{t+1}}{A_t} = g(e_t, L_t) \tag{3.11}$$

$$g(0, L_t) > 0, \frac{\delta g_{t+1}}{\delta e_t} > 0, \forall e_t \geq 0$$
$$\lim_{L_t \to \infty} g(e_t, L_t) \text{ is finite}, \frac{\delta g_{t+1}}{\delta L_t} > 0, \forall L_t > 0$$

Thus, g_{t+1} is an increasing and concave function of e_t and L_t. In addition, when the education level of generation t is zero, $g_{t+1} > 0$.

3.3 Functional Forms

In this section, a calibration analysis is performed in order to exam the model quantitatively. Firstly, the functional forms for technology and human capital that were defined only implicitly in the previous section need to be specified. Motivated by Largerlof(2006), here I assume that,

$$h_{t+1} = h(e_{t+1}, g_{t+1}) = [g_{t+1}(\rho\tau^q + e_{t+1})]^\mu \tag{3.12}$$

where $0 < \mu < 1$. $\rho\tau^e$ measures the human capital that can be built from parents' nursing , where $0 < \rho < 1$. Thus, $\rho\tau + e_{t+1}$ can be interpreted as effective education. Given $\rho < 1$, nursing is not as effective as education in terms of building a child's human capital.

The functional form for technological progress is also borrowed from Largerlof(2006),

$$g_{t+1} = g_(e_t, L_t) = (e_t + \rho\tau^q)a(L_t) + 1 \tag{3.13}$$

where $a(L_t)$ is a scale effect; it takes the form:

$$a(L_t) = min\{\theta L_t, a^*\} \tag{3.14}$$

where $\theta > 0$ and $a^* > 0$.

Thus, using these functional forms for g_{t+1} and h_{t+1} in $G(n_t, g_{t+1}, e_{t+1})$ (equation (3.6)), the optimal education level, e_{t+1}, can be written as an explicit function of e_t, g_t n_t and L_t,

$$e_{t+1} = max\{0, \sqrt[1-\mu\alpha]{\frac{\mu\phi\alpha}{R\omega} n_t^{\omega+\alpha-2}[(e_t + \rho\tau^q)\theta L_t + 1]^{1+\alpha(\mu-1)}(\tau^e h_t^\alpha)^{-1}} - \rho\tau\} \tag{3.15}$$

$$= \psi(n_t, e_t, g_t, L_t) \tag{3.16}$$

The optimal level of education increases as population size L_t increase. Thus, education switches from 0 to a positive number at a particular population level of $\hat{L}$, such that,

$$\hat{L}_t = \frac{(\tau^e h_t^\alpha \frac{R\omega}{\mu\alpha\phi} n_t^{2-\omega-\alpha}(\rho\tau^q)^{1-\mu\alpha})^{\frac{1}{1+\alpha(\mu-1)}} - 1}{\rho\tau^q\theta} \tag{3.17}$$

I assume that e_{t+1} switches from 0 to a positive level before $a(L_t)$ reaches its maximum.

3.4 The dynamical system

Using the functional forms for human capital and the rate of technological progress, income per worker, z_t, can be written as the function:

$$z_t = [(g_t(\rho\tau + e_t))^\mu]^\alpha (\frac{A_t X}{L_t}) - = z(A_t, g_t, e_t, L_t) \tag{3.18}$$

In addition, the expression for the optimal fertility rate, $F(n_t, g_{t+1}, e_{t+1})$ (equation 3.10), can now be written as a function of g_t, e_t, L_t. Thus,

$$n_t = \xi(g_t, e_t, L_t) \tag{3.19}$$

The development of this economy is characterized by the evolution of income per worker, population, technological progress, education per worker, and human capital per worker. The full dynamics are thus determined by a four dimensional non-linear system:

$$\begin{cases} A_{t+1} &= g(e_t, L_t)A_t \\ g_{t+1} &= g(e_t, L_t) \\ e_{t+1} &= \psi(e_t, g_t, L_t) \\ L_{t+1} &= \xi(g_t, e_t, L_t)L_t \end{cases}$$

3.4.1 Analysis of Three Regimes

As in Galor and Weil(2000), the model encompasses three distinct regimes: (1) the Malthusian Regime, (2) the Post-Malthusian Regime, and (3) the Modern Growth regime.

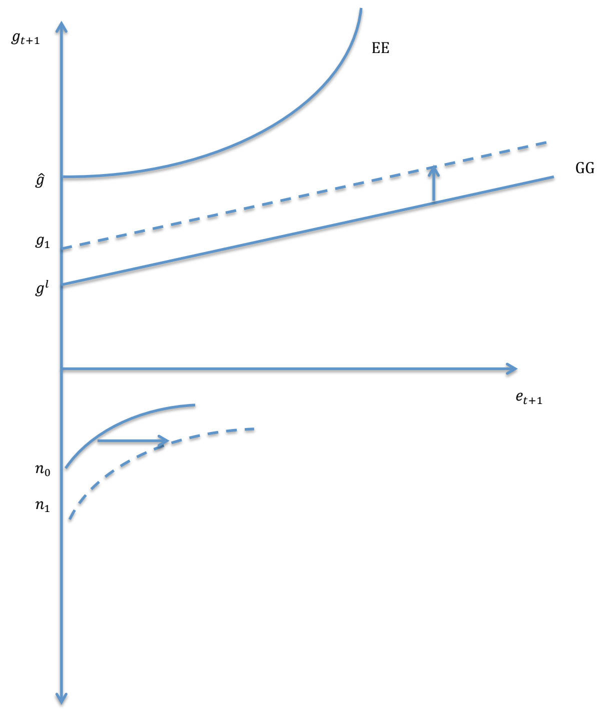


Figure 3.3: The Malthusuan Regime

The Malthusian Regime

Consider an economy in its early stage of development, the so-called Malthusian regime. In this regime, education is 0. This is because the low population size leads to a low rate of technological progress, which makes it unprofitable for parents to invest in their children's education. Thus, parents invest in the quantity of children only. Figure 3.3 shows the evolution of technological progress, education, and the fertility rate during this regime. From lemma 1 and A(1), the EE curve represents the optimal education level, which depends on technological progress, while holding the fertility rate constant.

$$EE : e_{t+1} = e(g(e_t)) \tag{3.20}$$

Given the functional form for technological progress (equation (3.13)), the GG curve represents the rate of technological progress, which depends on the education level, while holding population constant.

$$GG : g_{t+1} = g(e(g_t)) \tag{3.21}$$

The upper half of the graph thus shows the relationship between technological progress and education, holding the population size and fertility rate constant. The bottom half on the other hand shows the optimal number of children, which depends on the education level

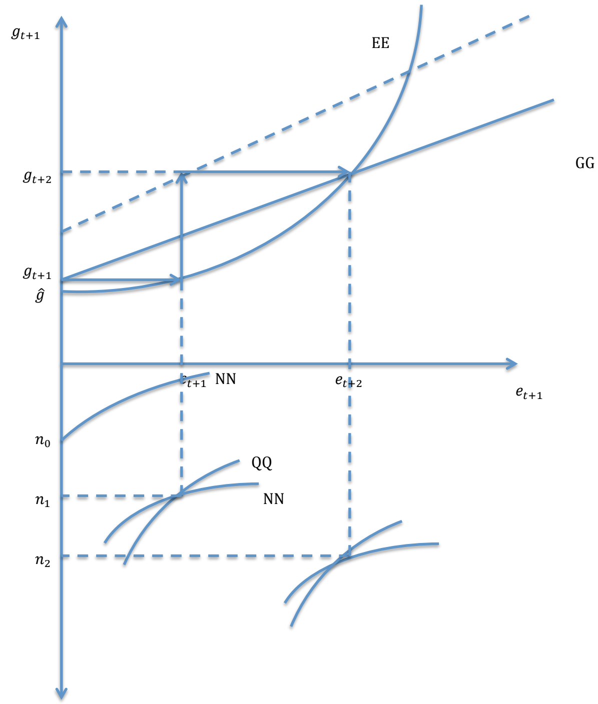


Figure 3.4: The Post-Malthusuan Regime

while holding technological progress constant.

$$NN : n_t = n(e_{t+1}) \tag{3.22}$$

In the Malthusian Regime, a small population leads to a low rate of technological progress. Consider a time $t = 0$, $g_0 = g^l$, which is lower than $\hat{g}$. Recall that when $g < \hat{g}$, the optimal education level is 0. Thus, given $g_0 = g^l$, the NN curve indicates that the optimal fertility rate at time $t = 0$ is n_0. Assume initial $n_0 > 1$, population is increasing at rate n_t. As population increases, the GG curve shifts up, and technological progress at $t = 1$, g_1, increases. From Lemma 2, as technological progress increases, the NN curve shifts down, and the fertility rate, n_1 increases. In this regime, as population expands, technological progress and income per worker increase at a relatively slow rate. In addition, population and technological progress increase in parallel.

The Post-Multhusian Regime

The transition from the Malthusian Regime to the Post-Malthusian regime emerges when the population becomes large enough, i.e. $L > \hat{L}$. Figure 3.4 shows the evolutions in the Post-Malthusian regime. As technological progress increases due to an increase in population, the rate of return to investing in human capital increases. Thus parents start to invest in their children's education when technological progress is high enough. Lemma 1 and A (1) suggests that a higher education level leads to a decrease in the fertility rate. The QQ curve in Figure 5 indicates the optimal education level that parents decide to endow their children with, the 'quality' of their children, while holding technological progress constant.

$$QQ : e_{t+1} = e(n_t) \tag{3.23}$$

Assume that at time t, $L_t > \hat{L}$, i.e. $g_{t+1} > \hat{g}$. Thus, the optimal education for generation $t+1$ switches form 0 to a positive level. From Lemma 2, faster technological progress leads to a faster increase in the fertility rate, i.e. the NN curve shifts down. However, a higher education level leads to a decrease in the fertility rate, i.e. movement up along the NN curve. The intuition is that more rapid technological progress leads to a higher return to investing in children's education. Thus, parents start to switch from investing in the quantity of their children to the quality of their children. The positive effect form technological progress dominates the negative effect from an increase in education during this regime. Thus, the fertility rate continues increasing during this regime. As population grows, the GG curve keeps shifting up while education continues to increase as well (the QQ curve shifts to the right). Higher population leads to a higher return on technological when education increases, thus the slope of GG curve become steeper as well. In the Post-Malthusian Regime, technological progress increases rapidly, the education level increases, and income per worker and population keep growing.

The Modern Gorwth Regime

As population continues to grow, once the population becomes large enough, i.e. $L_t > \frac{a^*}{\theta}$, the increase in population eventually has no effect on technological progress anymore. Once this happens, the economy transits from the Post-Malthusian Regime to the Modern Growth Regime. Figure 3.5 shows the evolutions in the Modern Growth regime. Consider a time t such that, $L_t > \frac{a^*}{\theta}$. Thus, the GG curve shifts up and has a slope of a^* at time $t+1$, and it will remain unchanged as population continues growing. In this regime, the increase in technological progress is slower due to the absence of the scale effect. Technological progress keeps increasing the incentive for parents to invest in their children's education. As with the growth rate of technological progress, education will be increasing at a decreasing rate. From Lemma 2 and the functional form for technology, the negative effect from education on fertility increases while the positive effect from technological progress decreases. Thus, as technological progress and education keep increasing at a slower rate, the negative effect will eventually dominate the positive effect. The fertility rate will start to decrease, while population increases at a decreasing rate. The economy will converge to a constant steady state rate of technological progress, education per worker, and fertility. Income per worker

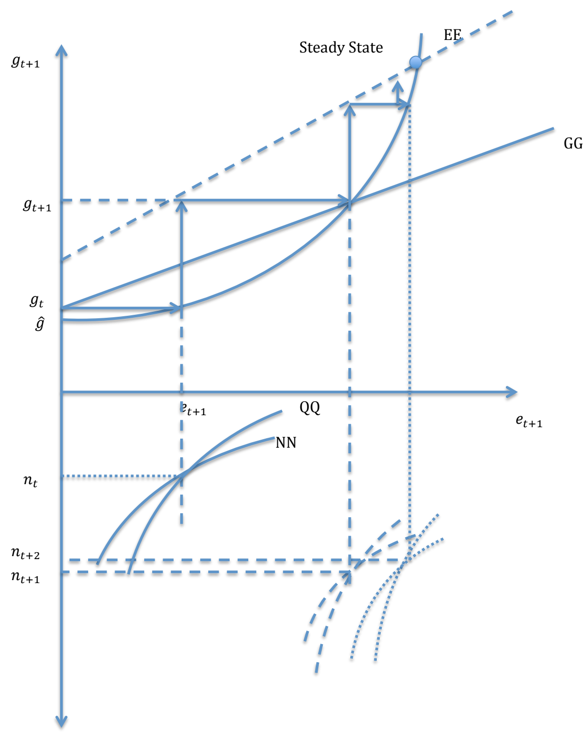


Figure 3.5: The Modern Growth Regime

will also increase at a constant rate. During the convergence phase of the Modern Growth Regime, the relationship between income per worker and the fertility rate is negative.

In conclusion, the model predicts that in the first two regimes, the Malthusian Regime and the Post-Malthusian regime, the fertility rate increases as worker's income increases. In the Modern Growth Regime, given a high enough population and technology, parents find it more profitable to invest in their children's education (quality) rather than the quantity of children. This "quality-quantity" trade-off leads to a negative relationship between income per worker and the fertility rate.

3.4.2 Impact of the One-Child Policy

So far, I have presented the model and the model predicted evolutions without an exogenous fertility control shock. In this section, I exam the effect of One-Child policy on long run economic growth. Consider an exogenous fertility control policy that is introduced at time t. [1] From time t onward, each agent is only allowed to have a constant number of children, $n_t = 1$. The full dynamics of this economy is thus determined by a three dimensional non-linear system:

[1]If the policy were introduced during Malthusian Regime, the economy would not be able to transit to the next regime due to the constant population size, i.e. $L < \hat{L}$ always holds.

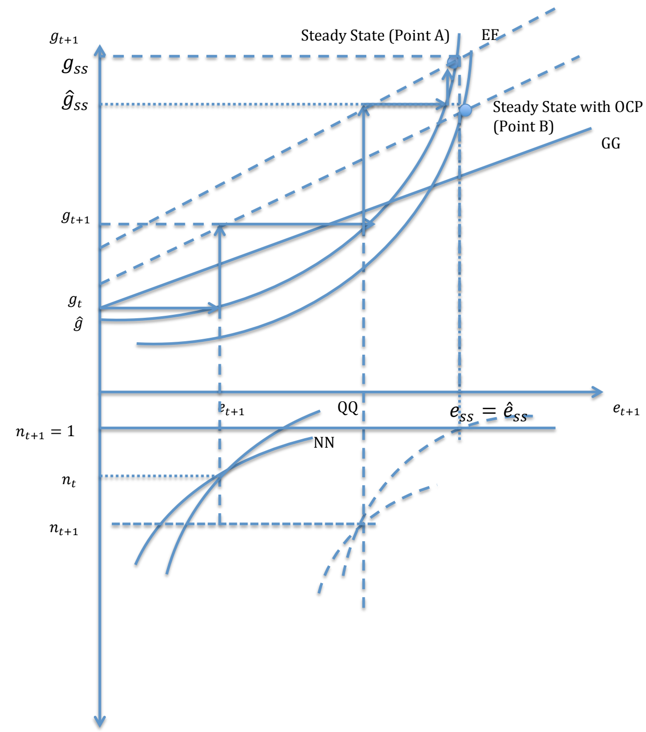


Figure 3.6: Impact of One-Child Policy (Case 1)

$$\begin{cases} A_{t+1} &= g(e_t)A_t \\ g_{t+1} &= g(e_t) \\ e_{t+1} &= \psi(e_t, g_t) \end{cases}$$

Thus, given $L_t = L_{t+1} = \bar{L}$, the optimal level of education becomes:

$$e_{t+1} = max\{0, \sqrt[1-\mu\alpha]{\frac{\mu\phi\alpha}{R\omega}[(e_t + \rho\tau^q)\theta\bar{L} + 1]^{1+\alpha(\mu-1)}(\tau h_t^\alpha)^{-1}} - \rho\tau\} = \psi(e_t, g_t) \quad (3.24)$$

In addition, technological progress is therefore,

$$g_{t+1} = (e_t + \rho\tau^q)\theta\bar{L} + 1 = g(e_t) \quad (3.25)$$

Case 1

Assume the One-Child policy was introduced during the Post-Malthusian Regime. Figure 3.6 shows the effect of the policy on the evolutions of technological progress, education per worker and the fertility rate. Assume the policy was introduced at time $t+1$. When the fertility rate is fixed at $n+1$ from then on, there is an immediate jump in e_{t+2} due to the "quantity-quality" trade off effect. When the one-child policy is implemented at

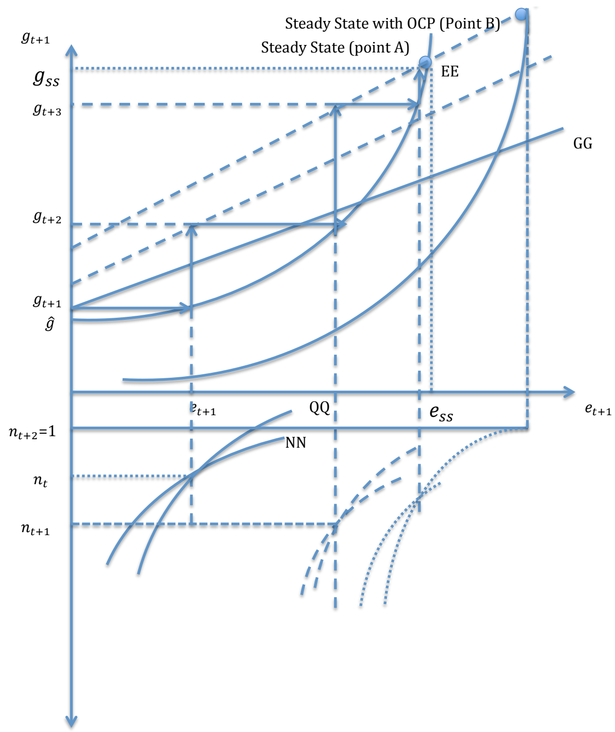


Figure 3.7: Impact of One-Child Policy (Case 2)

time t+1, parents expect to see a reduction in the future transfers form their children. In order to compensate the loss, they will invest more in their children's (generation $t + 2$) education. It is because that higher education level increases children's future income thus increases future transfers. In addition, since investing in children's education becomes the only option, marginal effect of technological progress on education also increases.

Higher education level leads to a faster technological progress. However, as population stays constant from time t and on, the scale effect $a(L_t)$ stays constant. Therefore, even though the model predicts a short-run increase in education, the long run effect will depend on the technological progress rate when the policy was implemented. Following A (1), rate of return on education increases as technological progress increases. Thus, only when the technological progress rate is high enough, the gain from the "quality-quantity" trade off is large enough to compensate the loss from population scale effect. Figure 3.6 indicates the case that the negative population effect and positive "quantity-quality" effect on education completely off set each other. Point A indicates the steady state without the fertility control policy while Point B indicates the steady state with the policy. As the graph shows, the education increases in short run but is the same as the benchmark model in long run while the long run technological progress is lower due to the decrease in population. In conclusion, the effect of One-Child policy on long run human capital per worker growth rate is ambiguous. In this paper, given the specific functional forms, if the fertility control policy was implemented when the technological progress rate is not high enough, one-child policy increases the short run education level, but decreases long run technological progress rate.

Case 2

Consider One-Child policy was implemented in time t during Modern Growth Regime when population is large enough, i.e. $L_t > \frac{a^*}{\theta}$. In this case, increase in the population size has no effect on technological progress. Figure 3.7 shows the effect of one-child policy on the evolution of technological progress, education and fertility when the policy is implemented at such time. As the graph shows, given that the negative effect from population on technological growth does not apply any more, the fertility control policy does not shift the GG curve. On the other hand, the "quantity-quality" trade off effect still leads to an increase in education level. Thus, One-Child Policy increases the long run technological progress rate, education per worker, human capital growth rate and income per worker.

3.5 Quantitative Analysis

3.5.1 Parameters and Calibrations

Table 3.1: Calibration of Model Parameters

Parameter	Value	Target (data)
Parameters		
R	1.017	annual deposit rate
β	0.982	$\beta R = 1$
α	0.4	Xue, Yip and Tou(2013)
μ	0.4	Lemma 1
X	1	/
θ	1	/
ω	0.756	transfers to elderly with 3children(2008)
ϕ	0.106	transfers to elderly with one child(2008)
ν	0.163	$n_{0-1} = n_0$ (assumption)
ρ	0.4	$\hat{Z}$
τ^q	0.23	observed nursing cost per income (2008)
τ^e	0.2258	$e_{t=1} > 0$ at the 25th period (assumption)
Threshold Conditions		
$\hat{n}$	1.03	average population growth rate in 1970s
$\hat{L}$	0.76	$\hat{g}$
$\hat{g}$	1.076	Income growth rate(1952-1972)
$\hat{A}$	1	/
e_0	0	/

Table 1 summarized the calibration of the parameters. In a three periods OLG model, we assume that each period is corresponding to 20 years. The model regards each couple as a single household. In other words, each couple is viewed as one agent. Thus, constant population means each family has two children on average. When the One-Child policy is implemented, the total population size decreases by half.

$R = 1.0175$, which is set to match with the annual real deposit rate. The discount factor β is set to 0.99 on an annual basis, thus $\beta R = 1$. The labor share of output is assumed to be 0.4, which is estimated by Xue, Yip and Tou (2013). The scale parameter and natural resources are normalized to be 1. Those parameters are neutral after initial conditions are calibrated.

Figure 2 indicates that the GDP per capita starts to increase at a faster rate around 1940s to 1950s. The threshold technological rate in the "Post-Malthusian Regime" is $\hat{g}$. Education switches from 0 to positive when technological progress is bigger than $\hat{g}$. Given the limited data availability, the earliest data that is available starting in 1952. Thus, $\hat{g}$ is set to be consistent with the average real output growth rate from 1952 to 1972, which is 4.5%. Thus, given the production function, $\hat{g}$ is 1.076.

The within family intergenerational transfers are set to match with the data provided by CHARLS (2008). The data indicates that families with three children, total transfers from children to elderly is about 17%, while families with one child is around 7%.

$$\begin{cases} \phi \frac{n_t^{\omega}}{\omega} & = 0.17 \qquad \text{when} \quad n_t = 3 \\ \phi \frac{n_t^{\omega}}{\omega} & = 0.07 \qquad \text{when} \quad n_t = 1 \end{cases}$$

In addition, CHARLS also provides the data on the cost of raising children. According to data, the average cost in terms of income is 23% for families with two children. The cost of education is set by assuming that the initial education is zero and threshold population $\hat{L}$ is reached at the 24th period, which means education becomes positive at the 25th period.

In addition, given tau and $\hat{g}$, $\hat{L}$ is calculated from equation (3.13). ρ is calibrated to match with the threshold income growth rate, growth rate of $\hat{Z}$.

Initial Condition The initial education is assumed to be 0. That is saying that the initial population is below $\hat{L}$. I assume the fertility rate is 1.03 in the threshold period, which is the period when $g = \hat{g}$ and education becomes positive. In addition, 1.03 is the average population growth rate in China from 1960 to 1970, which is consistent with the threshold period. In addition, different values threshold fertility rate were tested, the results show that different $\hat{n}$ will alter the overall population size, but not the structure of the long run growth pattern. In addition, ν is calculated from the optimal fertility function, equation (8), assuming the increases in fertility rate is relatively low before the threshold period. Given the threshold values of $\hat{n}$, $\hat{g}$ and $\hat{Z}$, I then dynamically simulate the model forward for periods of $g > \hat{g}$, and backwards for periods of $g < \hat{g}$.

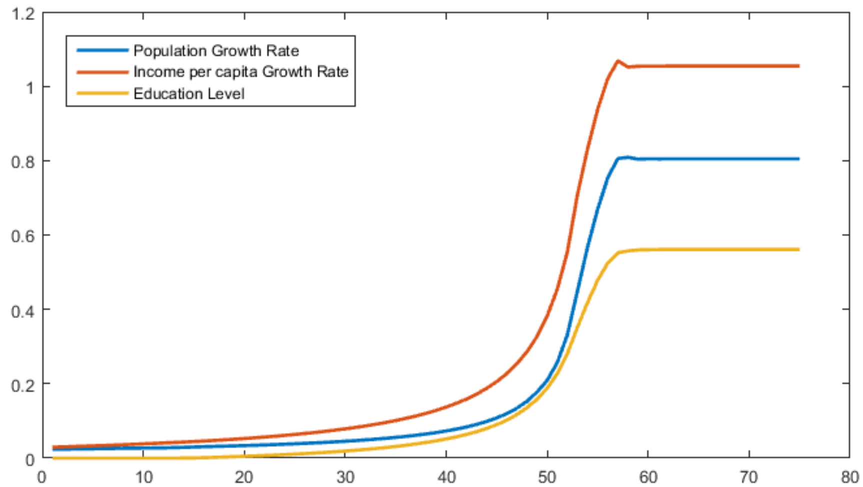


Figure 3.8: Benchamrk Model Grwoth Rates and Education level

3.5.2 Benchmark Model Simulations

Figure 3.8 shows simulated time paths for the constructed economy without the one-child policy. This figures presents the percentage changes for population and income per capita, as well as the long-run education level. At the beginning stage of the development, both population and income per capita are increasing at a relatively slow rate. This is consistent with the model predicted "Malthusian Regime". As population increases, the rate of technological progress increases, which speeds up the increasing rate of income per capita. In this regime, technological progress is relatively low due to the small population size. Thus, it is not profitable for parents to invest in their children's education.

The economy transits from the "Malthusian Regime" to the "Post-Malthusian Regime" when the population is large enough, such that $L_0 > \hat{L}_t$. In this regime, technological progress is high enough for parents to invest in their children's education. Assume that the threshold population is reached at the 24th period. According to the model, a positive education level leads to faster technological progress, thus increasing the rate of return on children. Fertility increases faster. As figure 3.8 illustrates, after the 25th period, education becomes positive, and population and income per capita increase at a faster rate. This result is consistent with the model predicted "Post-Malthusian Regime". In addition, due to the switch from 0 to positive education, a jump in income per capita is expected at the 25th period.

According to the model, the economy will transit to the third regime, "Modern Growth Regime" once the population scale effect reaches its maximum, a^*. In the calibrated model, once the population scale effect becomes constant, the fertility rate decreases and population begins to increase at a decreasing rate, and eventually reaches its steady state growth rate.

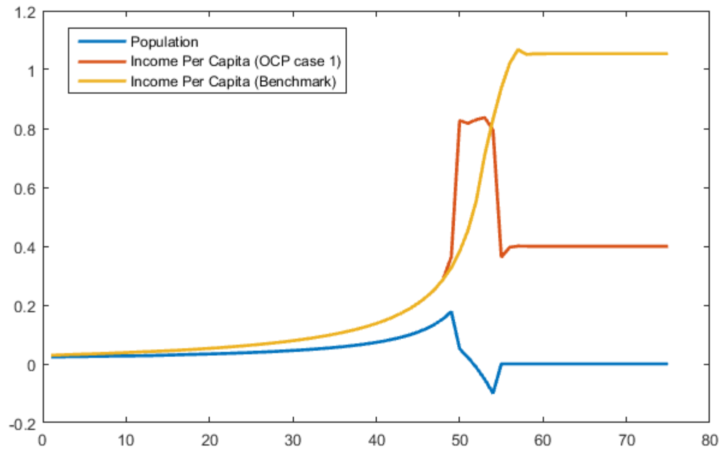


Figure 3.9: Impact of One-Child Policy on Income(Case 1)

On the other hand, as technological progress and education level reaches its steady state, income per capita eventually converges to its steady state as well.

Recall Figure 3.2, which depicts the observed population and income per capita growth rates from 1500 to 2008. So far, the model predicted results are consistent with the data in terms of long-term growth pattern before the one-child policy is implemented. In the initial years, the "Malthusian Regime", population and income per capita increase at a slow rate. Then, during the 1840s, the increasing rates of both population and income per capita speeds up. In my model, the faster growth rates are explained by the transition from the "Malthusian Regime" to the "Post-Malthusian Regime" due to the increase in education.

The population growth rate starts to decrease in 1980s. However, this decrease is not due to an endogenous fertility change. This is caused by the exogenous fertility control policy, the one-child policy. In the next sub-section, I exam the impact of this policy on China's education and per capita income growth.

3.5.3 Quantitative Analysis of the Impact of the One-Child Policy

China's one-child policy was first announced at the end of 1979, and was implemented beginning in 1980. The policy restricted the number of children that each family could have to 1. As the fertility rate is significantly decreased after the policy was enforced, several serious problems start to occur. For example, sex imbalance, population aging, and other social problems. In early 2000, China starts to relax the policy by allowing two children if both parents are the only-child in their families. In 2013, China further relaxed the policy by allowing two children per family without any restrictions. The previous "one-child policy" is now called the "two-child" policy. Therefore, in my model, the one-child policy is treated as a temporary fertility shock. The one-child policy was implemented for

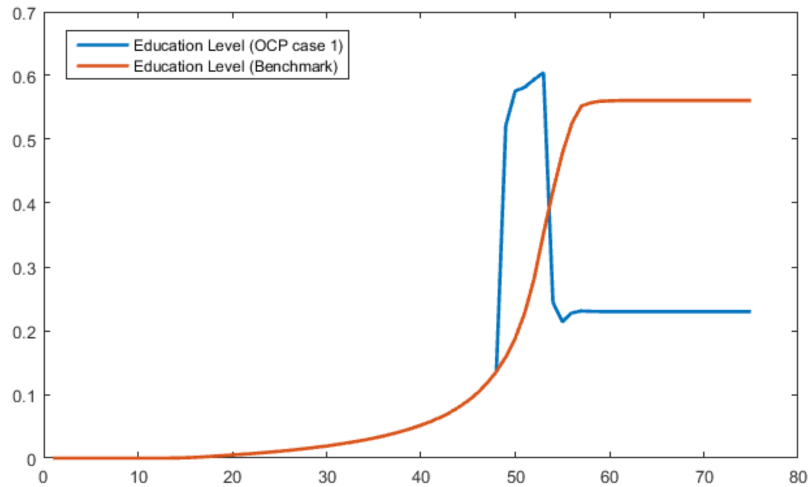


Figure 3.10: Impact of One-Child Policy on Education(Case 1)

one period, which decreases the total population in the next period by half. As one-child policy becomes two-child policy, the population stays constant afterwards. As mentioned in section 3.4.2, according to the model, the impact of the fertility control policy depends on the timing of the policy implementation.

Figures 3.9 and 3.10 compare the long run income per capita and education level respectively in case 1, which assumes the policy is implemented during the early stage of development. As the graph shows, I assume the policy was implemented in the 6th period; there is an immediate jump in income per capita and education. The one-child policy triggers a "quantity-quality" trade-off effect, which boosts the income per capita and education level in the short run. However, since technological progress is low due to the small population size at this stage, the negative population scale effect dominates the positive education effect. Thus, the fertility control policy harms long run economic growth.

On the other hand, Figures 3.11 and 3.12 show the comparison between the economy with the one-child policy and the benchmark model under case 2. In this case, the one child policy is introduced when technological progress is high, and the population scale effect is constant. Figures 3.11 and 3.12 reveal that the fertility control policy speeds up the growth of income per capita in the short run due to the "quantity-quality" trade off effect. In addition, given the population size does not affect the theological progress in this stage, there is no negative population scale effect. Therefore, the one-child policy increases the long-run income per capita and education level.

In conclusion, the model predicted results are consistent with the theory that the timing of the implementation of the one-child policy is important. In case 1, when the population scale effect is still significant, the one-child policy decreases the long-run economic growth. In case 2, on the other hand side, if the one-child policy is implemented at the time when

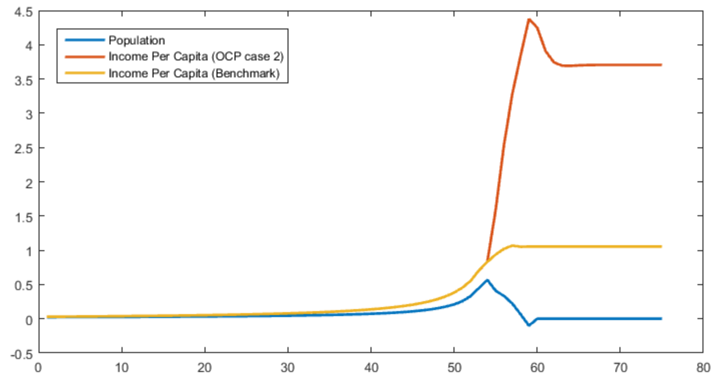


Figure 3.11: Impact of One-Child Policy on Income(Case 2)

the population scale effect is phrased out, it enhances the long-run economic growth. So, to determine the overall impact of the one-child policy, the question here is: How important the population scale effect is when the one-child policy was implemented. In 1979, another significant event also occurred, namely, the Chinese Economic Reform. China started opening the country to foreign investment. This reform enabled China to import pre-existing advanced foreign technology. Therefore, the population scale effect becomes less important. In contrast, high education is required to adopt new technology, which leads to a stronger "quantity-quality" trade-off effect. Therefore, the second case seems more relevant to China's actual experience.

3.6 Conclusion

The Galor-Weil provides a unified economic growth model that captures the long run comovements of income per capita and population in Western Europe. Historical data from China show a similar pattern. However, the decrease in population in the 1980s was not caused by an endogenous fertility choice. Instead, it was caused by an exogenous fertility control policy, the so-called "One-Child" Policy.

In this paper, I quantitatively studied the impact of China's One-Child Policy on its long run education level, the rate of technological progress, and income per capita. The key new feature of my model is to incorporate within family intergenerational transfers into the Galor-Weil model. In the Galor-Weil model, technological progress depends on the population size and the level of education. Children provide a crucial source of financial support for the elderly in China. Thus, children are not just a source of pleasure, but are also an important investment. The one-child policy restricts the number of children each family has, which decreases total transfers from children to parents when the parents are retired. In order to compensate that loss, parents choose to increase investment in their children's education, since this increases their children's future income. This is called the "quantity-

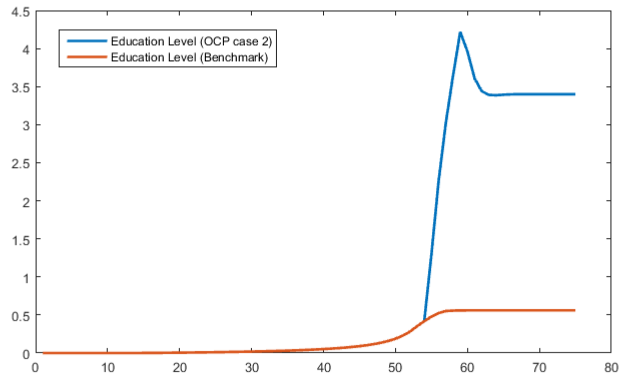


Figure 3.12: Impact of One-Child Policy on Education(Case 2)

quality" trade off effect in this paper. Therefore, by incorporating intergenerational transfers into the model, the one-child policy increases the level of education, which increases the rate of technological progress. However, the policy also decreases total population, which negatively affects technological progress. The results suggest that the impact depends on the timing of the policy.

The quantitative analysis was carried out under two different circumstances. In the first case, I assume the fertility control policy was introduced at the stage when technological progress is not high enough to compensate the loss from the negative population scale effect. In this case, even though the "quantity-quality" effect increases education in the short run, the decrease in total population lowers the rate of economic growth. On the other hand, if the fertility control policy is introduced at a later stage, when the level of technology is high enough and the population scale effect is constant, the "quantity-quality" effect dominates in both the short run and long run, and the one-child policy thus enhances the long run economic growth rate in China.

In conclusion, even though some recent studies have argued that the one-child policy lowered the rate of long run economic growth, this paper suggests an alternative possible conclusion. The one-child policy could actually increase China's long-run economic growth if the negative population scale effect is dominated by the positive education effect. Given China's actual experience such that there exists a large stock of more advanced foreign technology for them to import, the relationship between population size and technology becomes relatively insignificant. Therefore, the second case seems more relevant. China's one-child policy increases long-run education level and technological progress, thus enhances its long-run economic growth rate. However, a further quantitative analysis that includes the effect of foreign technology would be helpful.

Bibliography

[1] Bacchetta, Philippe; Benhima, Kenz and Kalantzis, Yannick. (2013), *"Capital Controls with International Reserve Accumulation: Can this Be Optimal?"*, American Economic Journal: Macroeconomics 5(3), 229-262

[2] Choukhmane, Taha; Coeurdacier, Nicolas and Jin, Keyu. (2014), *"The One-Child Policy and Household Savings"*, Yale University.

[3] Lucas, Robert E. Jr. (1990), *"Why Doesn't Capital Flow from Rich to Poor Countries?"*, American Economic Review 80, 92-96.

[4] Gourinchas, Pierre-Olivier and Jeanne, Olivier . (2013), *"Capital Flows to Developing Countries: The Allocation Puzzle"*, Review of Economic Studies.

[5] Jeanne, Olivier and Romain RanciÃÍre. (2011), *"The Optimal Level of International Reserves for Emerging Market Countries: A New Formula and Some Applications"*, The Economic Journal 121, 905-930

[6] Song, Zheng; Storesletten, Kjetil and Zilibtti, Fabrizio. (2011), *"Growing Like China"*, American Economic Review 101, 202-241.

[7] Song, Zheng; Wang, Yikai; Storesletten, Kjetil and Zilibtti, Fabrizio. (2015), *"Sharing High Growth across Generations: Pensions and Demographic Transition in China"*, American Economic Jounal: Macroeconomics 7(2), 1 -39.

[8] Wei, Shang-Jin and Zhang, Xiaobo. (2014), *"The Competitive Saving Motive: Evidence from Rising Sex Ratios and Savings Rates in China"*, Journal of Political Economy 119, 511 - 564.

[9] Malthus, T. R. *"An Essay on the Principle of Population"*, 1798

[10] Barlow, Robin. *"Birth Rate and Economic Growth: Some More Correlations"*, Population and Development Review 1994, 20, 153-165

[11] Simon, Julian. *" On Aggregate Empirical Studies Relating Population Variables to Economic Development"*, Population and Development Review 1989, 15, 323-332

[12] Kelly, Allen C. *" Economic Consequences of Population Change in the Third World"*, Journal of Economic Literature 1988, 26, 1685-1728

[13] Becker, Gary S.; Murphy, Kevin M. and Tamura, Robert. *"Human Capital, Fertility, and Economic Growth"*, Journal of Political Economy 1990, 98(5), S12- S37

[14] Denison, Edward F. *"Trends in American Economic Growth, 1929-1982"*, Washington: Brooking Inst, 1985

[15] Lagerlöf, Nils-Petter. *"The Galor-Weil model revisited: A quantitative exercise"*, Review of Economic Dynamics 2006, 9, 116-142

[16] Galor, Oded and Weil, David N. *"Population, Technology, and Growth: From the Malthusian Regime to the Demographic Transition"*, American Economic Review 2000, 110, 806-828

[17] Kuznets, Simon *"Population Change and Aggregate Output"*, Princeton, NJ: Princeton University Press, 1960

[18] Simon, Julian. *"The Economics of Population Growth"*, Princeton, NJ: Princeton University Press, 1977

[19] Simon, Julian. *"The Ultimate Resource"*, Princeton, NJ: Princeton University Press, 1981

[20] Aghion, Philippe and Howitt, Peter. *"Amodel of Growth Through Creative Destruction"*, Econometrica 1992, Vol 60, No. 2, 323-351

[21] Schultz, T. W. *"Transforming Traditional Technological Agriculture"*, New Haven: Yale University Press, 1964

[22] Maddison, Angus. *"Chinese Economic Performance in the Long Run 960-2030 "*, OECD Paris, 2007

[23] Li, Hongbin and Zhang, Junsen *"Do High Birth Rates Hamper Economic Growth?*, The Review of Economics and Statistics 2007, 89 (1), 110-117

[24] Xue, Jianpo; Yip, Kong K. and Tou, Wai-kit Si. *"One-Child Policy and the Long-Run Development of China: A Unified Growth Approach"*, 2013

[25] Largerlöf, Nils-Petter *"From Malthus to Modern Growth: Can Epidemics Explain the Three Regimes?"* International Economics Review 2003, Vol44, NO.2

[26] Rosenzweig, Mark R. and Zhang, Junsen *"Do Population Control Policies Induce More Human Capital Investment? Twins, Birth, Weight and China's One-Child Policy"*, Review of Economic Studies 2009, 76, 1149-1174