The One-child Policy: A Macroeconomic Analysis

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Abstract

This paper studies the effects of China's one-child policy. Using a calibrated general-equilibrium model, a benchmark with a fertility constraint in place is compared to a counterfactual experiment without the fertility constraint. The results indicate that the implementation of the one-child policy promotes the accumulation of human capital and increases per capita output. In addition, the policy leads to different welfare effects across generations and skill groups. The initial generation would benefit from relaxing the one-child policy, but the following generations would be hurt. A redistribution effect between skilled and unskilled workers is also observed. These findings demonstrate that focusing solely on GDP per capita as a measure of economic well-being paints an incomplete picture of the welfare consequences of population policies.

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1 Introduction

China's central government introduced the one-child family policy in 1979 with the aim of controlling rapid population growth. The merits and demerits of this policy are still discussed three decades after it was first implemented. On the positive side, the policy has resulted in a reduction in fertility rates, which has contributed to economic growth and an improved standard of living for many families in China.[1] However, Bongaarts and Greenhalgh (1985) discuss the possible social and economic consequences of the policy, such as the detrimental effects on the age composition of the population and the effects on the support of elderly people.

Previous studies explore the effects of the policy from an empirical perspective. In contrast to the existing literature, this paper takes the lead in studying the effects of the one-child policy using a theoretical approach: a general equilibrium overlapping-generations model with a fertility constraint is employed to discuss the impacts of the policy on fertility, age composition, human-capital accumulation, and per capita output. Changes in welfare resulting from the one-child policy are also quantified. In addition, this paper considers heterogeneous individuals. Different groups in an economy will react differently to the policy. To this end, this paper examines how the one-child policy affects skilled versus unskilled workers.

China's one-child policy restricts a couple to only one child. Parents who adhere to the policy will be rewarded with additional benefits, such as government subsidies, and will be given priority in schooling, housing, health care, and work. The policy also incorporates penalties. For example, government workers will be punished for having a second child with a twenty percent cut in their basic salary for seven consecutive years. Section 2 discusses the specific details of China's one-child per family policy. For simplicity's sake, the one-child policy is treated as a fertility constraint in this paper: a couple is allowed to have at most $\bar{n}$ children when the policy is imposed. Subsidies and punishments are

[1] McElroy and Yang (2000) suggest that China's population policies have played an important role in lowering China's total fertility rate. Li, Zhang, and Zhu (2005) also find similar results. In addition, Li and Zhang (2007) show that the birth rate has had a negative impact on economic growth, suggesting that China's birth control policy is growth enhancing.

not considered here.

The framework is a three-period overlapping generations economy with a fertility constraint, which represents the one-child policy. In the model, children do not work but depend on their parents for support. If they survive, children become adults. Adults make decisions and supply labor to the production sector. Subsequently, subject to a survival probability, adults become the elderly and start to consume their own savings. Adults choose consumption, asset holdings, the number of children they want, and the education level of their children. Education is discrete, either skilled or unskilled. The production sector is perfectly competitive. There exists a representative firm using skilled labor, unskilled labor, and physical capital as inputs. To capture the elements of a command economy, price distortions are included in our model.

Two numerical analyses are provided. First we do a steady-state comparison. The model is calibrated to data from China in 1977 and 2005.[2] In 1977, China was a command economy and the one-child policy had not yet been imposed. Thus, a model with price distortions only is calibrated. In contrast, twenty-five years after its economic reform in 1980, China became a market economy with the one-child policy. Therefore, we calibrate a market model (no price distortions) with a fertility constraint to China in 2005.

Second, based on the calibrated results, further experiments are explored in this paper. The benchmark represents China's demographic change during the period 1977-2005. Then, a counterfactual experiment without the one-child policy is carried out in comparison to the benchmark. The purpose of this experiment is to study what would have happened in China if the one-child policy had not been imposed in 1979.

The results suggest that introducing the one-child policy promotes the accumulation of human capital and increases per capita output. These findings are consistent with the suggestions in the literature. For example, Bloom, Canning, and Malaney (2000) and Li and Zhang (2007).[3] Unsurprisingly, introducing the policy also results in an

[2] Both are calibrated as steady states. Because the data of 2005 is more abundant, we calibrate 2005 first and then change some parameters so that we can also match the moments in 1977. See Section 4.1 for the details.

[3] However, Rosenzweig and Zhang (2009) suggest that the contribution of the one-child policy in China to the development of its human capital is modest. The policy results in an increase in schooling

older population. The fraction of elderly as a percentage of the total population in the benchmark is higher than that in the counterfactual experiment. This result is consistent with the actual experience in China. China will undoubtedly be burdened with a rapidly aging population in the next few decades. As Table 1 shows, the fraction of the population aged 65 and above in China will double over the next twenty years. Specifically, China will have more people over the age of 65 than below 15 by the year 2035.

Our analysis also gives rise to two interesting novel results that go beyond the existing literature. First, we find that, counterintuitively, some parents actually choose to have fewer children when the one-child policy is removed. This is because without the policy other people have more children, which changes wage rates. In particular, the ratio of skilled labor to total labor decreases, thereby increasing the skill premium and making children more expensive for skilled parents. Second, removing the one-child policy leads to different welfare effects across generations and skill groups. For the initial generation, the initial conditions are fixed. Here the results confirm the intuition that people benefit from having the one-child policy relaxed. However, future generations suffer from removing the one-child policy due to capital dilution.[4] Physical capital is determined by the past generation, but the past generation faces a trade-off between having children and savings. In addition, children born in the past period become workers in this period. Therefore, a lower physical capital-labor ratio results in lower welfare for future generations when the one-child policy is removed.[5]

We further examine the impacts of implementing the one-child policy in a simplified

attainment by 4 percent at most, the probability of attending college by less than 9 percent, and school grades by 1 percent.

[4]This paper compares the benchmark to outcomes without the implementation of the one-child policy. Alternatively, we could follow the approach suggested by Eckstein and Wolpin (1985) to find "optimal steady states". Optimal steady states are defined as stationary allocations for which there is no alternative stationary allocation that makes one agent better off without making the other worse off. Once optimal steady states are explored, one could test if the one-child policy delivers an optimal allocation.

[5]Golosov, Jones, and Tertilt (2007) propose two notions of efficiency (P-efficiency and A-efficiency) to make the concept of Pareto efficiency applicable to models with endogenous fertility. They show that a generalization of Barro and Becker's recursive equilibrium is both P-efficient and A-efficient. However, our analysis shows that there are winners and losers for removing the one-child policy.

framework: a two-period overlapping generations model without physical capital. There is no old generation and no savings. The influence of capital dilution disappears, so almost every generation is better off when the one-child policy is removed. In addition, we observe that future unskilled workers are slightly hurt if the one-child policy is removed, while skilled workers are always better off. Because children's education is determined by parents, there exists an implicit redistribution between skilled and unskilled workers. However, the redistribution effect is smaller than the impact of capital dilution.

This paper provides a framework for analyzing the effects of the one-child policy. Our experiments show that removing the one-child policy results in winners and losers, both across generations and skill groups. These findings demonstrate the importance of considering group-specific welfare changes when discussing population policies. If only GDP per capita is considered as a measure of economic well-being, as in Young (2005), those people who are worse off will be ignored in the analysis.

The rest of this paper is organized as follows. Section 2 summarizes the implementation of China's one-child policy. Section 3 describes the model. Section 4 discusses the calibration. The experiments and results are provided in Section 5. Finally, Section 6 concludes this paper.

2 China's One-child Policy

In the early 1970s, China's central government began to control its rapid population growth with the "Later, Longer, and Fewer" family planning program (later marriage, longer intervals between births, and fewer children). As shown in Figure 1, the total fertility rates sharply declined during the 1970s. However, these policies did not successfully reach the ideal population growth rate. Therefore, in 1979 the government moved to directly target the number of children per family and the one-child policy was officially formalized. The one-child policy further lowered the total fertility rates to be less than two.

The one-child policy, which stated that each couple is allowed to have only one child, was initiated by the central government. However, the implementation of the policy, including benefits and penalties, was formalized by local governments. Thus, local policies inevitably varied between provinces, regions (urban and rural), and ethnic groups (*Han* people and ethnic minorities).

Overall, single-child families can obtain benefits and financial rewards, including a child allowance that continues until the child reaches age 14, priority access to schools, college admission, employment, health care, and housing. In rural areas, single-child families are allowed to pay lower taxes and can obtain a larger area of land. The penalties on above-quota births in cities include 10-20 percent of both parents' wages lasting for 3-14 years. Parents who violate the policy will be demoted or will not eligible for promotion if they work in government sectors. Furthermore, the "above-quota" children are not allowed to attend public schools. However, in rural areas, the most common punishment is a large one-time fine, which may account for a large percentage of a worker's annual income. Demotions in the workplace and permission to attend public schools are usually not as important in rural areas as they are in cities.[6]

A second child is permitted under special conditions, such as the first child is disabled, a spouse returns from overseas, the first child is a girl and the couple has real difficulties, or one spouse is a deep-sea fisherman or works in underground mining for more than five years. Provinces have flexibility in deciding under which circumstances couples may have a second child, as long as they do not contradict the guidelines of the one-child policy and exceed the province's population target. Therefore, the rules for second-child permission vary between provinces. For example, the citizens in the urban areas of Shanghai are allowed to have a second birth if one spouse or both spouses are single children; but under the same condition, a second birth in the urban areas of Beijing is not allowed.[7]

The one-child policy is strictly applied to *Han* Chinese, while ethnic minorities are normally allowed to have more than one child.[8] Furthermore, there are exceptions for allowing a third and even a fourth child. "For example, in Xinjiang, minorities can have as many as four children. In rural areas of Tibet, there are no restrictions on the number

[6]See, for example, Zhang and Spencer (1992); McElroy and Yang (2000); and Li, Zhang, and Zhu (2005) for the details.

[7]Table 2 in Scharping (2003) summarizes the conditions for second-child permits for each province.

[8]See Hardee-Cleavland and Banister (1988).

of children that ethnic minority families can have."[9]

The implementation of China's one-child policy differs between provinces, areas, and ethnic groups. The policy also incorporates subsidies and punishments. To focus on the spirit of China's one-child policy, the policy is simplified and treated as a fertility constraint in the model. A population-weighted implied total fertility rate is computed for the calibration in order to capture the policy strength in China.

3 The Model

An individual can live for at most three periods: childhood, young adulthood, and old adulthood. Children are assumed not to work but to depend on their parents for support. If they survive, they become young adults. The survival probability for children is π^c. Then, subject to the survival probability for young adults π^y, young adults become the elderly and begin to consume their savings. Only young adults supply labor and make decisions. A young adult independently chooses consumption, asset holdings, the number of children he wants (fertility), and the education level of his children. Education level is discrete, either skilled or unskilled. The model with endogenous fertility is provided in the first part of this section. A fertility constraint is then introduced in the second part, representing the implementation of the one-child policy.

3.1 The Basic Model

It is assumed that an individual can have children at the beginning of his young adulthood. N^z is defined as the population of z, where $z \in \{c, y, o\}$ represents children, young adults, and old adults, respectively. Besides, a young adult can be either skilled (s) or unskilled (u), which was determined by his parent. Thus, N_s^y denotes the population of skilled young adults and N_u^y is the population of unskilled young adults. The evolution of population

[9] See Li, Zhang, and Zhu (2005).

is given by:

$$
\begin{aligned}
N^c &= (n_{ss}+n_{su})N_s^y + (n_{us}+n_{uu})N_u^y,\\
N^{y'} &= \pi^c N^c,\\
N^{o'} &= \pi^y N^y,
\end{aligned}
$$

where n_{ij} is the number of j-type children that an i-type young adult has, $(i,j) \in \{s,u\}$. The population of children is determined by fertility. Then, children will become young adults if they can survive to the next period. Young adults will become the elderly with the survival probability of young adults.

Given his type is i, a young adult derives utility from consumption for his young adulthood (c_i^y), consumption for his old adulthood (c_i^o), and his surviving children. The number of his skilled children is n_{is}, and the number of his unskilled children is n_{iu}. The lifetime utility of an i-type young adult is given by:

$$
\frac{c_i^{y1-\sigma}}{1-\sigma} + \beta\pi^y\left(\frac{c_i^{o1-\sigma}}{1-\sigma}\right) + \psi[\pi^c(n_{is}+n_{iu})]^{-\varepsilon}[\pi^c n_{is}V_s' + \pi^c n_{iu}V_u'], \tag{1}
$$

where β is the subjective discount factor with respect to the utility of consumption; ε determines the elasticity of altruism with respect to the number of children; and $\frac{1}{\sigma}$ denotes the elasticity of inter-temporal substitution. We assume $0<\beta<1$, $0<\varepsilon<1$, and $0<\sigma<1$. ψ represents how much a young adult loves his children. V_s' is the utility that a child will receive when he becomes a skilled young adult, and V_u' is the child's utility when he becomes an unskilled young adult.[10] Both utilities are foreseeable and are known when a current young adult is making decisions.

Each young adult has one unit of time. By assumption, only skilled young adults can become teachers. Thus, a skilled young adult can allocate his time between working in the production sector, teaching, and raising children. In contrast, an unskilled young adult only has two options: working in the production sector and raising children. The skilled

[10]The setting of the utility function implies certainty equivalence for children. In other words, raising two children with a survival probability of one half for each child is equivalent to having one child with certainty. It is a standard assumption in the fertility literature.

wage rate for one unit of time is w_s. The compensation for being a teacher is also equal to w_s. The unskilled wage rate is w_u. To capture the elements of a command economy, d_w is introduced to denote the distortion on wage rates.

Children cannot work but depend on their parents for support. Thus, a young adult needs to pay the time cost ϕ of raising a child. In addition, the education time cost is ϕ_s. Thus, the cost of raising a child is given by:

$$p_{ij} = \begin{cases} \phi(1+d_w)w_i + \phi_s(1+d_w)w_s & \text{if} \quad j = s; \\ \phi(1+d_w)w_i & \text{if} \quad j = u; \end{cases} \tag{2}$$

where i denotes the type of young adult and j represents the child's type. The budget constraint for an i-type young adult in his young adulthood and old adulthood is given by:

$$c_i^y + \pi^y a_i' + \phi_s(1+d_w)w_s n_{is} = [1 - \phi(n_{is} + n_{iu})](1+d_w)w_i; \tag{3}$$

$$c_i^o = (1+r')(1+d_a)a_i'; \tag{4}$$

where r' is the interest rate in the next period. d_a is the distortion on the return of physical capital. There exists an annuity market. An i-type young adult saves $\pi^y a_i'$ in his young-adult period. If he survives, he will receive a_i' for his consumption in old age. Otherwise, he will receive nothing.

The production side is perfectly competitive. There exists one representative firm using skilled labor, unskilled labor, and physical capital as inputs. Because capital-skill complementarity is observed in many developing countries, the main purpose of setting the production function is to generate capital-skill complementarity. Therefore, this paper employs a CES function. The production function in this economy is given by:

$$Y = A[\mu L_u^\alpha + (1-\mu)(\theta K^\rho + (1-\theta)L_s^\rho)^{\frac{\alpha}{\rho}}]^{\frac{1}{\alpha}}, \tag{5}$$

where A denotes total factor productivity, μ and θ are factor weights that govern income shares, and α and ρ govern the elasticities of substitution between unskilled labor, physical capital, and skilled labor. L_u refers to unskilled workers and L_s is skilled workers. K is physical capital. Capital-skill complementarity requires that $\alpha > \rho$. The production function can be rewritten as:

$$y_{pc} = \frac{L}{N} A[\mu l_u^\alpha + (1-\mu)(\theta k^\rho + (1-\theta) l_s^\rho)^{\frac{\alpha}{\rho}}]^{\frac{1}{\alpha}}, \tag{6}$$

where y_{pc} denotes output per capita, k is the capital-labor ratio, l_u is the fraction of unskilled labor as a percentage of total labor, l_s is the fraction of skilled labor as a percentage of total labor, and N is the total population.[11]

In terms of children's education, only corner solutions exist in equilibrium: a young adult will send either all or none of his children to school. Skilled children and unskilled children will not live in the same family.[12] In addition, if any unskilled young adult has skilled children, all skilled young adults will. The reason is that the relative cost of raising a skilled child is higher for unskilled young adults than for skilled adults. In a balanced growth path, skilled young adults always have skilled children and unskilled adults are indifferent between having skilled children and having unskilled children.[13] The fraction of unskilled adults having skilled children is determined by the relative utility of having skilled and unskilled children.

Following the corner solutions and the indifference condition, a young adult only has

[11] In equilibrium, the skilled wage rate (w_s) is equal to the marginal product of skilled labor; the unskilled wage rate (w_u) is equal to the marginal product of unskilled labor; the interest rate (r) is equal to the marginal product of physical capital minus the depreciation rate. The distortion on the return of physical capital (d_a) is exogenously determined. The distortion on wage rates (d_w) is determined to keep a balanced budget. A recursive competitive equilibrium is defined in Appendix A.

[12] See Appendix B for the proof. Intuitively, if ε is equal to 0, utility is linear in the fraction of the two types of children. Then, a parent will be indifferent between going to one of the corner solutions and having a fraction of each type of children. However, this case implies that utility is linear in fertility, so it is ruled out by assumption. If $\varepsilon > 0$, utility becomes a convex function of the fraction of the two types of children. Therefore, a parent will choose a corner solution.

[13] Given corner solutions and indifference conditions, there are in principle three possibilities: (1) skilled adults always have skilled children while unskilled adults are indifferent; (2) unskilled adults always have unskilled children while skilled adults are indifferent; (3) skilled adults always have skilled children and unskilled adults always have unskilled children. However, in the latter two possibilities the fraction of skilled agents would converge to zero over time, because a skilled adult's fertility is lower than an unskilled adult's fertility. This would result in an unskilled wage rate of zero, which cannot happen in equilibrium. Thus, any balanced growth path is of type (1).

one type of child. The model can be simplified as follows:

$$\max_{c_{ij},a'_{ij},n_{ij}} \left\{ \frac{c_{ij}^{y1-\sigma}}{1-\sigma} + \beta\pi^y \left(\frac{c_{ij}^{o1-\sigma}}{1-\sigma} \right) + \psi(\pi^c n_{ij})^{1-\varepsilon} V'_j \right\}, \tag{7}$$

subject to

$$\begin{aligned} c_{ij}^y + \pi^y a'_{ij} + p_{ij} n_{ij} &= (1+d_w)w_i, \\ c_{ij}^o &= (1+r')(1+d_a)a'_{ij}, \end{aligned}$$

where p_{ij} is defined in (2) and $(i,j) \in \{(s,s),(u,s),(u,u)\}$.

3.2 The One-child Policy

Our framework makes no distinction based on gender or area. Every young adult is considered to be identical in every respect except for education. Thus, the one-child policy is imposed on every young adult without exception. In addition, this model ignores marriage, so there is only one young adult per family and each young adult is restricted to have at most $\bar{n}$ or fewer children when the policy is imposed. The maximization problem of (7) becomes:

$$\max_{c_{ij},a'_{ij},n_{ij}} \left\{ \frac{c_{ij}^{y1-\sigma}}{1-\sigma} + \beta\pi^y \left(\frac{c_{ij}^{o1-\sigma}}{1-\sigma} \right) + \psi(\pi^c n_{ij})^{1-\varepsilon} V'_j \right\}, \tag{8}$$

subject to

$$\begin{aligned} c_{ij}^y + \pi^y a'_{ij} + p_{ij} n_{ij} &= (1+d_w)w_i, \\ c_{ij}^o &= (1+r')(1+d_a)a'_{ij}, \\ n_{ij} &\leq \bar{n}, \end{aligned}$$

where p_{ij} is defined in (2) and $(i,j) \in \{(s,s),(u,s),(u,u)\}$. If a young adult prefers to have more than $\bar{n}$ children, he is forced to satisfy the fertility constraint. If his preference is smaller than $\bar{n}$, he is not affected by the constraint.

To preview some of the effects of the fertility constraint, suppose that the constraint is initially binding for all parents in a homogeneous agent model. If the fertility constraint is removed, a parent's fertility rebounds and the resources allocated to savings and education are partially crowded out. The next generation (a larger generation) will work with less physical capital. Through the general equilibrium effect, the wage rate and output per capita decrease. Therefore, the next generation will be hurt by removing the policy because of capital dilution. The magnitude of capital dilution depends on how tight the constraint is.

Now consider the model with skilled and unskilled parents. If the policy is binding for both types, the results will be similar to those in a homogenous agent model. In contrast, suppose that initially skilled parents are not constrained (because they prefer a low number of children even without the constraint) but unskilled parents' fertility is restricted. When the one-child policy is relaxed, unskilled parents are willing to have more children. Thus, the effects of capital dilution also exist in the heterogenous agent economy. Capital dilution and more supply of unskilled labor result in an increase in skill premium, which makes children more expensive for skilled parents. In addition, removing the one-child policy implies a redistribution between skilled and unskilled parents. This result follows the fact that education is determined by parents: children cannot invest in their own education.

3.3 Command vs. Market Economies

Before proceeding to the calibration, it is important to comment on using a neo-classical market model to describe the Chinese economy.

In the late 1970s, the dual-track system (a hybrid of the central planning and market systems) started to emerge in Chinese industry as a result of its market-oriented reforms.[14] Under the dual-track system, each economic agent has an obligation to deliver a specified quantity of output to the state government at a fixed price, and similarly a right to buy a given quantity of inputs at a fixed price. Above-quota output can be sold to the state at a lower price or traded on the free market, and additional inputs can be bought on the market as well. Therefore, the problem of distortions in prices and in resource allocation has been a concern of characterizing the Chinese economy.

However, for example, Chow (1985) uses a market model (a multiplier-accelerator

[14] See Byrd (1989); and Lau, Qian, and Roland (2000).

model) to investigate China's output, consumption, and investment from 1953 to 1982. The deviations of the historical observations from the predictions of the model are attributed to political factors. He concludes that the market model, which can explain national income of developed economies, is also applicable to the Chinese economy. The deviations are large only during the Great Leap Forward (1959-1962), the Cultural Revolution (1967-1968), and other periods with special government policies.

This paper carefully deals with the possible distortions of the Chinese economy. Specifically, the distortions in the prices of input factors (d_w and d_a) are considered in the model to capture the element of a command economy. They can be regarded as a tax/subsidy on labor income and capital gain imposed by the government. In present day, they will be close to zero. In our setting, the distortion on labor income will not alter a parent's fertility decision because it also changes the total cost of raising a child.

4 Calibration

In this section, we do a simple steady-state comparison. The model is calibrated to data from China in 1977 and 2005. In 1977, the one-child policy had not yet been introduced. Therefore, the model without fertility constraint is employed for calibrating 1977. In contrast, the steady state of 2005 is solved using the model with the fertility constraint in place in order to characterize China's one-child policy. In Section 5, to explore the impacts of the one-child policy, we further solve a transition path starting with the steady state of 1977, which is calibrated in this section, in comparison with a counterfactual experiment without the one-child policy.

4.1 Parameters

Table 2 summarizes the parameters in the calibration. Our strategy is to calibrate the parameters such that the model matches the moments in 2005, and then technology and exogenous driving forces (survival rates and costs of children) are changed so that another steady state also matches the data in 1977. In other words, we assume preference parameters (σ, ε, ψ, and β_a), the depreciation rate of physical capital, the elasticities of substitution between inputs, and the income share of total labor are constant. Data sources are summarized in Appendix C.

Technology

The time period in the model is twenty-five years. The total factor productivity is normalized to 10 for 2005. Then the total factor productivity of 4.934 is selected for 1977 in order to match the actual annual growth rate of per capita GDP 9.9 percent from 1977 to 2005. Following Chow and Lin (2002), the annual depreciation rate is equal to 4 percent. The corresponding depreciation rate of one period in the model is then computed by $\delta = 1 - (1 - \delta_a)^{25}$. The elasticities of substitution are computed following the suggestions in Krusell, Ohanian, Rios-Rull, and Violante (2000). They estimate that the elasticity of substitution between unskilled labor and physical capital is about 1.67. Furthermore, they also estimate the elasticity of substitution between skilled labor and physical capital to be 0.67. Following their estimate, α is equal to 0.401 and ρ is -0.493, so capital-skill complementarity is guaranteed.[15]

In addition, we need the income shares of labor and physical capital (kr) in China for production parameters. Chow (1985, 1993) and Chow and Lin (2002) use 0.4 for the income share of labor. The values estimated by Hu and Khan (1997) are 0.411 for the aggregate economy and 0.399 for non-agricultural sectors in 1952-1994. Using GDP data in Hsueh and Li (1999), Wang and Yao (2003) estimate that the share of labor is roughly stable at 0.5 in the reform period. They suggest that the slightly higher estimate is due to a bias toward capital accumulation in the command economy during the pre-reform periods.[16] According to the literature, China's labor income share seems to be lower than

[15]Krusell et. al (2000) consider a production technology with two forms of capital: equipment and structures. Equipment is complementary with skilled labor, while the elasticity of substitution between structures and other inputs is 1. To simplify the setup, this paper considers a model with only one form of physical capital, which is complemented with skilled labor.

[16]There are other studies estimating the labor income share of China. For example, Li, Jorgenson, Zheng, and Kuroda (1993) report the value of 0.484 in 1952-1990; but implicit housing subsidies, which are not systematically counted in the aggregate value added in the official statistics, are included in labor compensation. Young (2003) obtains a value of 0.6 using national income data. Bai and Qian (2010) find

that of other countries. Gollin (2002) points out that labor share estimates can be biased, especially in poor countries, if the labor income of the self-employed is omitted in the estimation of factor shares.[17] However, in China, the self-employed accounted for a small proportion of total employment, for example 3.3 percent in 1990. Besides, Young (2003) cautions that the Chinese national accounts explicitly make adjustments to the labor income of self-employment and suggest that there is no reason to modify the estimates of China's labor income share.[18] Consequently, in our calibration, the income share of labor is set to be 0.4 and the income share of physical capital is 0.6.

The income share of labor can be broken down into two parts: the income share of skilled labor and the income share of unskilled labor (ur). The unskilled labor income share is given by the following formula:

$$\frac{w_u L_u}{w_s L_s + w_u L_u} = \frac{1}{\frac{w_s}{w_u}\frac{l_s}{l_u} + 1},$$

where l_s is the ratio of skilled workers to total workers and l_u is the ratio of unskilled workers to total workers. In this paper, "skilled" workers are defined as those who have at least completed a senior secondary education. In 1975, the fraction of skilled workers as a percentage of total workers was about 10.2 percent. It increased to 10.5 percent in 1980. Thus 10.35 percent is chosen to represent the ratio of skilled workers in 1977. The skill premium in 1978 was 1.218.[19] Therefore, the share of unskilled labor to total labor income was 0.8767 in 1977. In 2005, the fraction of skilled workers was 18.9 percent and the skill premium was 1.471. Thus, the income share of unskilled labor income was 0.7447. Finally, μ and θ are the factor weights of the production function, and are determined by the physical capital income share and the income share of unskilled labor. μ is equal to 0.1957 and 0.3714 and θ is 0.9302 and 0.9528 in 1977 and 2005, respectively.[20]

a dramatic decline in labor income share from 1995 to 2007 because of structural transformation between the agriculture and non-agriculture sectors and shifts in the labor share within the industry sector.

[17] China is not included in the dataset of Gollin (2002).

[18] Also see Hsueh and Li (1999).

[19] Due to data availability, skill premium is computed using wages by sectors from *China Statistical Yearbook*. We rank sectors according to their average wage. Then the first half is used to represent skilled wage and the second half is unskilled wage. The same computation is applied to skill premium of 2005.

[20] In 1977-2005, China experienced rapid structural transformation (from agriculture to manufacture

Preferences

It is common to assume a high intertemporal elasticity of substitution in the Barro-Becker model, though typically lower than with the log utility model.[21] Following Doepke and Zilibotti (2005), this paper chooses a CRRA preference with risk-aversion parameter $\sigma = 0.5$.[22] The elasticity of altruism with respect to the number of children (ε) is 0.5, so that the fertility difference between unskilled and skilled workers is 1.45.[23] The third preference parameter is altruism coefficient ψ. Since the model is formulated at the level of individuals rather than couples, ψ is chosen to be 0.1752 to match half of the total fertility rate in 2005. The final preference parameter is the annual discount factor (β_a). It is equal to 0.9557 to match capital-output ratio 3.56. The corresponding discount factor of one period in the model is computed by β_a^{25}. It is also assumed that preferences do not change over time. Therefore, the preference parameters in 1977 are the same as those in 2005.

Exogenous Driving Forces

The World Development Indicators report the mortality rates for adults and for children under five. Using these mortality rates, we calculate the corresponding survival rates. However, because in the model one period is twenty-five years, we adjust the survival rates accordingly. For example, suppose that the survival rate for children under five is π_a, and the survival rate for adults is π_b. The survival rate for children in the calibration is obtained by $\pi^c = {\pi_a}^3 {\pi_b}^{10/45}$ and the survival rate for adults is $\pi^y = {\pi_b}^{25/45}$. In the calibration, $\pi^c = 0.8004$ and $\pi^y = 0.9038$ in 1980 is selected for the steady state of 1977;

and then to services). Changes in the factor weights across steady states partly reflect the structural changes of China during this period.

[21] For example, Becker, Murphy, and Tamura (1990), Doepke (2004), and Doepke and Zilibotti (2005).

[22] Jones and Schoonbroodt (2010) revisit the necessary restriction on a low risk-aversion parameter. Using a higher risk-aversion parameter, they show that decreased mortality and increased productivity growth can well explain changes in fertility. They also point out that their paper differs from the typical setting in that different driving forces are important. In our experiments, we increase both survival probabilities and costs of raising a child to capture changes in fertility.

[23] In the calibration, the fertility difference is calculated by $\frac{n_{us}\lambda_{us}+n_{uu}(1-\lambda_{us})}{n_{ss}}$. In the data, the total fertility rate of unskilled and skilled women was 1.336 and 0.9186, respectively.

$\pi^c = 0.8988$ and $\pi^y = 0.9288$ for 2005.

There are two costs associated with children: the education time cost ϕ_s, and the time cost ϕ. The education time cost is chosen to match the ratio of skilled workers to total workers 10.35 percent and 18.9 percent in 1977 and 2005, respectively. Therefore, ϕ_s is equal to 0.0181 and 0.0495. Ye and Ding (1998) compare the cost of child care in Xiamen to Beijing. A child in Xiamen costs about 34 percent of a family's annual income. If the education cost is excluded, the cost of child care is roughly equal to 29 percent in 1996. In Beijing, raising a child costs 20 percent of a family's annual income in 1995. It is around 16.4 percent when the education cost is excluded. Thus, the average cost of child care (excluding the education cost) is 22.7 percent of a family's income. The time cost of raising a child in the steady state of 2005 becomes 0.1741.[24] The child-raising cost estimated in Ye and Ding (1998) was in the middle of the 1990s, which may not be appropriate to apply to the 1970s of China. Here we choose $\phi = 0.1226$ to match half of the total fertility rate in 1977.

Fertility Constraint

China introduced the one-child policy in 1979. Therefore, there is no fertility constraint ($\bar{n}$) in the steady state of 1977.

As discussed in Section 2, China's one-child policy allows a second child under special conditions. In addition, ethnic minorities are usually allowed to have more than one child. Therefore, imposing a fertility constraint $\bar{n} = 0.5$ in 2005 cannot reflect the actual fertility control in China. Instead, we use the implied total fertility rate of 1990 reported in Scharping (2003) to compute $\bar{n}$. Weighted by population in each province, we set $\bar{n} = 0.815$ for the second steady state. See Appendix C for the detail of the implied total fertility rates.

[24] We use the average cost 22.7 percent of a family's income to compute the time cost of raising a child in 2005. The time cost of raising a child is obtained by:

$$\phi w_i = 0.227(1 - \phi n)w_i.$$

Applying the fertility rate, 1.338, in 2005, we have $\phi = 0.1741$.

Distortions

To capture the elements of a command economy, two distortions are included in the model: the distortion on the return of physical capital (d_a) and on labor income (d_w). China in 2005 was very close to a market economy; therefore, $d_a = d_w = 0$ (no distortion) in the calibration of 2005.

Zhuang (1996) uses a general equilibrium model to quantify substantial distortions in prices in the 1983 Chinese economy. He finds that labor was overpaid and physical capital was underpaid in non-agricultural sectors. Following the results reported in Table 2 of his paper, in 1977 d_a is set to be -0.35. In other words, the government collects tax from capital gain. We assume the government keeps a balanced budget, so the subsidy on labor is financed by capital-gain tax. The result of d_w is reported in Table 3.

4.2 Calibrated Results

Table 3 outlines the calibrated results. Young adults would like to have more children if the survival rate for children increases, regardless of the type of young adult. However, the time cost of childrearing in 2005 increases. Thus, the fertility of each type declines. From the first steady state to the second steady state, fertility on average decreases by about 53 percent. The main decline is observed for type *ss* (56 percent) and type *us* (54 percent), rather than type *uu* (50 percent). Because the increase in the unskilled wage rate is lower than that in the skilled wage rate, the increase in the cost of childrearing for unskilled adults is not as large as that for skilled adults. Therefore, even though type *uu* is affected by the implementation of the one-child policy, the decline of its fertility is still smaller than the decline presented in other groups.

The ratio of skilled workers to total workers increases from 10.4 percent to 18.9 percent. First of all, the skill-biased technology and skill premium provide an incentive for parents to send their children to school. Second, the fraction of unskilled parents having skilled children increases from 2.8 percent to 7.3 percent.[25] Thus, the implementation of the one-child policy induces parents to provide education to the only child. Third, as reported in

[25] The fraction of unskilled parents having skilled children is not reported in this paper.

Table 4, skilled adults spend less time on raising children.[26] More skilled labor is therefore released to the production sector. These three effects result in an increase in the ratio of skilled workers to total workers in 2005.

We assume that subsidies on labor are financed by the capital-gain tax. With a tax on capital gain of 0.35, the balanced budget implies that the subsidies on labor income are about 0.558, which is close to the estimate 0.534 in Zhuang (1996).

5 The Effects of the One-child Policy

This section further discusses the economic impacts of the one-child policy. Different from the steady-state comparison in Section 4, the experiments here are counterfactual: namely, what China would be like if the one-child policy had not been imposed on the Chinese economy. Outcomes in the benchmark model (with the one-child policy) are compared to an alternative in which the policy is removed.

5.1 Experimental Results

Methodology

In the benchmark, we solve a transition path, which starts with the steady state of 1977. 20 periods are solved for the transition path.[27] Period 0 reported in this paper is equal to the eleventh point in the transition path in order to make sure that the initial several periods are close to the steady state of 1977 and the last several periods converge to a new steady state.[28]

[26] By assumption, each young adult has one unit of time. A skilled adult spends ϕn_{ss} of his time on childrearing.

[27] Due to the space limit, this paper only provides the results for the three periods before and after the removal of the one-child policy. Results for other periods are upon request.

[28] Taken literally, the model period of 25 years would imply that the transition path stretches out for hundreds of years. This is a common problem in OLG models with subsequent generations and should not be interpreted literally. A more complicated model in which many cohorts live at the same time would result in a much shorter transition. In interpreting the results, rather than emphasizing timing predictions, we focus on the welfare implications for different groups, which should be robust to timing

At period 0, three components are changed in order to capture changes in China in the past decades. First, the exogenous driving forces permanently increase in period 0 (from the values of 1977 to those of 2005 in Table 2) to represent the natural demographic change: the survival probability for children, the survival probability for young adults, the time cost for childrearing, and the education time cost. This paper follows Barro and Becker's spirit to set up the theoretical model. In other words, our model assume the number of children (quantity) and the utility of children (quality) are complements. Thus, the two survival rates and the costs of children are changed in order to match the decline in fertility. The increases in survival rates may be due to improvements in sanitation, potable water, and the development medical science. The increase in the time cost may be attributed to the smaller contribution of children to home production. The increase in the education time cost may be because parents decided to spend more time on education in response to technological change. Second, the fertility constraint with $\bar{n} = 0.815$ is permanently imposed from period 0 to capture the implementation of the one-child policy since 1979. Third, price distortions decline to zero in period 0 to reflect China's economic reform toward a market economy.[29] In the model, people have full information. Thus, people anticipate the changes even before period 0 and can adjust their behavior accordingly. However, the model predicts that changes in behavior before the implementation of the one-child policy are small, so that the anticipation assumption makes little difference to the results.

In the counterfactual experiment, we also solve a transition path that starts with the steady state of 1977, but only the first and the third components are changed. In other words, the counterfactual experiment differs from the benchmark in the implementation of the one-child policy.

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issues.

[29]In Section 4, the production shifts to skill-biased technology. In other words, the factor weights μ and θ alter between 1977 and 2005. Besides, TFP also grows. However, in the experiments here, we focus on demographic change and the effects of imposing the one-child policy. Thus, the production does not shift to skill-biased technology i.e., μ, θ, and TFP remain unchanged in the experiments.

Effects on Labor Income

Figure 2 provides the skill premium with and without the imposition of the one-child policy. Clearly, the implementation of the policy reduces the skill premium and income inequality. There are two effects at work here. First, unskilled parents tend to have more children than skilled parents. If the policy imposes the same fertility constraint on each parent, an unskilled parent will have to lower his fertility more than a skilled parent. As a result, an unskilled parent will increase his working time more than a skilled parent does. For example, in Table 5, at period 0 an unskilled parent increases his working time by 1.9 percent when the one-child policy is imposed, while a skilled parent reduces working time by 0.13 percent. Second, the implementation of the policy reduces the future supply of unskilled labor, and therefore increases the future unskilled wage rate. These two effects combine to make the skill premium and income inequality smaller.

Effects on Human Capital and Output

Figure 3 plots the fraction of skilled labor as a percentage of total labor and per capita output. The implementation of the one-child policy promotes the accumulation of human capital. Furthermore, output per capita is higher in the benchmark. Based on the results, we conclude that China would have had a lower per capita output and a slower accumulation of human capital if the one-child policy had not been introduced in 1979. In fact, rapid human-capital accumulation and fast increases in per capita GDP have been observed in China after the introduction of the one-child policy.[30]

[30]Both environments have detrimental effects: per capita output increases at period 0 but declines later on. Output per capita can be decomposed into three parts:

$$y_{pc} = \frac{N^y}{N}\frac{L}{N^y}y, \tag{9}$$

where y denotes output per labor. The decrease in $\frac{N^y}{N}$ is due to population aging from period 0 to period 1. However, lower fertility results in more labor supply and more production; thereby an increase in $\frac{L}{N^y}$ and y. The magnitude of the detrimental effect depends on the relative changes of the three parts in each environment.

Effects on Fertility

Table 6 summarizes the effects of removing the one-child policy on fertility. In the environment without the policy, at period 0 type ss and us choose a fertility rate that is lower than $\bar{n}$. In contrast, parents with the third type, uu, prefer 0.91 children, which is above the constraint. Therefore, in the benchmark only type uu faces a binding constraint. In addition, we observe that the first two types in the benchmark prefer slightly more children than they do in the economy without the fertility constraint. In other words, when the constraint is relaxed, they choose to have fewer children. This counterintuitive result is explained by the fact that other parents now have more children, which changes wage rates. In particular, the lower ratio of skilled labor to total labor leads to higher skill premium, so that children become more expensive for some parents.

Effects on Age Composition

Figure 4 displays the age structure. In period 0, the implementation of the one-child policy generates a higher proportion of young adults (37 percent) and a lower proportion of children (29 percent). However, after one generation, the proportion of young adults in the benchmark becomes lower than that in the environment without the fertility constraint. At the new steady state, the proportion of the old generation in the benchmark increases to 43 percent, which is much larger than that in the economy without the fertility constraint (39.5 percent).[31] Therefore, the implementation of the one-child policy results in an older population. In fact, this is what China will undoubtedly experience in the near future. In 1980, the proportion of people in China aged 65 or above was 4.7 percent. After 25 years, the ratio almost doubled (7.6 percent). According to the UN population projection (the 2008 revision), the elderly will comprise over 20 percent of China's total population in 2040.

[31] In the experiment, age is classified as aged 0-24, aged 25-49, and aged 50 and above. Therefore, the proportion of old generation reported here is much larger than that in data.

Effects on Welfare

The common intuition is that an individual will benefit by removing the one-child policy. Table 7 reports consumption equivalent variation for young adults if the one-child policy is relaxed. It is a comparison of one generation living in two different environments. Compared with an environment with the one-child policy, the young generation living at period 0 is better off when the fertility constraint is removed.[32] However, for the young generation living after period 0, the welfare effects are different. As shown in Table 7, all young generations living in periods 1, 2, and 3 are worse off in the environment without the one-child policy.

For the initial generation (the young generation at period 0), initial conditions are fixed. Thus, they can gain from having the fertility constraint relaxed. In contrast, the following generations suffer from physical capital dilution. First, physical capital in period 1 is determined by the past generation. When the fertility constraint is relaxed, the generation living in period 0 chooses to have more children and fewer savings. The capital stock in period 1 declines. Second, children born in period 0 become young adults after one period, i.e., labor increases in period 1 when the fertility constraint is relaxed. Therefore, through the general equilibrium effect, lower capital per labor in period 1 results in a decline in labor income, a lower level of per capita output, and thereby lower welfare.[33]

To further explore the role of capital dilution in explaining changes in welfare, a two-period overlapping generations model without physical capital is constructed in the next section. We will show that everyone gains from having fertility constraint relaxed in the simplified model. We will also observe a redistribution effect between skilled and unskilled workers.

[32]Because utilities are foreseeable and are known when the current generation is making decisions, the effects of removing the one-child policy may reflect in the periods earlier than period 0.

[33]Jones and Schoonbroodt (2010) suggest that children and family consumption are substitutes when a higher risk-aversion parameter is applied. In this case, a decline in mortality becomes more important in explaining changes in fertility. Therefore, if children and family consumption are substitutes in our paper, the rebound of fertility is smaller when the one-child policy is removed and the quantitative results in Table 7 might be smaller in magnitude.

In the analysis of welfare effects, our results indicate that there exist both winners and losers across generations and skill groups when the one-child policy is relaxed. These findings present a clear step forward relative to the existing literature: when only GDP per capita is considered as a measure of economic well-being, the fact that some people are hurt due to the implementation of population policies is being ignored.

Sensitivity Tests

Before moving to the two-period model, several sensitivity tests are provided in the rest of this section. There are three effects that are imposed at period 0: exogenous driving forces, the fertility constraint, and the removal of price distortions. These three effects may interact with each other so that the effects of removing the fertility constraint alone are not clear. To deal with this issue, we do the following experiment: two survival rates, two costs of children, and price distortion remain unchanged at the level of 1977 in the benchmark and the counterfactual experiment. We start with the steady state of 1977 to do a transition path for an environment with the fertility constraint in comparison to one without the fertility constraint. In other words, the only difference between the two transition paths is the implementation of the one-child policy. The results are similar to the main experiment: the young generation living at period 0 enjoys the relaxation of the one-child policy, while future generations are hurt.

In the above experiment, the price distortion remains unchanged at the level of 1977. In other words, physical capital is underpaid by 35 percent and labor is overpaid by 55.8 percent. To test if the existence of price distortion affects the impacts of removing the one-child policy, we further exclude the price distortions in the experiment ($d_a = d_w = 0$). The results are similar to the previous experiments, but consumption equivalent variation is larger in absolute terms.

We use a CES production function to capture the capital-skill complementarity observed in developing countries. Here, we repeat the main experiment using a Cobb-Douglas production function. Following Table 2, the income share of physical capital and labor is 0.6 and 0.4, respectively. Thus, the income share of unskilled labor is 0.3507 in 1977 and 0.2979 in 2005. The income share of skilled labor is 0.0493 and 0.1021 in 1977 and 2005, respectively. The results are consistent with the previous findings.[34]

5.2 A Model without Physical Capital

In the last section, we argue that future generations suffer from the relaxation of the one-child policy because of capital dilution. To understand the importance of physical capital, we simplify our framework to a two-period model without physical capital. An individual lives two periods at most: childhood and adulthood. At adulthood, an individual solves the following maximization problem:

$$\max_{c_{ij},n_{ij}} \quad \left\{ \frac{c_{ij}^{1-\sigma}}{1-\sigma} + \psi(\pi^c n_{ij})^{1-\varepsilon} V_j' \right\},$$

subject to

$$c_{ij} + p_{ij} n_{ij} \quad = \quad w_i,$$

where $(i,j) \in \{s, u\}$. All notations are similar to Section 3. We have shown that the results are not sensitive to price distortions, so here we assume it is a perfect market economy. In addition, we employ a Cobb-Douglas production function to simplify the model:

$$Y = A L_s^{1-\zeta} L_u^{\zeta}.$$

In the calibration, following Table 2, the income share of unskilled labor ζ is equal to 0.8767 and 0.7447 in 1977 and 2005, respectively. Total factor productivity A is set to be 10 in 2005. In 1977, A is chosen to be 0.835 to match the annual growth rate of per capita GDP, 9.9 percent. Other parameters are the same as those in Table 2. Then, starting with 1977, a transition path of the benchmark is solved in comparison to the one without the one-child policy.

The experimental results are summarized in Tables 8 and 9. Similar to the experiment in Section 5.1, only the fertility of type uu is constrained. When the fertility constraint is relaxed, the fertility of type uu largely increases; others are relatively stable. Now there is no physical capital. Thus, the effects of capital dilution disappear. It will not affect

[34] Results for these sensitivity tests are available upon request.

welfare changes through the general-equilibrium effect. As Table 9 shows, almost every generation is better off when the one-child policy is removed.

In addition, we observe that unskilled adults who live several periods after removing the fertility constraint are slightly hurt. In contrast, skilled adults obtain 0.5 percent more consumption in each period. This is explained by the fact that our model implies that children's education is determined by parents. They cannot choose or change their own education when they become young adults. Therefore, there is an implicit redistribution between skilled and unskilled workers when the one-child policy is removed. The redistribution effect is much smaller than the impact of capital dilution.

As a general point, the first welfare theorem does not apply in this setting because there are missing markets. Specifically, parents cannot borrow against the future earnings of their children (or equivalently, children are not present at time zero and cannot engage in any date and event-contingent trading). This market imperfection (which is standard in intergenerational models) implies that the equilibrium is not necessarily Pareto efficient.

6 Conclusions

The debate on China's one-child per family policy still continues three decades after it was first introduced. To explore this issue, this paper introduces a fertility constraint into an overlapping generations model. An environment with a fertility constraint is built to represent the implementation of the one-child policy. Then we remove the fertility constraint to study the economic effects of the one-child policy.

The model is calibrated to data from China in 1977 and 2005. We further explore the impacts of the one-child policy by doing counterfactual experiments. The results suggest that imposing the one-child policy promotes the accumulation of human capital. In addition, the economy enjoys higher per capita output. However, output per capita fluctuates after the policy is enforced. This paper also shows that future generations will suffer from relaxing the one-child policy because of capital dilution. Finally, we find a redistribution effect between skilled and unskilled adults. Therefore, welfare analysis is important when analyzing population policies.

This paper does not make judgments regarding China's one-child policy. Our results suggest the important role of general equilibrium effects and heterogeneity. However, it is important to note that our model is simplified and some issues are not included. For example, in an open economy, foreign direct investment may reduce the effects of capital dilution. Furthermore, China's one-child policy is more complicated than a fertility constraint. It provides economic incentives (penalties and subsidies) for parents to change their fertility decisions. This paper also abstracts from pension systems and education subsidies, which may have effects on the evaluation of population policies. An analysis of the tax and transfer schemes associated with the one-child policy is left to future research.

Appendix A: Recursive Competitive Equilibrium

The maximization problem of an i-type young adult is described by the Bellman equation:

$$\begin{aligned} V_i(x) = \max_{c_i, a_i', n_{is}, n_{iu}} \Bigg\{ \frac{c_i^{y1-\sigma}}{1-\sigma} &+ \beta\pi^y \frac{c_i^{o1-\sigma}}{1-\sigma} \\ &+ \psi[\pi^c(n_{is}+n_{iu})]^{-\varepsilon}[\pi^c n_{is} V_s(x') + \pi^c n_{iu} V_u(x')] \Bigg\}, \end{aligned} \quad (10)$$

subject to the budget constraint:

$$c_i^y + \pi^y a_i' + \phi_s(1+d_w(x))w_s(x)n_{is} = [1-\phi(n_{is}+n_{iu})](1+d_w(x))w_i(x), \quad (11)$$

$$c_i^o = (1+r'(x'))(1+d_a)a_i', \quad (12)$$

and a law of motion of the state vector $x' = G(x)$, where $i \in \{s, u\}$ and the state vector $x \equiv \{N_s^y, N_u^y, K\}$.

The firm's problem is given by:

$$\max_{L_s^f, L_u^f, K^f} \quad Y - w_s(x)L_s^f - w_u(x)L_u^f - r(x)K^f, \quad (13)$$

where Y is defined by (5).

In equilibrium, only corner solutions exist. Define λ_{ij} as the fraction of i-type young adults having j-type children. Then, the following conditions should be satisfied:

$$\lambda_{ss}(x) + \lambda_{su}(x) = 1; \quad (14)$$

$$\lambda_{us}(x) + \lambda_{uu}(x) = 1. \quad (15)$$

By assumption, only skilled adults can be teachers. Therefore, the supply of skilled labor is equal to total skilled labor supply minus skilled labor spent on raising children and on teaching:

$$L_s(x) = [1-(\phi+\phi_s)n_{ss}(x)\lambda_{ss}(x) - \phi n_{su}(x)\lambda_{su}(x)]N_s^y - \phi_s n_{us}(x)\lambda_{us}(x)N_u^y,$$

Unskilled parents can allocate their time between working and raising children. The unskilled labor supply is given by:

$$L_u(x) = [1-\phi n_{us}(x)]\lambda_{us}(x)N_u^y + [1-\phi n_{uu}(x)]\lambda_{uu}(x)N_u^y.$$

Assume that skilled young adults can supply both skilled and unskilled labor, while unskilled young adults can only work as unskilled workers. Thus the market clearing conditions for the labor market are:

$$L_s^f(x) \leq L_s(x), \tag{16}$$

$$L_u^f(x) = L_u(x) + [L_s(x) - L_s^f(x)]. \tag{17}$$

The equality of the skilled labor market holds if $w_s(x) > w_u(x)$.

Define A_s and A_u to be the aggregate asset holding per skilled adult and per unskilled adult, respectively. Aggregate supply of physical capital tomorrow is given by:

$$K'(x) = \pi^y(A_s' N_s^y + A_u' N_u^y). \tag{18}$$

where $A'_s = g_s(x)$ and $A'_u = g_u(x)$. In equilibrium, aggregate demand of physical capital ($K^f(x)$) has to equal aggregate supply of physical capital K. The market clearing condition for the physical-capital market is:

$$K^f(x) = K. \tag{19}$$

The law of motion of skilled and unskilled young adults are given by:

$$N_s^{y'} = \pi^c[n_{ss}(x)\lambda_{ss}(x)N_s^y + n_{us}(x)\lambda_{us}(x)N_u^y]; \tag{20}$$

$$N_u^{y'} = \pi^c[n_{su}(x)\lambda_{su}(x)N_s^y + n_{uu}(x)\lambda_{uu}(x)N_u^y]. \tag{21}$$

The government keeps a balanced budget. The following condition holds in equilibrium:

$$\begin{aligned} & [1 + r(x)]d_a\pi^y[(a_{ss}\lambda_{ss,-1} + a_{su}\lambda_{su,-1})N_{s,-1}^y + (a_{us}\lambda_{us,-1} + a_{uu}\lambda_{uu,-1})N_{u,-1}^y] \quad (22) \\ = \; & [(1 - \phi n_{ss} + \phi_s n_{ss})\lambda_{ss}(x) + (1 - \phi n_{su})\lambda_{su}(x)]d_w(x)w_s(x)N_s^y \\ & +[(1 - \phi n_{us})w_u(x) + \phi_s n_{us} w_s(x)]d_w(x)\lambda_{us}(x)N_u^y \\ & +(1 - \phi n_{uu})w_u(x)d_w(x)\lambda_{uu}(x)N_u^y. \end{aligned}$$

A recursive competitive equilibrium consists of value functions $V_s(x)$ and $V_u(x)$, pricing functions $w_s(x)$, $w_u(x)$, and $r(x)$, mobility functions $\lambda_{ss}(x)$, $\lambda_{su}(x)$, $\lambda_{us}(x)$, and $\lambda_{uu}(x)$, policy functions $n_{ss}(x)$, $n_{su}(x)$, $n_{us}(x)$, $n_{uu}(x)$, $a_s'(x)$, and $a_u'(x)$, decision functions of the firm $K^f(x)$, $L_s^f(x)$, and $L_u^f(x)$, a law of motion of state variables $x' = G(x)$, $A'_s = g_s(x)$ and $A'_u = g_u(x)$, and the government policy $d_w(x)$ such that:

1.Given the pricing functions, the value functions and policy functions solve the young adult's dynamic programming problem.

2.If $\lambda_{ij}(x) > 0$, where $(i, j) \in \{s, u\}$, $n_{ij}(x)$ maximizes the young adult's problem.

3.Given the pricing functions, the decision functions of the firm maximize its profit.

4.The market-clearing conditions (16), (17), and (19) are satisfied.

5.The mobility functions (14) and (15) are satisfied .

6.The law of motion G for the state variable x is given by (18), (20), and (21).

7. The government keeps a balanced budget, i.e., (22) is satisfied.

8. Perceptions are correct: $A'_i(x) = a'_i(x)$, where $i \in \{s, u\}$.

Appendix B: Proof

Corner Solutions

The maximization problem can be broken down into two stages. In the first stage, a young adult chooses consumption for young adulthood (c_i^y), asset holdings (a_i'), and total expenditure on children (E_i) to maximize his lifetime utility. In the second stage, the young adult allocates E_i to skilled children and unskilled children.

To simplify the notation, the subscript of the young adult's type, i, will be ignored in the proof. The total expenditure of children is determined in the first stage. Given the E, the young adult spends a fraction f on skilled children and $(1-f)$ on unskilled children. Thus, the number of skilled children is $n_s = \frac{fE}{p_s}$; the number of unskilled children is $n_u = \frac{(1-f)E}{p_u}$. The maximization problem is given by:

$$\max_{0 \le f \le 1} \left\{ \frac{c^{y1-\sigma}}{1-\sigma} + \beta \pi^y \frac{c^{o1-\sigma}}{1-\sigma} + \psi \pi^{c^{1-\varepsilon}} E^{1-\varepsilon} \left(\frac{f}{p_s} + \frac{1-f}{p_u} \right)^{-\varepsilon} \left(\frac{fV_s}{p_s} + \frac{(1-f)V_u}{p_u} \right) \right\},$$

where $c^y = (1 + d_w)w - \pi^y a' - E$. By assumption, β, π^c, π^y, σ, and ε are between zero and one; $\psi > 0$; $p_s > p_u > 0$; $V_s > 0$; and $V_u > 0$. No interior solution implies that the optimal f in the above maximization problem is equal to either zero or one.

The first derivatives of U with respect to f is given by:

$$\begin{aligned}\frac{\partial U}{\partial f} &= \psi\pi^{c1-\varepsilon}E^{1-\varepsilon}\Bigg[(-\varepsilon)\left(\frac{f}{p_s}+\frac{1-f}{p_u}\right)^{-\varepsilon-1}\left(\frac{1}{p_s}-\frac{1}{p_u}\right)\left(\frac{fV_s}{p_s}+\frac{(1-f)V_u}{p_u}\right) \\ &\quad +\left(\frac{f}{p_s}+\frac{1-f}{p_u}\right)^{-\varepsilon}\left(\frac{V_s}{p_s}-\frac{V_u}{p_u}\right)\Bigg].\end{aligned}$$

On the right-hand side, the term outside the bracket is positive. Because $p_s > p_u$, the first term in the bracket is also positive. The second term in the bracket determines the existence of interior solutions. If $\frac{V_s}{p_s} \geq \frac{V_u}{p_u}$ holds, the first-order condition cannot be satisfied so there is no interior solution. For an interior solution to be possible, it has to be the case that $\frac{V_s}{p_s} < \frac{V_u}{p_u}$. In the following discussion, we focus on this case. We will set the first derivatives to be zero to solve the unique f. Then we plug this f into the second derivatives to show that the second-order condition for a maximum can not be satisfied. This implies that there is no interior solutions.

Setting the first derivatives to be zero, f can be solved as:

$$f = \frac{\varepsilon(\frac{V_u}{p_s}-\frac{V_u}{p_u})-(\frac{V_s}{p_s}-\frac{V_u}{p_u})}{(1-\varepsilon)p_u(\frac{1}{p_s}-\frac{1}{p_u})(\frac{V_s}{p_s}-\frac{V_u}{p_u})}.$$

The second derivatives of U with respect to f is given by:

$$\begin{aligned}\frac{\partial^2 U}{\partial f^2} &= \psi\pi^{c1-\varepsilon}E^{1-\varepsilon}\varepsilon\left(\frac{f}{p_s}+\frac{1-f}{p_u}\right)^{-\varepsilon-1}\left(\frac{1}{p_s}-\frac{1}{p_u}\right)\Bigg[(\varepsilon+1) \\ &\quad \left(\frac{f}{p_s}+\frac{1-f}{p_u}\right)^{-1}\left(\frac{1}{p_s}-\frac{1}{p_u}\right)\left(\frac{fV_s}{p_s}+\frac{(1-f)V_u}{p_u}\right)-2\left(\frac{V_s}{p_s}-\frac{V_u}{p_u}\right)\Bigg].\end{aligned}$$

The whole term outside the big bracket is negative. Therefore, the second derivatives is positive if the whole term in the big bracket is negative. Plugging in f, the inequality becomes:

$$(1+\varepsilon)\left(\frac{V_u}{p_s}-\frac{V_u}{p_u}\right) < \varepsilon\left(\frac{V_u}{p_s}-\frac{V_u}{p_u}\right)+\frac{V_s}{p_s}-\frac{V_u}{p_u}.$$

After some algebra, this inequality yields $V_u < V_s$. Thus, if $V_u < V_s$, the second-order condition for a maximum can not be satisfied. The interior solutions do not exist. On the other hand, if $V_u > V_s$, parents always prefer unskilled children with certainty because they are cheaper. Parents do not have incentives to have skilled children. Thus, we conclude that only corner solutions exist. Parents have either skilled or unskilled children. They do not want a mixture of children types.

Indifference Condition

Suppose the type of the young adult is i; the type of his children is j and his total expenditure on children is E_i.

Given that there are no interior solutions, the number of children the young adult has is $\frac{E_i}{p_{ij}}$. The young adult's maximization problem can be re-written as:

$$\max \quad \left\{ \frac{c_i^{y1-\sigma}}{1-\sigma} + \beta\pi^y \frac{c_i^{o1-\sigma}}{1-\sigma} + \psi\pi^{c^{1-\varepsilon}} \left(\frac{E_i}{p_{ij}}\right)^{1-\varepsilon} V_j \right\},$$

where $c_i^y = (1+d_w)w_i - E_i - \pi^y a'_i$ and $c_i^o = (1+r')(1+d_a)a'_i$. The first two terms are independent of the type of children (independent of j). Only the last term is relevant to the children's type. The last term contains the cost and the utility of a child. Thus, the young adult is indifferent between having skilled or unskilled children if and only if the following condition holds:

$$\frac{V_s}{p_{is}^{1-\varepsilon}} = \frac{V_u}{p_{iu}^{1-\varepsilon}}.$$

If this condition is satisfied, every i-type young adult faces the same maximization problem at the first stage, that is, he allocates resources between consumption, asset holdings, and total expenditures on children regardless of the type of children. Then, given the optimal E_i, there is a trade-off between quantity and quality of children. The higher cost of having skilled children reduces the number of children that a young adult has.

The indifference condition can be re-written as:

$$\frac{V_s}{V_u} = \left(\frac{p_{is}}{p_{iu}}\right)^{1-\varepsilon}.$$

The right side of this equation is the price of a skilled child relative to that of an unskilled child. The relative price for a skilled young adult is given by:

$$\frac{p_{ss}}{p_{su}} = \frac{\phi w_s + \phi_s w_s}{\phi w_s};$$

the relative price for an unskilled young adult is given by:

$$\frac{p_{us}}{p_{uu}} = \frac{\phi w_u + \phi_s w_s}{\phi w_u}.$$

Furthermore, we know that $w_s > w_u$ in equilibrium, so the relative price for a skilled young adult is always smaller than the relative price for an unskilled young adult. Thus, only one type of young adult can be indifferent between having skilled and unskilled children.

Appendix C: Data Source and Implied TFR

<Insert Table 10 and 11 here>

Appendix D: Algorithm for Solving a Transition Path (not for publication)

The initial period is a steady state representing China in 1977. The state variables are physical capital (K), the population of skilled young adults (N_s^y), and the population of unskilled young adults (N_u^y). All state variables are normalized by the population of young adults. In steady state, the initial population distribution is the data in 1977, but adjusted to match the age group in the model: aged 0-24 for childhood, aged 25-49 for young adulthood, and aged 50 or above for old adulthood. The initial physical capital per young adult is equal to 0.1.

To solve a transition path, we initially guess a sequence for each of these variables: $\{w_s, w_u, r, V_{ss}, V_{uu}, \lambda_{us}\}$ and then update all sequences at the same time. Given the initial guess, the fertility of each type (n_{ss}, n_{us}, n_{uu}) can be solved. Then, we compute the number of skilled workers, the number of unskilled workers, the fraction of skilled labor as a percentage of total labor (l_s), the fraction of unskilled labor (l_u), and physical capital per labor (k). The new price (w_s, w_u, r) can now be computed by marginal product. Since the fertility of each type has been calculated, the following variables for each type can be solved: asset holdings, consumption for young adulthood, consumption for old age, new life-time utility, and output per capita. At this point, based on the initial guess, the second period is solved. Then, state variables of the next period are computed so that the third period can be solved. This procedure is repeated to compute every period.

After all periods are calculated, we have new sequences of w_s, w_u, r, V_{ss}, and V_{uu}. They are updated by a linear combination of the initial guess and the new values. λ_{us} is updated by the following equation:

$$\lambda_{us} = \lambda_{us} \left(\frac{V_{us}}{V_{uu}} \right)^{v}, \tag{23}$$

where ν is the updated speed. The iteration stops if two criteria are satisfied at the same time: (i) The guess and the new values are very close to each other; (ii) V_{us} and V_{uu} are close to each other. In equilibrium, V_{us} is equal to V_{uu} so that an unskilled young adult is indifferent between having skilled and unskilled children.

In the environment without fertility constraint, four parameters go up at period 0: the survival rate for children (π^c), the survival rate for young adults (π^y), the time cost of childrearing (ϕ), and the time cost of education (ϕ_s). Table 2 reports the values in the first steady state and in the second steady state. For example, the survival rate for children is equal to 0.9305 before period 0, and it is equal to 0.9666 at and after period 0. Other parameters remain unchanged.

In addition to the permanent increases in the four parameters, the fertility constraint $n_{ij} \leq \bar{n}$ is permanently imposed at and after period 0 in the environment with the one-child policy. Before period 0, the same algorithm is applied to compute the transition path. After period 0, the fertility constraint should be taken into account. We initially assume that all types are not constrained and solve the fertility decisions. Then, five possible cases are checked to determine the correct fertility: (1) If the fertility decisions without constraint are all smaller than or equal to $\bar{n}$, the constraint is not binding. Thus, the correct fertility is equal to the fertility decisions without constraint. (2) If the fertility decisions without constraint are all larger than $\bar{n}$, the constraint is binding for all types. Thus, the correct fertility of each type is equal to $\bar{n}$. (3) If the type ss and uu are both binding but the type us is not binding, n_{ss} and n_{uu} should be equal to $\bar{n}$. Then, given n_{ss} and n_{uu} are both equal to $\bar{n}$, we solve n_{us} again. If the new n_{us} is smaller than or equal to $\bar{n}$. The new n_{us} is the correct fertility for type us. Otherwise, the correct fertility for type us should be equal to $\bar{n}$. (4) If n_{us} and n_{uu} are binding but n_{ss} is not binding, the correct fertility of type us and type uu are both equal to $\bar{n}$. Then we solve n_{ss} again. If the new n_{ss} is smaller than or equal to $\bar{n}$, it is the correct fertility of type ss; otherwise, the correct fertility of type ss is equal to $\bar{n}$. (5) If n_{uu} is binding but n_{ss} and n_{us} are not binding, then n_{uu} is equal to $\bar{n}$. Then we solve n_{ss} and n_{us} again. There are four possibilities for the new n_{ss} and n_{us}. First, if both of them are smaller than or equal to $\bar{n}$, the new n_{ss} and n_{us} are the correct fertility for the corresponding types. Second, if both of them are larger than $\bar{n}$, the correct fertility for both types should be equal to $\bar{n}$. Third, if n_{ss} is larger than $\bar{n}$ but n_{us} is not binding, the correct fertility of type ss is $\bar{n}$. Given n_{ss} and n_{uu} are both equal to $\bar{n}$, we solve n_{us} again. If the new n_{us} is smaller than or equal to $\bar{n}$, it is the correct fertility for type us; otherwise, n_{us} is equal to $\bar{n}$. Fourth, if n_{ss} is not binding but n_{us} is binding, n_{us} should be equal to $\bar{n}$. Given n_{us} and n_{uu} are both equal to $\bar{n}$, we solve n_{ss} again. If the new n_{ss} is not binding, it is the correct fertility for type ss; otherwise, n_{ss} should be equal to $\bar{n}$.

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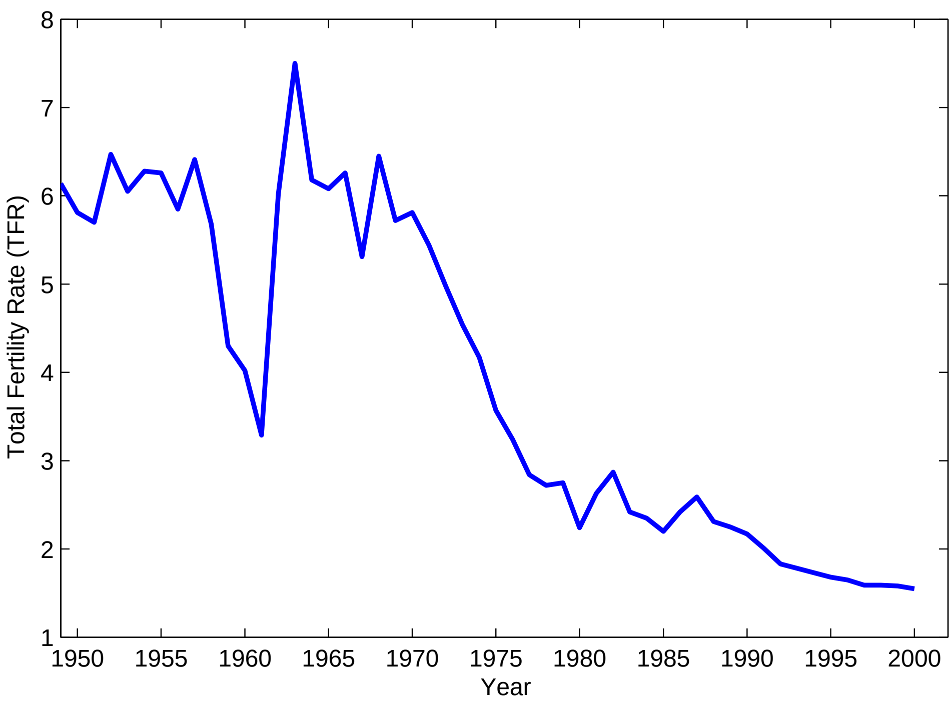
Table 1: Age Composition in China

	1970	1990	2005	2010	2030	2050
Age 0-14	39.7	28.4	22.0	19.9	16.9	15.3
Age 15-64	56.0	66.1	70.4	71.9	67.2	61.4
Age 65 and above	4.3	5.5	7.6	8.2	15.9	23.3

Note: Percentage of total population. Source: *World Population Prospects*, the 2008 revision, Population Division of the Department of Economic and Social Affairs, UN. http:// esa.un.org/unpp

Figure 1: Total Fertility Rates in China



Source: *China Statistical Yearbook*.

Table 2: Parameters

Parameters	1977	2005	Target/Method
Technology			
δ_a	0.04	0.04	Chow and Lin (2002)
$\frac{1}{1-\alpha}$	1.67	1.67	Krusell et. al (2000)
$\frac{1}{1-\rho}$	0.67	0.67	Krusell et. al (2000)
A	4.934	10	annual growth rate of GDP per capita = 9.9%
kr	0.6	0.6	Chow (1985, 1993)
ur	0.8767	0.7447	by calculation
μ	0.1957	0.3714	by calculation
θ	0.9302	0.9528	by calculation
Preferences			
β_a	0.9557	0.9557	capital-output ratio = 3.56
σ	0.5	0.5	Doepke and Zilibotti (2005)
ε	0.5	0.5	TFR difference between skill/unskill in 2005 = 1.45
ψ	0.1752	0.1752	a half of TFR in 2005 = 0.669
Exogenous Driving Forces			
π^c	0.8004	0.8988	conditional probability
π^y	0.9038	0.9288	conditional probability
ϕ_s	0.0181	0.0495	l_s = 10.35% in 1977; 18.9% in 2005
ϕ	0.1226	0.1741	2005: Ye and Ding (1998)
			1977: a half of TFR = 1.42
Constraint and Distortions			
$\overline{n}$	N.A.	0.815	a half of the implied TFR = 1.63
d_a	-0.35	0	Table 2 in Zhuang (1996)

Table 3: Calibrated Results

	1977		2005	
	Data	Calibration	Data	Calibration
n_{ss}		1.241		0.552
n_{us}		1.385		0.640
n_{uu}		1.634		0.815
Average fertility	1.420	1.420	0.669	0.669
l_s	10.35%	10.35%	18.90%	18.90%
$\frac{w_s}{w_u}$	1.218	1.218	1.471	1.471
y_{pc} (annual growth)			9.9%	9.9%
d_w		0.5582		0

Note: Because the model is formulated at the level of individuals rather than couples, a half of TFR is matched in the calibration.

Table 4: Time Allocation in the Calibration

	Skilled worker			Unskilled worker	
	Raising	Teaching	Working	Raising	Working
1977	0.152	0.029	0.819	0.200	0.800
2005	0.096	0.037	0.867	0.140	0.860

Table 5: Effects on Time Allocation in the Experiment

	One-child Policy			No Constraint		
Period	Working	Teaching	Raising	Working	Teaching	Raising
Unskilled Parent						
-1	0.8433		0.1567	0.8426		0.1574
0	0.8587		0.1413	0.8427		0.1573
1	0.8593		0.1407	0.8430		0.1570
Skilled Parent						
-1	0.8498	0.0301	0.1201	0.8495	0.0299	0.1206
0	0.8498	0.0377	0.1126	0.8509	0.0394	0.1096
1	0.8592	0.0387	0.1021	0.8574	0.0419	0.1006

Table 6: Effects on Fertility in the Experiment

	One-child Policy			No Constraint		
Period	n_{ss}	n_{us}	n_{uu}	n_{ss}	n_{us}	n_{uu}
-3	1.2463	1.3912	1.6413	1.2464	1.3913	1.6413
-2	1.2556	1.4015	1.6535	1.2558	1.4018	1.6539
-1	0.9793	1.0958	1.2913	0.9836	1.1005	1.2968
0	0.6467	0.6977	0.8150	0.6299	0.6797	0.9128
1	0.5864	0.6650	0.8150	0.5782	0.6572	0.9165
2	0.5656	0.6508	0.8150	0.5618	0.6480	0.9153
3	0.5578	0.6448	0.8150	0.5561	0.6443	0.9137

Table 7: Welfare Effects of Removing the One-child Policy

	Consumption Equivalent Variation (%)		
Period	Type *ss*	Type *us*	Type *uu*
-3	0.00	0.00	0.00
-2	0.01	0.00	0.00
-1	0.02	0.03	0.03
0	0.46	0.45	0.45
1	-2.16	-2.70	-2.70
2	-3.54	-4.16	-4.16
3	-4.19	-4.78	-4.78

Table 8: Two-period Model - Fertility

	One-child Policy			No Constraint		
Period	n_{ss}	n_{us}	n_{uu}	n_{ss}	n_{us}	n_{uu}
-3	1.2388	1.3829	1.6314	1.2388	1.3829	1.6315
-2	1.2306	1.3738	1.6207	1.2306	1.3739	1.6208
-1	1.1886	1.3275	1.5657	1.1891	1.3280	1.5662
0	0.6168	0.6660	0.8150	0.6182	0.6675	0.8966
1	0.5709	0.6486	0.8150	0.5717	0.6500	0.9064
2	0.5578	0.6426	0.8150	0.5581	0.6438	0.9093
3	0.5540	0.6408	0.8150	0.5541	0.6419	0.9102

Table 9: Two-period Model - Welfare Effects of Removing the Policy

	Consumption Equivalent Variation (%)		
Period	Type ss	Type us	Type uu
-3	0.00	0.00	0.00
-2	0.00	0.00	0.00
-1	0.01	0.01	0.01
0	0.05	0.04	0.04
1	0.28	0.02	0.02
2	0.41	0.00	0.00
3	0.46	-0.00	-0.00
4	0.49	-0.00	-0.00
5	0.50	-0.01	-0.01

Table 10: Data Source

Data	Source
GDP per capita	NationMaster.com
Ratio of skilled workers in 1975 and 1980	Barro and Lee (2001)
Ratio of skilled workers in 2005	Asuyama (2009)
Wage by sectors	China Statistical Yearbook
TFR by education	2000 Population Census
TFR	China Statistical Yearbook
Ratio of self-employment in 1990	China Statistical Yearbook
Capital-output ratio	Chow and Lin (2002)
Mortality rate for adults	WDI
Mortality rate for children under 5	WDI
Implied TFR in 1990	Scharping (2003)
Population by provinces	China Statistical Yearbook
Population in 1977 and 2005	WDI
Age composition in 1977 and 2005	WDI

Figure 2: Effects on Wage Rates

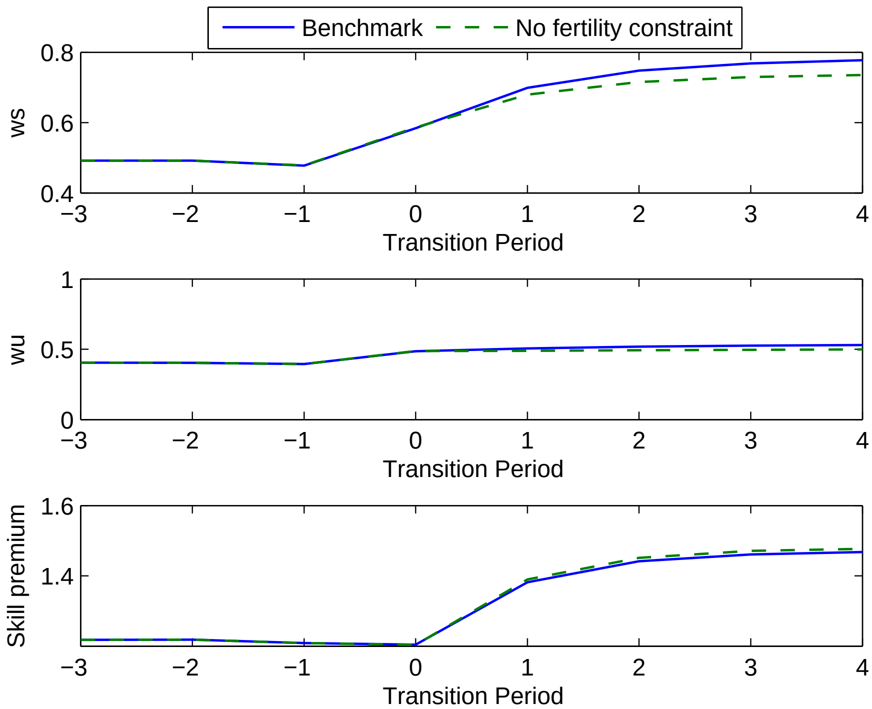


Table 11: Implied TFR

Province	Implied TFR in 1990	Population Percentage	Weighted TFR
Shanghai	1.28	1.16%	0.0148
Beijing	1.33	0.98%	0.0130
Tianjin	1.35	0.80%	0.0108
Heilongjiang	1.44	3.20%	0.0460
Liaoning	1.50	3.56%	0.0534
Jilin	1.50	2.20%	0.0330
Jiangsu	1.52	6.11%	0.0928
Jiangxi	1.52	3.44%	0.0523
Zhejiang	1.54	3.82%	0.0589
Shandong	1.55	7.60%	0.1178
Hubei	1.55	4.91%	0.0761
Henan	1.56	7.80%	0.1218
Sichuan	1.57	7.12%	0.1118
Guangxi	1.57	3.83%	0.0601
Gansu	1.58	2.03%	0.0322
Anhui	1.61	5.11%	0.0822
Fujian	1.61	2.74%	0.0441
Hunan	1.64	5.51%	0.0904
Shaanxi	1.64	2.99%	0.0490
Hebei	1.67	5.56%	0.0928
Shanxi	1.69	2.62%	0.0442
Guizhou	1.74	2.95%	0.0513
Inner Mongolia	1.80	1.95%	0.0351
Guangdong	1.85	5.64%	0.1043
Hainan	1.97	0.60%	0.0118
Ningxia	2.06	0.42%	0.0087
Qinghai	2.08	0.40%	0.0084
Yunnan	2.13	3.37%	0.0717
Xinjiang	2.40	1.38%	0.0331
Tibet	2.81	0.20%	0.0055
Weigthed average			1.63

Note: Because of the fluid nature and the weak organization of birth planning in Tibet, the State Birth-Planning Commission did not calculate an implied TFR for Tibet. In the table, it is the actual TFR in Tibet of 1990. Source: Scharping (2003) and China Statistical Yearbook.

Figure 3: Effects on Human Capital and Output per capita

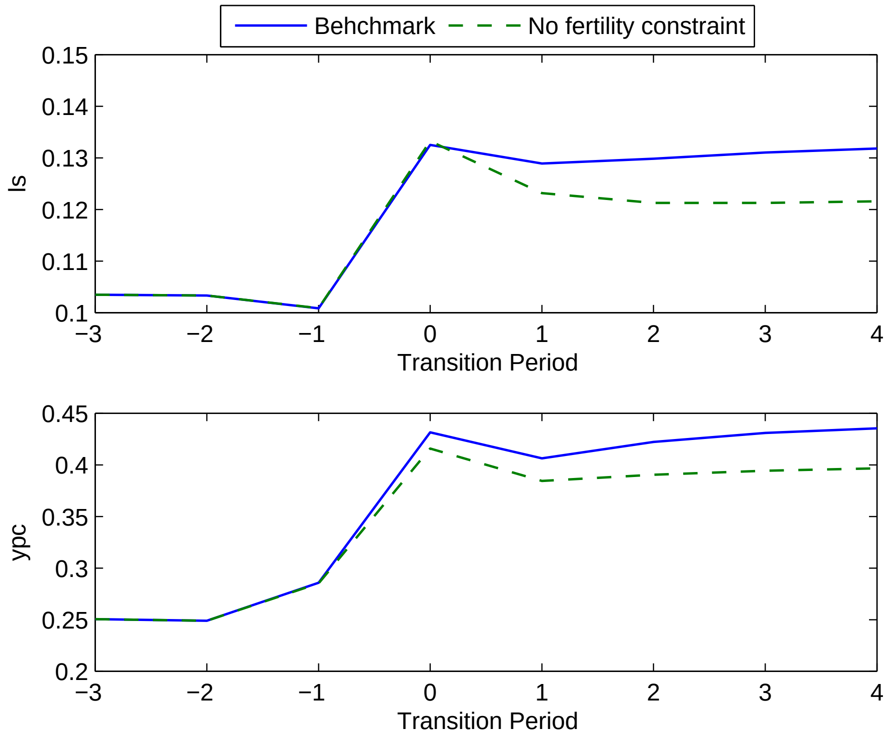


Figure 4: Effects on Age Composition