China's Demographic Transition: A Quantitative Analysis*

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China's fertility decline was very fast. But the drivers of this decline are not well understood. The common wisdom attributes it to the strict population control policies, particularly the One-Child Policy. Yet, fertility decline might also be due to the spectacular economic transformation and substantial mortality decline. To quantify the effects of different factors on China's demographic and economic transition, I develop a two-sector overlapping-generation model with workers' movement from rural to urban areas and endogenous fertility and education choices. Quantitative analysis shows that even without any population policy, the total fertility rate (TFR) would decline from 5.78 children around 1950 to 2.65 children around 2010. However, the population policies were crucial for the TFR to fall below the replacement level and do so very quickly after the 1980s. By around 2010, the cumulative effect of population policies reduced fertility from 2.65 to 1.30 children. The baseline model is also extended to incorporate the *hukou* system, considering that different *hukou* types are linked to different child quotas under the One-Child Policy and government transfers. The extended model suggests that the impact of the *hukou* system on fertility decisions was relatively minor.

Keywords: Demographic transition; Structural transformation; Population policies; Productivity growth; Mortality; China.

JEL codes: D1, J13, O41.

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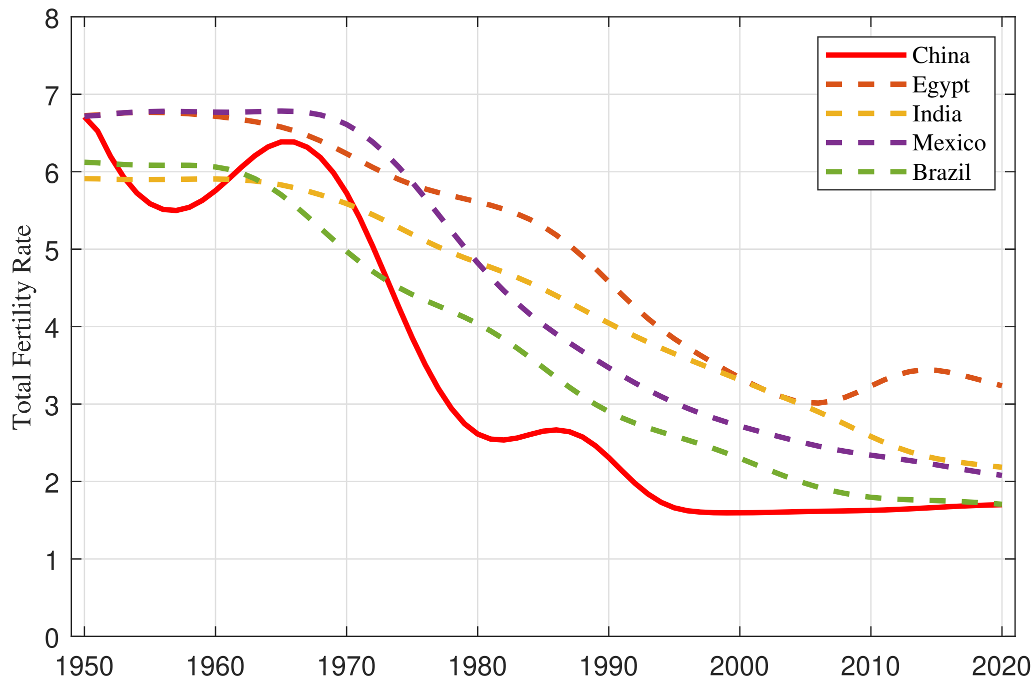
1 Introduction

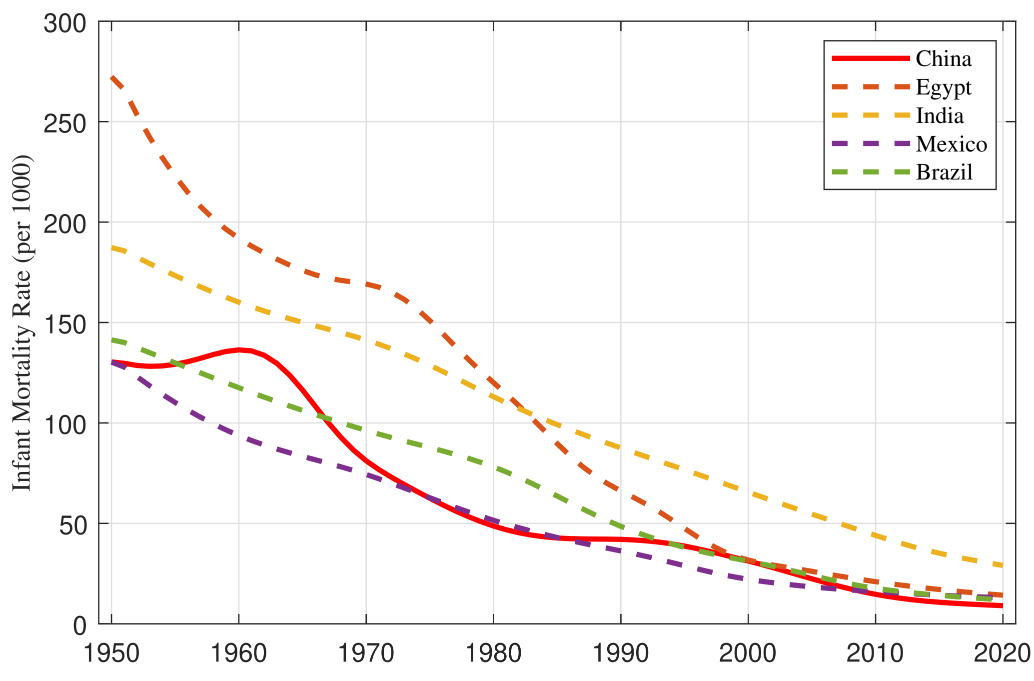
China's demographic transition was very fast. The total fertility rate (TFR) declined from about 6 in the 1950s to about 1.5 in the late 1990s. The decline was much faster than in other middle-income countries. Fig. 1 shows the TFR for several middle-income countries since 1950. While it took about 50 years for the TFR to drop from above 6 to the replacement level (2.1) in the other countries, China's demographic transition was completed in just 24 years, from 1968 to 1992.



Note: Data are from the 2019 Revision of World Population Prospects (United Nations, 2019).

Fig. 1. TFR for Selected Middle-Income Countries, 1950-2020

What were the driving forces behind this fast transition? The common wisdom attributes it to the strict and unique population policies in China (Li et al., 2005; Babiarz et al., 2018; Chen and Huang, 2020). The government launched the Later Longer Fewer (LLF) Campaign in the early 1970s, which encouraged people to get married *later*, to have a *longer* interval between births, and ultimately to have *fewer* children. This policy was replaced with the well-known One-Child Policy (OCP) in 1979, which assigned child quotas to parents and imposed harsh monetary punishments for above-quota children.[1] Despite the heavy-handed policy interventions, some other researchers argue that the fertility decline was a result of economic development (Cai, 2010) and urbanization (Guo et al., 2012), which were driven by high productivity growth (Zhu, 2012). There has also been a fast decline in child mortality. Fig. 2 shows the infant mortality rate (IMR) for some middle-income countries. While the IMR declined gradually for the other countries, China's IMR decline concentrated in the period 1960-1980, which was driven by several rounds of large-scale public health campaigns (Banister and Hill, 2004; Zhao and Kinfu, 2005; Babiarz et al., 2015).



Note: Data are from the 2019 Revision of World Population Prospects (United Nations, 2019).

Fig. 2. IMR (per 1000 Live Births) for Selected Middle-Income Countries, 1950-2020

What was the contribution of different factors to China's fertility decline? Would

[1] In 2016, the OCP was replaced with the Two-Child Policy (2CP), allowing parents to have at most two children. In 2021, the 2CP was replaced with the Three-Child Policy (3CP), increasing the child quota to three children per couple.

China's fertility decline so quickly even without strict population policies? Did the population policies aimed at controlling fertility have an impact on structural transformation? To answer these questions, I build a one-good, two-sector, overlapping-generation model with endogenous fertility and education choices. The fundamental driving forces behind fertility decline are mortality decline, changes in the sectoral productivity growth rates, and population policies. In the model, there are two sectors producing the same consumption goods, the unskilled (agricultural) sector and the skilled (manufacturing) sector. The unskilled sector uses land and unskilled labor as inputs, while the skilled sector uses only skilled labor. Individuals derive utility from consumption and care about the quantity and quality of their children. There is a basic amount of goods that can be produced domestically instead of bought from the market, so the utility function is non-homothetic. Raising children implies a time cost for parents, and providing them with skills requires an additional time cost. If children are skilled, they can work in manufacturing and earn a higher wage. Otherwise, they work in agriculture as unskilled workers.

In the model, productivity growth affects fertility and structural transformation through two channels. First, productivity growth increases wages. Since people's preferences are non-homothetic, households with increasing incomes tend to substitute children for consumption, leading to a lower fertility rate. Second, if labor productivity does not grow at the same rate in the two sectors, labor will be pulled to the sector with faster growth. For example, if labor productivity grows faster in manufacturing, then the relative demand for skilled labor will be increased, and parents will have fewer but better-educated children.

Finally, population policies are introduced into the model. The LLF Campaign was voluntary since it mainly *encouraged* people to have fewer children. Therefore, the LLF Campaign is modeled as a lower marginal utility from children. In contrast, the OCP essentially assigned child quotas to parents, which were higher for rural parents than urban parents, and imposed monetary punishments for above-quota children. Therefore, in the presence of the OCP, the marginal cost of children jumps up if the number of surviving children exceeds the child quota.

The population policies might also affect structural transformation, but the effect is ambiguous in theory. On the one hand, when people raise fewer children, they educate them more. As a result, more skilled labor will be supplied and the manufacturing sector will grow larger. On the other hand, a lower fertility rate will lead to a smaller labor force in the following periods. Given the fixed land supply, this will raise labor productivity and the unskilled wage in agriculture, reducing the incentive for parents to have skilled children working in manufacturing.

The model is calibrated to the time path of the Chinese economy since the 1950s. The exogenous driving forces in the model are the decline in mortality rates, changes in sectoral productivity growth rates, and population policies. The model is then contrasted with the data on the TFR in rural and urban areas and the share of agricultural employment. The model does a good job of replicating the changes in the data. To quantify the effects of each factor on China's fertility decline and structural transformation, I carry out a series of counterfactual experiments. First, I only allow mortality decline to play a role. Next, I add the changes in the TFP growth rates in addition to the mortality decline. Finally, I add the LLF Campaign and the OCP (and its descendent, the current Three-Child Policy, or 3CP).

The first finding is that there would have been a significant decline in fertility even without any population policy. In the benchmark economy with all exogenous changes, the TFR declines from 5.78 around 1950 to 1.30 around 2010. With only the decline in mortality, the TFR would be 4.35 around 2010. If we also add the changes in the TFP growth rates, the TFR would be 2.65 around 2010. Hence, these two forces alone can account for about 70% of the total decline in the number of children.

However, the population policies were crucial for reducing the TFR to below the replacement level and doing so in a short window. Adding the LLF Campaign to the decline in mortality and the changes in the TFP growth rates reduces the TFR from 4.62 to 4.10 around 1970. The impact of the OCP is much more significant. Introducing the OCP reduces the TFR from 3.12 to 1.53 around 1990 and from 2.65 to 1.30 around 2010. This is about 30% of the total decline in the TFR.

The results also reveal that changes in the sectoral productivity growth rates are the main driving force behind China's structural transformation. In the benchmark economy, the share of agricultural employment declines from 81.3% around 1950 to 35.0% around 2010. All of the decline can be accounted for by the changes in productivity growth rates. In contrast, mortality decline has a negligible effect, and the population policies even slow down the structural transformation. Indeed, if there are not any population policies, the share of agricultural employment would further drop by 4.7 percentage points around 1990 and 9.1 percentage points around 2010.

A key feature of the Chinese economy is the *hukou* (household registration) system. Residents can either hold a rural or urban *hukou*, which are associated with different child quotas and government transfers. The child quota was higher for rural *hukou* holders under the OCP. Moreover, local *hukou* holders are eligible for government-provided services, which are financed through taxation on local workers. People can convert their *hukou* type, but this is subject to a quota restriction. Therefore, workers who left the countryside but did not obtain urban *hukou* were allowed to have more children than urban natives, which undermined the effectiveness of the OCP. Meanwhile, such workers pay taxes to urban governments but receive no transfers, which may discourage rural-urban migration. An extended model incorporating the *hukou* system suggests that eliminating the *hukou* restriction would reduce the TFR, but the effect would be small, around 0.26 children around 1990 and 0.23 children around 2010. This would also have a small effect on structural transformation, reducing the share of agricultural employment by 4.7 percentage points around 1990 and 1.1 percentage points around 2010.

This study contributes to the literature on fertility and development. There is extensive literature that investigates the joint evolution of economic development and demographic changes hinging on the quantity-quality trade-off theory (Becker and Lewis, 1973; Becker et al., 1990). Some emphasize the role of technological progress and the movement of people from agriculture (rural areas) to manufacturing (urban areas) (see, e.g., Galor and Weil, 2000; Greenwood and Seshadri, 2002; Hansen and Prescott, 2002; Delventhal et al., 2020; Adams, 2021). Others point to the role of child mortality (Ehrlich and Lui, 1991; Kalemli-Ozcan, 2002, 2003; Bar and Leukhina, 2010), adult mortality (Soares, 2005; de la Croix and Licandro, 2013), and education policies (Doepke, 2004). Some recent studies examine how family planning policies affect the fertility rate and economic development (Ashraf et al., 2013; de Silva and Tenreyro, 2020; Cavalcanti et al., 2021). In particular, de Silva and Tenreyro (2020) use a quantitative model to analyze how population planning policies could accelerate the fertility decline by altering family-size norms in developing countries. In their model, there is a social norm on the number of children that a family should have, and parents derive disutility from deviating from the norm. Family planning policies reduce fertility by establishing a new small-family norm. Cavalcanti et al. (2021) investigate how family planning interventions affect living standards by reducing unwanted fertility. They embed a pregnancy risk in a quantity-quality trade-off model. Parents can insure against this risk by using costly contraceptives and can further avoid unwanted fertility by abortion. Family planning interventions that subsidize the price of contraceptive use or abortion will reduce unwanted fertility. My study differs from de Silva and Tenreyro (2020) and Cavalcanti et al. (2021) in the sense that the policies in my framework affect fertility in different ways. First, the LLF Campaign reduces wanted fertility by directly reducing people's preference for children. Second, the OCP forces people to have fewer children by imposing punishment in case of violation.

This paper also complements the empirical studies on the determinants of China's fertility rate. Some studies focus on the population policies (e.g., Babiarz et al. (2018) and Chen and Huang (2020) on the LLF Campaign, McElroy and Yang (2000) and Li et al. (2005) on the OCP), but some other studies argue that China's demographic transition was mainly driven by the economic development and urbanization (e.g., Cai, 2010 and Guo et al., 2012). Finally, although the child mortality rate declined fast at the same time as the fertility decline in China, its effect is largely ignored in the literature. An exception is Zhang (1990), who shows that the death of one child can result in 0.6 more births on average based on a survey of Chinese women aged 15-49 years in 1985. Usually, these studies focus on one factor, which might be subject to two issues. First, these factors changed simultaneously, whose effects are difficult to isolate. Second, these factors may interact with each other. For instance, the OCP aimed at controlling fertility may change investment in the education of children, which will affect income in the long run. In this study, I make use of a dynamic model to quantify the contributions of multiple factors.

The remainder of the paper is organized as follows. Section 2 documents some empirical facts that motivate this study. Section 3 describes the model, which will be used for the quantitative analysis. Section 4 explains how the parameters are calibrated. Section 5 shows the quantitative analysis to disentangle the effects of the exogenous factors on China's demographic and economic transition. Section 6 discusses the impact of China's unique household registration system. Section 7 concludes.

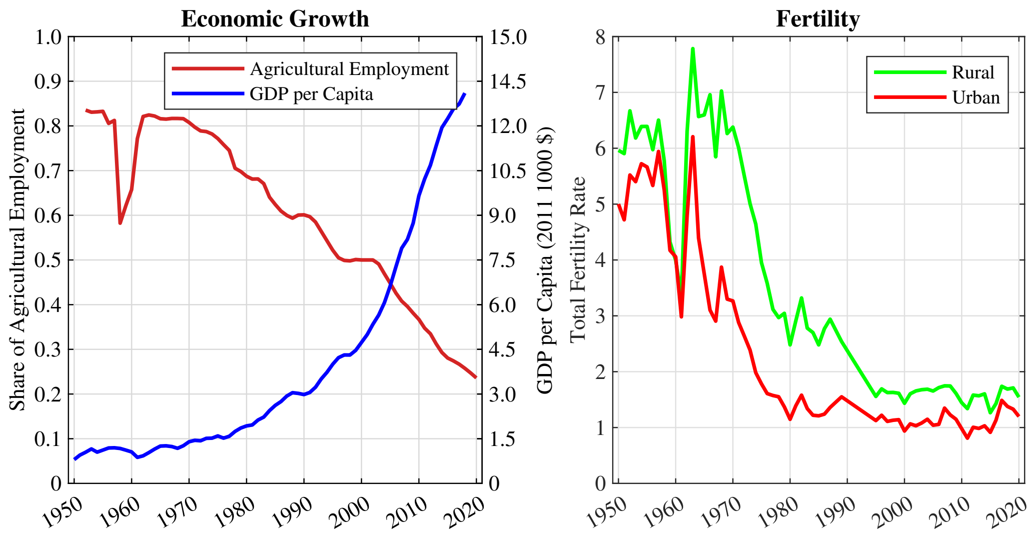
2 Facts

Fact 1. China experienced fast structural transformation and economic growth.

After the People's Republic of China was established in 1949, the Chinese economy was dominated by state ownership and central planning. The GDP per capita grew at a slow rate (2.8% per year before 1978), which was mainly driven by capital accumulation rather than TFP growth (Zhu, 2012).

Since 1978, a series of reforms have been carried out. In the late 1970s and early 1980s, the agricultural sector was de-collectivized with the "household-responsibility system," which generated strong positive incentives on farmers' efforts and input choices (Lin, 1992). In addition, the country was opened up to foreign investment, and domestic entrepreneurs were allowed to start businesses. In the late 1980s and 1990s, many state-owned firms were privatized. After joining the World Trade Organization in 2001, China began to lift its protectionist policies by cutting tariffs, allowing more domestic firms to trade internationally, and liberalizing foreign direct investment (Branstetter and Lardy, 2008).

These reforms were followed by rapid productivity growth (Dekle and Vandenbroucke, 2012; Zhu, 2012). As a result, labor moved to the manufacturing sector and GDP grew rapidly. The graph on the left-hand side in Fig. 3 shows the share of agricultural employment and GDP per capita during the 1950-2020 period. The share of agricultural employment was about 70% in 1978 but dropped to below 30% in 2020.[2] Meanwhile, the GDP per capita almost doubled in every decade in the post-reform period.



Note: Employment data are from *New China 65 Years* (National Bureau of Statistics of China (NBSC), 2014) and *China Statistical Yearbook 2021* (NBSC, 2021). GDP data are from the Maddison Project Database (Bolt et al., 2018). TFR data in 1950-1992 are from *Basic Data on China's Population* compiled by Yao and Yin (1994). TFR data in 1994-2020 are computed by the author based on the age-specific fertility rates from *China Population Statistics Yearbook* (NBSC, 1995-2021).

Fig. 3. Economic Growth and Total Fertility Rate

During the same period, the TFR dropped in both rural and urban areas, as shown on the right-hand side in Fig. 3. In the 1950s, the TFR was around 5.4 in urban areas and around 6.2 in rural areas. The fertility rate dropped sharply in the 1970s. The TFR was about 1.4 in urban areas and 2.9 in rural areas around 1980, which further dropped to 1.0 and 1.5 around 2010, respectively.

Overall, Fig. 3 highlights how the structural transformation of the Chinese economy

[2]The share of agricultural employment was very low in the period 1958-1960 due to the "Great Leap Forward" Economic Campaign. The TFR was very low in 1959-1961 because there was a great famine.

might have affected the TFR. First, as many rural people migrated to urban areas and worked in manufacturing, the fertility rate would be lower due to a composition effect. Second, the decline in fertility in both areas might be caused by the nationwide income growth.[3]

Fact 2. China achieved fast child mortality decline.

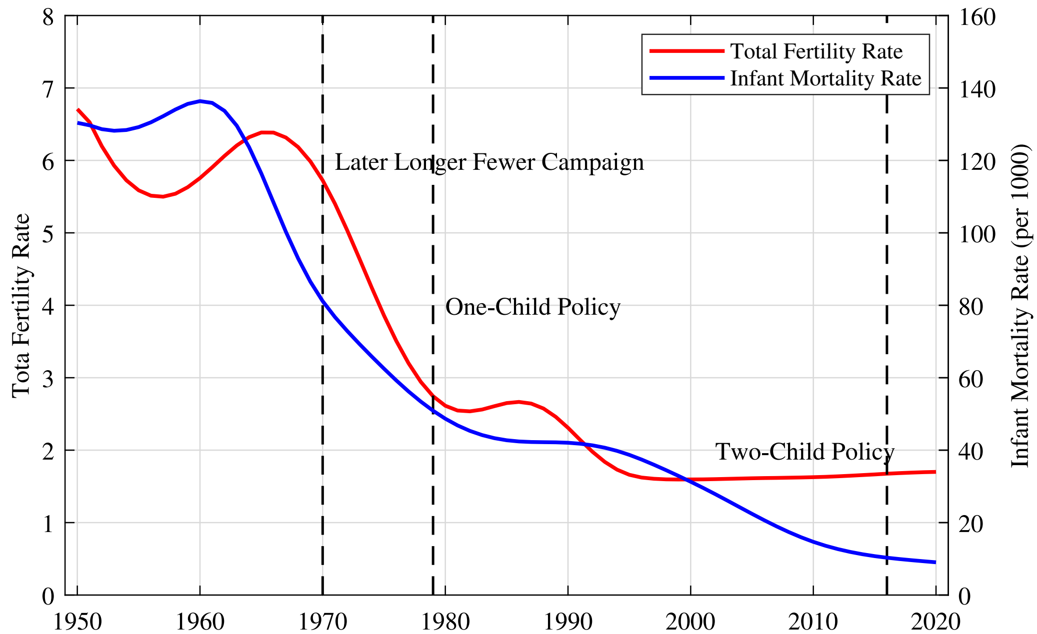
Fig. 4 plots the infant mortality rate against the total fertility rate.[4] In the 1950s, about 13% of newborns could not survive to the age of one. To improve people's health and well-being, China launched multiple rounds of large-scale public health campaigns between 1950 and 1980, including sanitation campaigns, childhood vaccinations, and communicable disease control programs (see Babiarz et al. (2015) for more details). These campaigns were successful in controlling and even eradicating some parasitic and infectious diseases, such as schistosomiasis, malaria, tuberculosis, and smallpox. At the same time, there was a large expansion of primary health care services (Sidel, 1972; Dong and Phillips, 2008). As a result, in the 1980s only less than 5% of infants could not survive to age one. This number continued to decline and is below 1% nowadays.

Fact 3. China implemented strict population control policies.

China was one of the first countries that implemented population control policies. After the great famine during 1959-1961, China's fertility rate rebounded and the TFR reached nearly 6 in 1960. In 1962, China issued the No. [62]698 document to advocate "family planning in urban areas and densely populated rural areas" to control population growth (Peng, 1997). In 1964, the family planning commissions were gradually established

[3]Fig. A.1 in Appendix A shows the cross-country evidence that TFR is positively associated with the share of agricultural employment and negatively associated with GDP per capita.

[4]Fig. A.2 in Appendix A shows the cross-country evidence that TFR is negatively correlated with infant mortality rate.



Note: Data are from the 2019 Revision of World Population Prospects (United Nations, 2019).

Fig. 4. Infant Mortality and Fertility

first at the national level and afterward at the province, prefecture, and county levels. However, the Cultural Revolution in 1966 promptly shut down most of the institutions (Chen and Huang, 2020).

At the end of the 1960s, China's population exceeded 800 million due to high birth rates in the earlier years. Meanwhile, economic growth stagnated. The leaders in China attributed the economic stagnation to the large population size rather than the economic institutions (Zhang, 2017). In early 1970, Premier Enlai Zhou stressed that the implementation of family planning policy should not stop (Chen and Huang, 2020). In 1971, a document was issued by the State Council requiring to establish a family planning leading group at the province level to organize and lead family planning work (Peng, 1997). In fact, a pilot trial had been launched in Guangdong province in 1969 and Shandong province in 1970, and by 1975 all provinces had established a leading group.

As summarized by Chen and Huang (2020) from Peng (1997), the LLF Campaign mainly organized professionals to propagate family planning, which encouraged people to get married *later* (23 years for females and 25 for males), to have a *longer* interval between births (more than three years), and ultimately to have *fewer* children (at most two for each couple). As part of the propaganda, the knowledge about contraception and sterilization and the benefit of birth control were broadcast. To complement the propaganda work, practical technical support was offered by distributing contraception pills and condoms. Finally, a system of rewards and penalties was also designed. Specific examples included paid vacation after a sterilization operation and priority in housing arrangements. The LLF was mainly voluntary. Although there was a system of rewards and penalties, they were very small.

The LLF Campaign was replaced with the OCP in 1979, which required each couple to have at most one child. Additional children were excluded from free public education, and parents were subject to monetary punishments and would lose their jobs if they were working in governments or state-owned enterprises (Ebenstein, 2010; Zhang, 2017). However, this policy was strongly resisted by rural families, especially those having only one daughter, due to the traditional son preferences and large ideal family size. After a coercive abortion campaign in 1983 that caused civil unrest, China relaxed the policy in 1984 to make it less draconian (Gu et al., 2007). Considering the geographic variation in demographic and socioeconomic conditions, the government enacted a localized population policy according to which inhabitants in different regions were subjected to different restrictions. In general, rural couples were subject to a looser restriction compared with their urban counterparts. On average, urban couples were limited to having about 1.0 children, while rural couples were allowed to have about 1.8 children.[5] Following this pol-

[5]According to Ebenstein (2010), provinces can be simply grouped into three categories, 1-child zones,

icy relaxation, the fertility rate rebounded considerably in 1984-1986 (Zhang, 2017). In addition, couples who lived in remote areas or belonged to specific socioeconomic groups, including ethnic minorities, could have a second or third child or even be exempted from such restrictions (Zhang, 2017).

The Chinese government has been increasingly concerned about the negative effects of the OCP, including a rapidly aging population, a shrinking labor force, and an imbalanced gender ratio, which may threaten China's future economic growth (Hvistendahl, 2010; Peng, 2011; Banister et al., 2012; Basten and Jiang, 2015). The stringent policy has been gradually relaxed since 2011, and in 2016 the universal Two-Child Policy (2CP) was introduced, allowing parents to have at most two children. In 2021, the policy was further replaced with the Three-Child Policy (3CP), increasing the quota to three children per couple.

Fig. 4 shows the TFR in China, together with the periods in which different population policies were in effect. Following the LLF Campaign, the TFR dropped sharply from nearly 6 to 2.7. After the OCP, the TFR continued to decline moderately and reached 1.6 in the late 1990s.

3 The Model

As in Hansen and Prescott (2002), this is a one-good, two-sector, overlapping-generation model. The two sectors are the unskilled (agricultural) sector and the skilled (manufacturing) sector, which produce the same consumption goods. The unskilled sector uses

1.5-child zones, 2-child zones. In the 1-child (2-child) zones, couples were limited to having at most 1 (2) children. In the 1.5-child zones, rural couples were allowed to have a second child if the first was a daughter.

unskilled labor and land as inputs, while the skilled sector uses only skilled labor.

Individuals live for four periods, one as a child and three as an adult (young, middle-aged, and old). Adults derive utility from consumption, and there is a basic amount of goods that can be produced domestically. Adults give birth when young and derive utility from the quantity and quality of their children. Raising children implies a time cost for parents, and educating them requires an additional time cost. When parents educate their children, the children obtain skills and can work in the skilled sector and earn a higher wage. Therefore, parents are faced with a quantity-quality trade-off when making fertility and education choices. They can either choose a large number of less-educated children or a few well-educated ones.

3.1 Firms

There are two sectors producing the same goods, the unskilled sector and the skilled sector. In the skilled sector, goods are produced with skilled labor by a representative firm using a linear technology,

$$Y_{s,t} = A_{s,t} S_t, \tag{1}$$

where S is the input of skilled labor and A_s is the productivity in the sector. Since labor is the only factor of input, A_s can be interpreted as either labor productivity or total factor productivity. The subscript t indicates the period.

Denote the skilled wage by $w_{s,t}$. The firm in the skilled sector solves the following problem to maximize its profit,

$$\max_{S_t} A_{s,t} S_t - w_{s,t} S_t. \tag{2}$$

The first-order condition implies that the skilled wage is equal to productivity in the sector, i.e.,

$$w_{s,t} = A_{s,t}. \tag{3}$$

In the unskilled sector, goods are produced with land and unskilled labor by a representative firm using a Cobb-Douglas technology,

$$Y_{u,t} = A_{u,t} L_t^{\alpha} U_t^{1-\alpha}, \tag{4}$$

where A_u is the total factor productivity, and L and U are the inputs of land and unskilled labor, respectively. Assume that land is owned by the firm and that land area is fixed and normalized to 1, then the production function becomes $Y_{u,t} = A_{u,t} U_t^{1-\alpha}$.

Denote the unskilled wage by $\tilde{w}_{s,t}$. The firm in the unskilled sector solves the following problem to maximize its profit,

$$\max_{U_t} A_{u,t} U_t^{1-\alpha} - \tilde{w}_{u,t} U_t. \tag{5}$$

The first-order condition determines the unskilled wage, i.e.,

$$\tilde{w}_{u,t} = (1-\alpha) A_{u,t} U_t^{-\alpha}. \tag{6}$$

The resulting profit of the unskilled firm is $\pi_{u,t} = \alpha A_{u,t} U_t^{1-\alpha}$. Assume that the profit is redistributed to unskilled labor, with each unit of labor receiving $\pi_{u,t}/U_t$. Thus, the effective unskilled wage is

$$w_{u,t} = \tilde{w}_{u,t} + \pi_{u,t}/U_t = A_{u,t} U_t^{-\alpha}, \tag{7}$$

which is equal to labor productivity in the unskilled sector.

3.2 Households

Individuals live for four periods, one as a child and three as an adult (young, middle-aged, and old). Individuals can have children when they are young. In each period, children and adults face a probability of death and may not survive to the next period. A newborn survives with probability s_t^c, a young adult with probability s_t^y, and a middle-aged adult with probability s_t^m.

Adults derive utility from consumption. A young adult is endowed with one unit of time. She works, consumes, and saves. She also decides how many children, Q_t, to have, and whether to educate them and make them skilled, $e_{t+1} \in \{0, 1\}$. Education is assumed to be a binary choice, following Greenwood and Seshadri (2002). There is a fixed time cost τ_0 associated with each newborn whether she survives or not. If the newborn survives, there is an extra time cost τ_1. This extra cost captures the fact that parents need to spend more time with the child and the child needs to receive some basic education. If the parent provides the child with skills, there is another time cost τ_2.[6] A middle-aged adult has λ unit of time ($\lambda < 1$). She works, consumes, and saves for old age. An old adult does not work and only consumes.

The expected lifetime utility function for a young adult is then given by

$$\begin{aligned} &V(c_t^y, c_{t+1}^m, c_{t+2}^o, Q_t, e_{t+1}) \\ &\quad = log(c_t^y + c_0) + \beta s_t^y log(c_{t+1}^m + c_0) + \beta^2 s_t^y s_{t+1}^m log(c_{t+2}^o + c_0) \\ &\qquad + \chi log(Q_t s_t^c) + \chi log[e_{t+1} w_{s,t+2} + (1 - e_{t+1}) w_{u,t+2}]. \end{aligned} \tag{8}$$

Here c^y, c^m, and c^o denote the individual's consumption when young, middle-aged,

[6] I abstract from the role of government in education. Fig. A.3 in Appendix B shows that government spending on education as a percentage of GDP in China was quite flat between 1970 and 2000, and that there was a substantial increase after 2000. In contrast, as will be shown in Fig. 8, the increase in educational attainment, as measured by the secondary school enrollment rate, occurred mainly before 2000.

and old, respectively. As in Greenwood et al. (2005), $c_0 \geq 0$ is the basic amount of goods that can be produced domestically instead of bought in the market. The utility from consumption when middle-aged and old is discounted by both the discount factor β and the survival rates.

Q_t is the number of newborns, among which a fraction s_t^c will survive. An individual derives utility from the quantity of surviving children, $Q_t s_t^c$, and the quality of them.[7] Quality is measured by the wage that the children will earn as middle-aged adults. e_{t+1} indicates whether the children are skilled or not. Skilled children ($e_{t+1} = 1$) will earn $w_{s,t+2}$ when they become middle-aged, while unskilled children ($e_{t+1} = 0$) will receive $w_{u,t+2}$. The parameter χ indicates the weight of children in the utility function.[8] The specification of utility from children captures two motives for having children. First, parents are altruistic and care about their children's welfare, which depends on the children's wages. Second, parents may receive old-age support from their children, which is related to the children's wages in their middle age.

Assume that the gross interest rate R is exogenously given and constant. Since young and middle-aged individuals may not survive to the next period and therefore lose their savings and interests, I assume that they face an actuarially fair interest rate adjusted for the mortality rates (Storesletten et al., 2004). That is, the actual interest rate is R/s_t^y for young adults who save for middle age, and is R/s_{t+1}^m for middle-aged adults who save for old age.

Let $w_t \in \{w_{u,t}, w_{s,t}\}$ denotes the wages at time t for parents. Then, the period budget

[7] When referring to the number of surviving children, I assume that the law of large numbers applies. I do not consider the uncertainty in the number of surviving children as in Kalemli-Ozcan (2002, 2003).

[8] Following Galor and Weil (2000), de la Croix and Doepke (2003), Kalemli-Ozcan (2002, 2003), Hazan and Zoabi (2006), and Lord and Rangazas (2006), I assign equal weights to the quantity and the quality of children and assume that parents care about the total earnings of children.

constraints are given by

$$\begin{aligned} c_t^y + Q_t[\tau_0 + s_t^c(\tau_1 + e_{t+1}\tau_2)]w_t + i_t^y &\leq w_t, \\ c_{t+1}^m + i_{t+1}^m &\leq \lambda w_{t+1} + i_t^y R/s_t^y, \\ c_{t+2}^o &\leq i_{t+1}^m R/s_{t+1}^m, \end{aligned} \tag{9}$$

where $i^y \geq 0$ and $i^m \geq 0$ are the savings when young and middle-aged. Assuming that households have perfect information on their survival rates, their wages when they become middle-aged, and their children's wages when the children are middle-aged, their optimization problems can be solved.

In each period, some households work in agriculture (the unskilled sector) and others work in manufacturing (the skilled sector). I interpret households that work in agriculture as residing in rural areas and others in urban areas. Hence, when a parent working in agriculture decides to educate their children, the children move to urban areas and work in manufacturing.

3.3 Fertility Decisions

Assuming an interior solution, parental choice of the number of children is given by,

$$Q_t = [\frac{\chi}{1 + \beta s_t^y + \beta^2 s_t^y s_{t+1}^m + \chi}][\frac{w_t + \lambda w_{t+1} s_t^y / R + C_0}{[\tau_0 + s_t^c(\tau_1 + e_{t+1}\tau_2)]w_t}], \tag{10}$$

where the term $C_0 = c_0 + \frac{c_0 s_t^y}{R} + \frac{c_0 s_t^y s_{t+1}^m}{R^2}$ appears due to non-homotheticity.[9] The right-hand side of Equation (10) is a product of two terms. The first term is the share of resources allocated to raising children, which depends on the relative importance of children in the utility of parents. The numerator of the second term is the total resources, i.e., the

[9]An interior solution is used here only to provide better intuition. It is not retained in the simulations. The solution can be a corner solution because the parents cannot borrow from the next period, as shown in the budget constraint (9).

lifetime income adjusted for non-homotheticity, while the denominator is the expected cost of a newborn.

What does Equation (10) imply about the preferred number of children? First, it is decreasing in the child survival rate s_t^c. When a newborn is more likely to survive, the expected cost is higher. Therefore, parents tend to have fewer children. Second, the number of children is smaller if parents decide to educate them ($e_{t+1} = 1$) since skilled children require more time commitment from parents. This is the quantity-quality trade-off. Therefore, if there is a structural transformation with more skilled labor in manufacturing, the overall fertility rate will decline. This allows imbalanced productivity growth to play a role, as labor will be pulled to the sector with faster growth of labor productivity (Hansen and Prescott, 2002; Alvarez-Cuadrado and Poschke, 2011). Third, the preferred number of children is decreasing in the wage rate when parents are young, w_t, because the utility function is non-homothetic due to a positive c_0. Indeed, with a higher wage rate, parents shift their demand from the number of children toward consumption.[10] This implies that productivity growth can also affect fertility through the wage rate.

3.4 Population Policies

Later Longer Fewer Campaign. The LLF Campaign was mainly voluntary. Although there was a system of rewards and penalties, they were very small. Therefore, it was mainly aimed at affecting people's preferences. de Silva and Tenreyro (2020) document that the family planning policies with similar features in other developing countries during the 1950-2010 period mainly tried to affect parents' preferences. Therefore, I introduce

[10]In addition to the Chinese pattern that TFR declined with GDP per capita over time, this is consistent with the widely documented evidence that fertility declines with the long-run economic growth in both developed countries today (Galor, 2011) and developing countries (Chatterjee and Vogl, 2018).

the LLF Campaign into the model in the following way. Without the policy, the utility from children is $\chi log(Q_t s_t^c) + \chi log[(1-e_{t+1})w_{u,t+2} + e_{t+1}w_{s,t+2}]$. With the LLF Campaign, the utility from children becomes

$$\chi log(Q_t s_t^c + q_0) + \chi log[(1-e_{t+1})w_{u,t+2} + e_{t+1}w_{s,t+2}], \tag{11}$$

where q_0 captures the effect of the LLF Campaign. The policy reduces the demand for children by lowering the marginal utility from surviving children.

One-Child Policy. The OCP assigned child quota to parents. Parents were subject to fines for additional children (Ebenstein, 2010) and would lose their jobs if they were working in governments or state-owned enterprises (Zhang, 2017). Therefore, the OCP affected directly the cost of children. Without the policy, the total cost of children is $Q_t[\tau_0 + s_t^c(\tau_1 + e_{t+1}\tau_2)]w_t$. With the policy, the cost becomes

$$Q_t[\tau_0 + s_t^c(\tau_1 + e_{t+1}\tau_2)]w_t + max\{Q_t s_t^c - \bar{q}_t, 0\}fw_t, \tag{12}$$

where $\bar{q}$ is the maximum number of children allowed, which can be different for rural and urban areas ($\{\bar{q}_{u,t}, \bar{q}_{s,t}\}$), and f is the fine rate per above-quota child. With this specification, the total fines are proportional to the wage rate of parents, which is consistent with the fact that the fines were proportional to their annual income.[11]

In the model, population policies can affect structural transformation in two ways. First, when people raise fewer children, they have more time available. The extra time can be allocated to working, which increases consumption. However, the diminishing marginal

[11] Since Q_t is a continuous variable in the model, I abstract from the *shidu* (bereavement) policy, under which parents who followed the OCP and lost all their children would be compensated by a cash transfer from the government. The *shidu* policy might strengthen the incentive for parents to follow the OCP and thus further reduce fertility. However, as the quantitative analysis will show, the OCP alone had a large negative effect on fertility. Therefore, the marginal effect of the *shidu* policy was likely to be quantitatively small.

utility of consumption implies that some of the extra time may be invested in children's education. As a consequence, more skilled labor will be supplied to the manufacturing sector. Second, population policies reduce the labor force in the next periods. Suppose the share of agricultural employment remains unchanged, the labor force in agriculture will be less than in the case without any population policies. As a result, labor productivity and the unskilled wage in agriculture will be higher, reducing the incentive for parents to educate their children. This will slow down the structural transformation. Overall, the effect of population policies on the share of agricultural employment is ambiguous.

3.5 Equilibrium and Balanced Growth Path

There are three types of households in the model: (uu) unskilled parents with unskilled children, (us) unskilled parents with skilled children, and (ss) skilled parents with skilled children. I assume that there is no skilled parent with unskilled children. This assumption is based on the fact that in China to work in agriculture people need to have a piece of land, which is hard to obtain if the parents work in manufacturing.

Denote the fraction of unskilled age-j adults in period t by u_t^j, and the fraction among them providing their children with skills by h_t^j, $j \in \{y, m, o\}$. The population growth rate of young adults will be

$$g_{n,t+1} = [u_t^y(1 - h_t^y)Q_{uu,t} + u_t^y h_t^y Q_{us,t} + (1 - u_t^y)Q_{ss,t}]s_t^c. \tag{13}$$

The term in the bracket is the average number of children of the young adults in period t. $Q_{uu,t}$, $Q_{us,t}$ and $Q_{ss,t}$ are the number of children of the type-uu, type-us and type-ss households, respectively, as given by Equation (10). A fraction s_t^c of the children will survive to the next period.

Let n_t^j denote period-t population size of age-j adults. The law of motion of population is

$$n_{t+1}^y = n_t^y g_{n,t+1}, \tag{14}$$

and

$$n_{t+2}^m = n_{t+1}^y s_{t+1}^y; \; n_{t+3}^o = n_{t+2}^m s_{t+2}^m. \tag{15}$$

The first equation states that the number of young adults in each period is equal to the number of young adults in the last cohort multiplied by the cohort population growth rate. The other two equations state that the number of middle-aged (or old) adults in each period is equal to the number of young (or middle-aged) adults in the last period multiplied by their survival rate.

Household decisions on fertility and education imply that the share of unskilled young adults in the next period will be

$$u_{t+1}^y = u_t^y(1-h_t^y)Q_{uu,t}/[u_t^y(1-h_t^y)Q_{uu,t} + u_t^y h_t^y Q_{us,t} + (1-u_t^y)Q_{ss,t}]. \tag{16}$$

The market clearing condition for unskilled labor is,

$$\begin{aligned} U_t =& n_t^y u_t^y(1-h_t^y)[1-Q_{uu,t}(\tau_0+s_t^c\tau_1) - max\{Q_{uu,t}s_t^c - \bar{q}_{u,t}, 0\}f] \\ &+ n_t^y u_t^y h_t^y[1-Q_{us,t}(\tau_0+s_t^c(\tau_1+\tau_2)) - max\{Q_{us,t}s_t^c - \bar{q}_{u,t}, 0\}f] \\ &+ n_t^m u_t^m \lambda, \end{aligned} \tag{17}$$

where unskilled young adults supply their time endowment net of childcare (and fines if they violate the OCP), while unskilled middle-aged adults supply all of their time endowment, which is λ.

Similarly, the market clearing condition for skilled labor is,

$$\begin{aligned} S_t =& n_t^y(1-u_t^y)[1-Q_{ss,t}(\tau_0+s_t^c(\tau_1+\tau_2))-max\{Q_{ss,t}s_t^c-\bar{q}_{s,t},0\}f] \\ &+n_t^m(1-u_t^m)\lambda. \end{aligned} \tag{18}$$

Equilibrium: Let LLF_t, OCP_t, and $3CP_t$ be three dummy variables indicating whether the LLF, the OCP, and the 3CP are present in period t, respectively. Given a sequence of survival rates, sectoral productivity, and population policies, $\{s_t^c, s_t^y, s_t^m, A_{u,t}, A_{s,t}, LLF_t, OCP_t, 3CP_t\}_{t=0}^{\infty}$, a competitive equilibrium is a sequence of wages $\{w_{u,t}, w_{s,t}\}_{t=0}^{\infty}$, a sequence of allocations of firms $\{U_t, S_t\}_{t=0}^{\infty}$, and a sequence of allocations of households $\{c_{uu,t}^y, c_{uu,t+1}^m, c_{uu,t+2}^o, Q_{uu,t}\}_{t=0}^{\infty}$, $\{c_{us,t}^y, c_{us,t+1}^m, c_{us,t+2}^o, Q_{us,t}\}_{t=0}^{\infty}$, and $\{c_{ss,t}^y, c_{ss,t+1}^m, c_{ss,t+2}^o, Q_{ss,t}\}_{t=0}^{\infty}$ such that firms maximize their profits, households maximize their utility, and the labor markets clear.[12]

Balanced growth path: Denote the TFP growth rate in the skilled and unskilled sectors by $g_{s,t}$ and $g_{u,t}$, respectively. Given constant surviving rates, productivity growth rates, and population policies, $\{s^c, s^y, s^m, g_u, g_s, LLF, OCP, 3CP\}$, a balanced growth path (BGP) is an equilibrium where the wage rates $\{w_{u,t}, w_{s,t}\}$ grow a constant rate g_w, the population grows at a constant rate g_n, the fraction of unskilled young adults u_t is a constant on the interval $(0, 1]$ or converges to 0,[13] and the fraction of unskilled young adults providing their children with skills h_t is a constant.

Depending on the productivity growth rates, the survival rates, and population policies, there can be three types of BGP's, which differ in the share of unskilled households: (1) the share of unskilled households converges to 0, (2) the share of unskilled households

[12]Note that unskilled parents also need to choose whether to become type-*uu* or type-*us* parents to maximize their utility.

[13]Note that due to the fixed land input, employment in the unskilled sector can never be 0. Otherwise, the unskilled wage will be driven to infinity.

is 1, (3) the share of unskilled households is a constant on the interval $(0, 1)$. I refer to them as a skilled BGP, an unskilled BGP, and a skilled-unskilled BGP, respectively.[14] A formal characterization of the three types of BGPs is provided in Appendix C.

It is important to note that the growth rate of wages can be 0 on a skilled-unskilled BGP. In such a case, the productivity growth rate is zero in the skilled sector such that the skilled wage is constant. In the unskilled sector, the TFP grows at such a rate that it offsets exactly the negative effect of unskilled labor growth on the unskilled wage.

4 Quantitative Analysis

In this section, I calibrate the model to the transition path of the Chinese economy. One period in the model corresponds to 20 years. Thus, an individual in the model can live up to 80 years. I assume that the economy is on a skilled-unskilled BGP with zero wage growth during the 1941-1960 period. This implies that the initial productivity growth rate is zero in manufacturing and positive in agriculture. With exogenous changes in the mortality rates, productivity growth rates, and population policies in the following periods, the economy transits from the initial balanced growth path to a new one. The new BGP turns out to be a skilled BGP. On an equilibrium path, I assume that households have perfect information on their survival rates, their wages when they become middle-aged, and their children's wages when the children are middle-aged.[15] The quantitative analysis

[14]In a model with similar BGPs, Bar and Leukhina (2010) refer to them as a Solow BGP, a Malthus BGP, and a Malthus-Solow BGP, respectively.

[15]To find an equilibrium transition path, I solve a computational fixed point problem. First, I look at the initial and final BGPs and obtain the skill wage premium, the share of unskilled parents, the share of unskilled parents who educate their children, and the population growth rate on the BGPs. Next, an initial guess is made about the unskilled wages and the share of unskilled parents who educate their children on the transition path. Given this guess, household problems are solved, and household decisions are used to update the initial guess. This process continues until unskilled wages and household decisions converge.

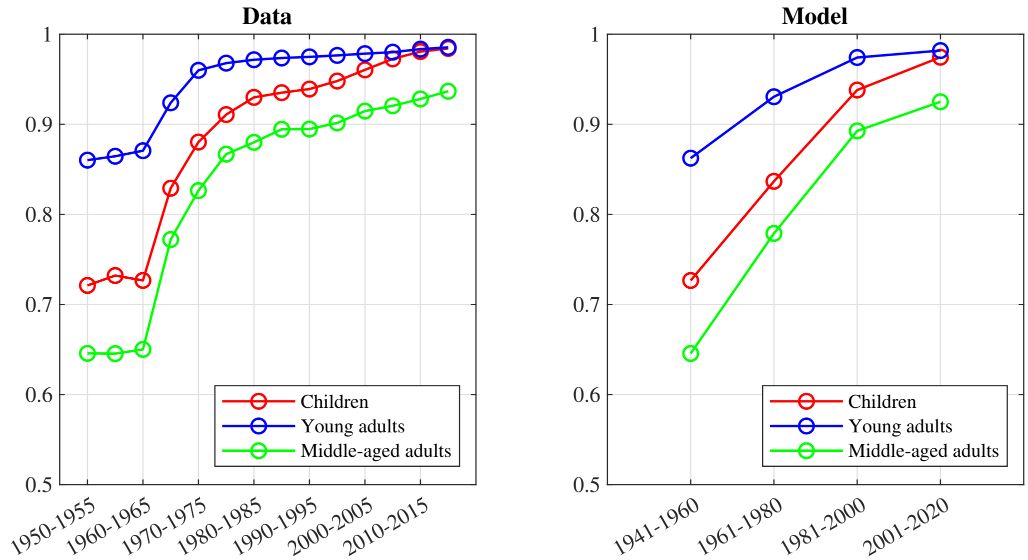
focuses on the 1941-1960, 1961-1980, 1981-2000, 2001-2020, and 2021-2040 periods. The Chinese economy gradually shifted from central planning to a market-oriented regime after 1978. In the quantitative analysis, this regime change is mainly reflected in the significant productivity growth in the model. While the planned economy of pre-1978 China had important differences from a market economy, to keep the analysis simple and transparent, the model focuses on a market equilibrium throughout this period.[16]

4.1 Exogenous Driving Forces

The survival rates are computed based on the life tables available for each five-year period 1950-1955, 1955-1960, and so on until 2015-2020 from the United Nations (2019). In the 1950-1955 period, nearly 30% of newborns could not survive to adulthood (age 20). However, in 2015-2020, just 1.6% could not. Survival rates of young adults and middle-aged adults also increased substantially from 86% to 99% and from 65% to 94%, respectively. I average these five-year survival rates to 20-year periods to get the survival rates used in the model. The details are shown in Fig. 5. In addition, I assume that the survival rates will not change after 2020, which is an innocuous assumption because they are already very close to 1.

Next, I borrow productivity estimates from the literature. Between 1952 and 1978, there was very little growth in aggregate productivity in China. Chow and Li (2002) estimate that the aggregate TFP had almost zero growth in this period. Holz (2006) and Zhu (2012) provide negative estimates, -0.62% and -1.07% per year, respectively. Since there are no reliable estimates separately for the two sectors for the pre-1978 period, I set

[16] One concern, for example, might be that under central planning, wage rates were generally not equal to the marginal product of labor. This affected workers' incentives and led to lower productivity in production (Lin, 1992; Groves et al., 1994).



Note: Data are from the 2019 Revision of World Population Prospects (United Nations, 2019).

Fig. 5. Survival Rates

the productivity growth rate in each sector to the aggregate TFP growth estimates, and assume that there is no productivity growth in the model between 1941 and 1980.

Since 1978, the TFP has been growing significantly. Dekle and Vandenbroucke (2012) estimate that from 1978 to 2003 the annual TFP growth rate was 3.7% in agriculture and 3.2% in manufacturing.[17] Therefore, I set the productivity growth rate in agriculture to 106.8% in 1981-2000 and 2001-2020 (3.7% per year), and set the productivity growth rate in manufacturing to 87.8% in these two periods (3.2% per year). After 2020, I assume that productivity in each sector grows at the long-run rate as in the US, which is 24.5% per model period (1.1% per year) in agriculture, and 32.1% per model period (1.4% per year) in manufacturing.[18]

[17]Dekle and Vandenbroucke (2012) also divide manufacturing to the public sector and the private sector with the growth rates being 1.3% and 8.8%, respectively. The estimates are close to those by Zhu (2012). Zhu (2012) estimate that the annual growth rate in agriculture was 2.79% in 1978-1988, 5.10% in 1988-1998, and 4.13% in 1998-2007. In the private sector, the annual growth rate was 5.87%, 2.17%, and 3.67% during the three periods. In the public sector, it was -0.36%, 0.27%, and 5.50%.

[18]To construct the long-run TFP growth rate in the US, I consider the period 1869-2019. Productivity in agriculture is from Kendrick (1961) for 1869–1948 and from the United States Department of Agriculture, https://www.ers.usda.gov/data-products/agricultural-productivity-in-the-u-s, for 1948-2019. Productivity in non-agriculture is from Kendrick (1961) for 1869–1948 and from the Bureau of

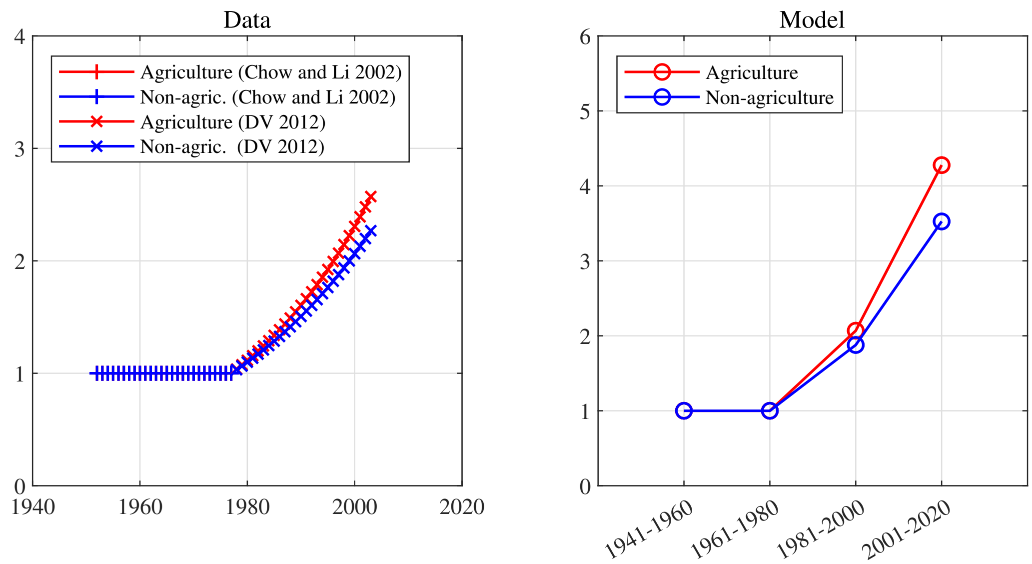


Fig. 6. Cumulative TFP Growth Rates

Finally, regarding the population policies, the LLF Campaign was introduced in 1970-1975 with different start dates in different provinces and was replaced with the OCP in 1979. The OCP was replaced with the 2CP in 2016, which was further replaced with the 3CP in 2021. Therefore, in the model, the LLF Campaign is present in the 1961-1980 period, the OCP is present in 1981-2020, and the 3CP is present after 2020. The sequences of all exogenous forces are reported in Table 1.

4.2 Calibration

To simulate the model economy, I first set some parameters to their data counterparts or borrow them from other studies. The annual discount factor is set to 0.96, a standard value in the macroeconomics literature. Therefore, the discount factor in the model is $\beta = 0.96^{20} = 0.44$. The average annual real interest rate is 2.07% in the period 1980-2020.[19] Therefore, the gross interest rate in the model is set to $R = 1.0207^{20} = 1.51$.

Labor Statistics, https://www.bls.gov/productivity, for 1948-2019.

[19]See https://data.worldbank.org/indicator/FR.INR.RINR?locations=CN.

Table 1: Sequence of Exogenous Changes

	Description	Value	Source
		1941-, 1961-, 1981-, 2001-, 2021-, ...	
s^c_t	Survival rate of children	$\{0.73, 0.84, 0.94, 0.97, 0.97, ...\}$	UN (2019)
s^y_t	Survival rate of young adults	$\{0.86, 0.93, 0.97, 0.98, 0.98, ...\}$	UN (2019)
s^m_t	Survival rate of middle-aged adults	$\{0.65, 0.78, 0.89, 0.93, 0.93, ...\}$	UN (2019)
$A_{u,t}$	Productivity in agriculture	$\{A_{u,0}, A_{u,0}, 2.07A_{u,0}, 4.28A_{u,0}, 5.32A_{u,0}, ...\}$	Literature
$A_{s,t}$	Productivity in manufacturing	$\{A_{s,0}, A_{s,0}, 1.88A_{s,0}, 3.53A_{s,0}, 4.66A_{s,0}, ...\}$	Literature
LLF_t	LLF Campaign	$\{0, 1, 0, 0, 0, ...\}$	
OCP_t	One-Child Policy	$\{0, 0, 1, 1, 0, ...\}$	
$3CP_t$	Three-Child Policy	$\{0, 0, 0, 0, 1, ...\}$	

Note: TFP estimates before 2020 are based on Chow and Li (2002) and Dekle and Vandenbroucke (2012). TFP growth rates after 2020 are set to the long-run growth rates in the US from Kendrick (1961), the United States Department of Agriculture, and the Bureau of Labor Statistics. See the text for further details.

The land share in agriculture, α, is set to 0.235. Chow (1993) estimates the production function in the Chinese agricultural sector using data in 1952-1988 and finds that the land share is 0.35. Using more recent data in 1978-2003, Dekle and Vandenbroucke (2012) show that the labor share in agriculture is 0.76, implying that the capital and land shares sum to 0.24. This leads them to use a land share of 0.12 in their analysis. In my model, I set the land share to the average of 0.35 and 0.12.

The productivity in manufacturing before the transition, $A_{s,0}$, is normalized to 1, while its counterpart in agriculture, $A_{u,0}$, will be implied by the initial BGP in the model. On the initial BGP with zero wage growth, the TFP growth rate in manufacturing, $g_{s,0}$, is set to 0, while the growth rate in agriculture, $g_{u,0}$, will be estimated within the model.

There are three costs associated with children, the cost of a newborn whether she survives or not, τ_0, the extra cost if a newborn survives to adult, τ_1, and the cost of providing a child with skills, τ_2. These costs come from two parts, a basic living cost and an education cost. I assume that the living cost is proportional to survival years and that the education cost is proportional to years of schooling. de Silva and Tenreyro (2020) estimate that the living cost of a surviving child is 0.025 for developing countries. Children who have not survived live up to 3.4 years old on average in China (United Nations, 2019),[20] so the living cost amounts to $\tau_0 = 3.4/20 \times 0.025 = 0.0043$. If a child survives and grows up as an unskilled child, she lives $20 - 3.4 = 16.6$ more years and receives 6.2 years of education on average (State Council and State Statistical Bureau of China, 1985, 1993, 2002, 2012). This results in an extra living cost, which is $16.6/20 \times 0.025 = 0.0208$. Since one year of schooling costs 17.7% of the annual income of a parent (Chi and Qian, 2016), the extra education cost is $6.2 \times 0.177/20 = 0.0549$.[21] Note that we have 20 as the denominator because a young parent works for 20 years. As a result, the extra cost of an unskilled child compared with a non-surviving child is $\tau_1 = 0.0208 + 0.0549 = 0.0757$. Finally, compared with an unskilled child, a skilled child receives 3.4 more years of education, implying that the extra education cost of a skilled child is $\tau_2 = 3.4 \times 0.177/20 = 0.0301$.[22]

When the OCP is present, there is an additional cost of children. Parents with above-quota children will be fined. The fines are proportional to the income of parents, and the rate varies across provinces and over time (Scharping, 2013). To compute the fine rate f in the model, I first convert the monetary cost to the time cost. For instance, a couple would be fined 1.29 times their annual income for each above-quota child in Shanxi

[20]The numbers have been relatively constant over years.

[21]Based on the population census data in 1982, 1990, 2000 and 2010 (State Council and State Statistical Bureau of China, 1985, 1993, 2002, 2012), agricultural (or unskilled) workers receives 6.2 years of education on average, and manufacturing (or skilled) workers receive 3.4 more years of education. Chi and Qian (2016) document that in 2011 one year of schooling costs 8.9% of annual household income. Assuming there are two parents in each household, the cost would be 17.7% of the annual income of one parent.

[22]The cost of an unskilled child is $\tau_0+\tau_1 = 0.0800$, while the cost of a skilled child is $\tau_0+\tau_1+\tau_2 = 0.1101$, implying that an unskilled child takes 8% of parental time and a skilled child takes 11%.

Province in 2000. Since each household has only one parent in the model, I compute the cost for one parent, which is $1.29 \times 2 = 2.58$ times her annual income. As young adults work for 20 years, the equivalent time cost is $2.58/20 = 0.129$ in this province. I use data on fines for different provinces for the 1979-2000 period from Ebenstein (2010) and weigh them with each province's employment share in 1982. This procedure gives an average fine rate of 0.1594.[23]

The child quota of the OCP is different for rural and urban couples. Although the policy is named the "One-Child Policy", exceptions could be made, and eligibility for exceptions was different across provinces (Gu et al., 2007). Following Ebenstein (2010), I group provinces into three categories, 1-child zones, 1.5-child zones, and 2-child zones. In the 1-child (or 2-child) zones, each couple was limited to having at most 1 (or 2) children. In the 1.5-child zones, rural couples were allowed to have a second child if the first was a daughter, so the quota was 1.5 for rural couples and 1 for urban couples. The child quota at the province level is weighted with employment in 1982 to get the child quota at the national level. The weighted average is 1.7794 for rural couples and 1.0374 for urban couples. Since there is only one parent in a household in the model, I divide the numbers by 2 and get $\bar{q}_a = 0.8897$ and $\bar{q}_m = 0.5187$. The 3CP allows each couple to have at most three children, so $\bar{q}_{a,m} = 3/2 = 1.5$.

Finally, the time endowment of middle-aged adults, λ, is set to 0.75, since workers retire at age 55. The parameters chosen outside the model are summarized in Table 2.

[23] If f is computed for rural and urban areas separately, it is 1.5704 in rural areas and 1.6588 in urban areas.

Table 2: Parameters Chosen outside the Model

	Description	Value	Source
β	Discount factor	0.44	Standard
R	Gross interest rate	1.51	World Bank
α	Land share in agriculture	0.235	Chow (1993), Dekle and Vandenbroucke (2012)
$A_{s,0}$	Initial TFP in manufacturing	1	Normalization
$g_{s,0}$	Initial TFP growth rate in manufacturing	0	Skilled-unskilled BGP with zero wage growth
τ_0	Fixed time cost of each child	0.0043	de Silva and Tenreyro (2020)
τ_1	Extra time cost of each surviving child	0.0757	UN (2019), Chi and Qian (2016)
τ_2	Time cost of educating each child	0.0301	Chi and Qian (2016)
f	Fines on each above-quota child	0.1594	Ebenstein (2010)
$\bar{q}_u$	OCP child quota of rural couples	1.7794/2	Ebenstein (2010)
$\bar{q}_s$	OCP child quota of urban couples	1.0374/2	Ebenstein (2010)
$\bar{q}_{u,s}$	3CP child quota	3/2	
λ	Time endowment when middle-aged	0.75	Workers retire at age 55

Note: Since there is only one parent in each household in the model, we need to divide the child quotas in the data by 2 to get the quotas in the model.

4.3 Estimation and Model Fit

We are left with the initial productivity growth rate in agriculture $g_{u,0}$ and three parameters governing household preferences: χ, c_0, and q_0. χ is the weight of children, c_0 is the non-homothetic part of consumption, and q_0 captures the effect of the LLF Campaign. Let $\Theta = \{g_{u,0}, \chi, c_0, q_0\}$ be the vector of parameters to be estimated. These parameters are calibrated to match (1) the TFR in rural and urban areas (Yao and Yin, 1994, NBSC, 1995-2021) and (2) the share of agricultural employment (NBSC, 2014, 2021) for the 1950-2020 period.[24] In the period 1941-1960, the economy is assumed to be on a skilled-unskilled BGP with zero wage growth where the mortality rates and the TFP growth rates are constant and there are no population policies. The economy starts its transition in the second period and will reach a new BGP after sufficiently many periods.[25] Overall, I have 12 data points to pin down four parameters. Denote the data moments by D and the corresponding model-generated moments by $M(\Theta)$. The parameters are chosen to minimize the distance between the model-generated moments and the data moments,

$$\hat{\Theta} = arg\min_{\Theta}[\frac{M(\Theta) - D}{D}]'[\frac{M(\Theta) - D}{D}].$$

The estimated parameters are shown in Table 3. The initial productivity growth rate in agriculture is 19.1% per model period (0.88% per year). The value of q_0 indicates that the LLF Campaign would reduce the TFR by about 0.42 since parents still enjoy q_0 children even if they do not have any children. Finally, the model implies that the TFP in agriculture before the transition $A_{u,0}$ is about 0.72. The moments from the data and

[24]The share of agricultural employment was very low in the Great Leap Forward period (1958-1960), and the TFR was very low in the Great Famine period (1959-1961). I drop the abnormal numbers in these years when I calibrate the parameters. Fig. A.4 in Appendix D shows the data without dropping these numbers.

[25]The economy reaches the new balanced growth path in about 30 model periods.

the model are shown in Fig. 7. The model replicates well the rural and urban fertility rates and the share of agricultural employment over time.

Table 3: Estimated Parameters

	Description	Value
$g_{u,0}$	Initial TFP growth rate in agriculture	1.1908
χ	Weight of utility from children	0.1407
c_0	Non-homothetic part of consumption	0.3731
q_0	Effect of the LLF Campaign	0.2127

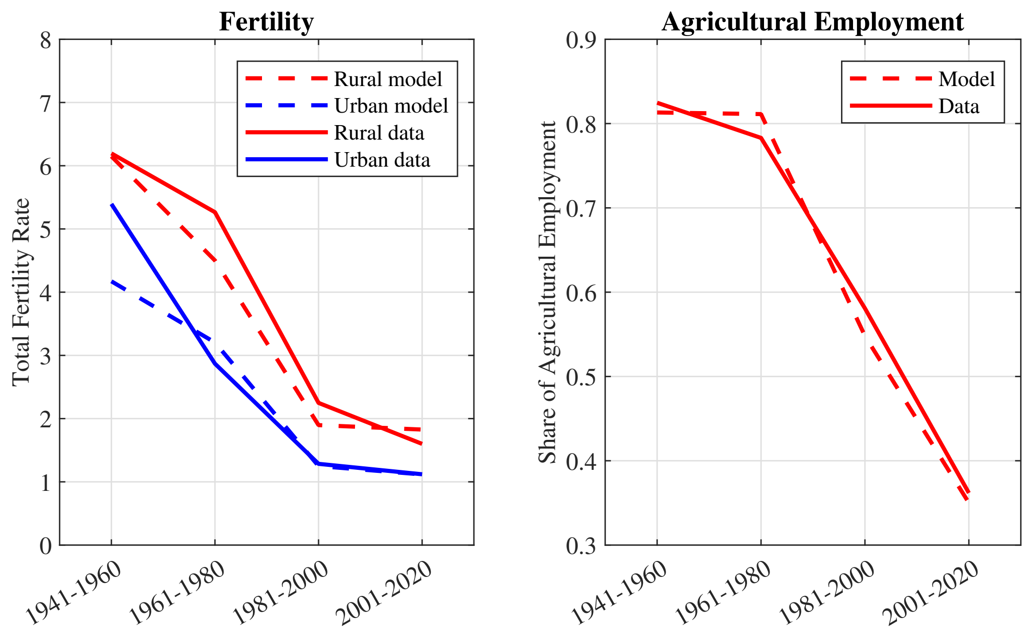
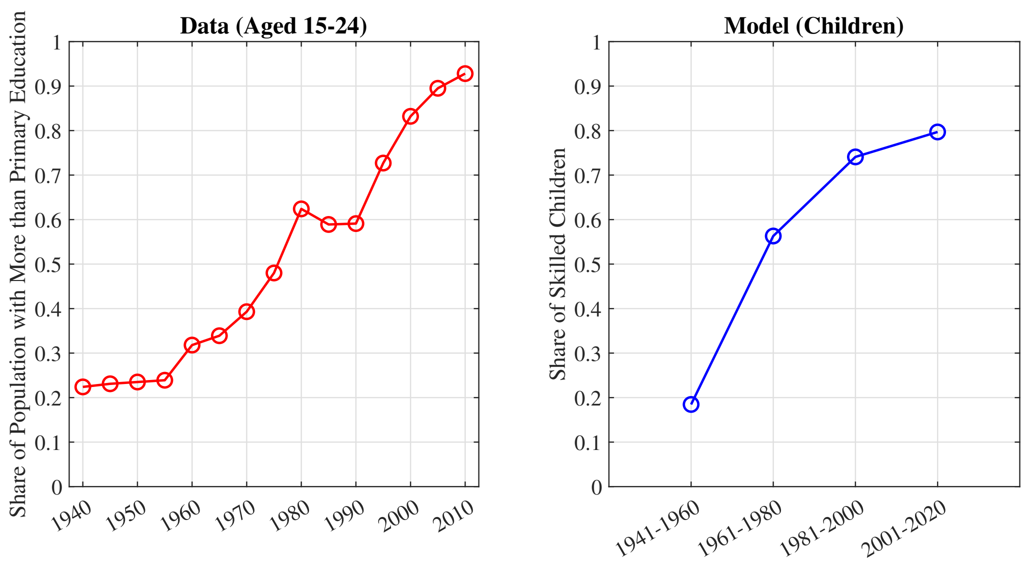


Fig. 7. Model and Data

4.4 Educational Attainment

In this subsection, I compare educational attainment between the model and data, which is not used as a target in the estimation. As I have shown in Section 4.2, agricultural workers on average have received about 6.2 years of education, which is roughly equivalent to primary education, while non-agricultural workers have received about 9.6 years of education, which is more than primary education. Therefore, one can roughly compare the enrollment rate for secondary school in the data and the share of skilled individuals in the model.

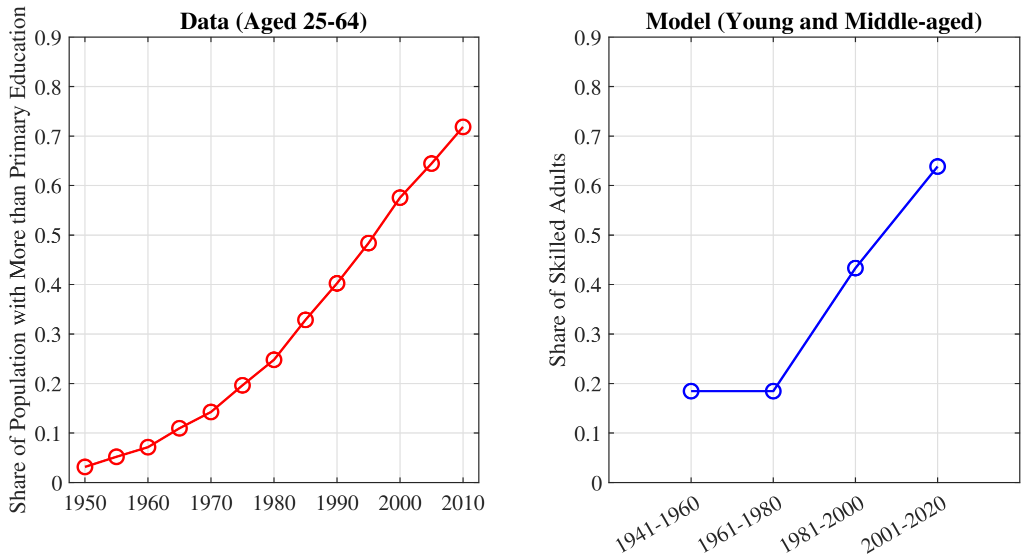
Fig. 8 shows the educational attainment of children in the data and model. The graph on the left-hand side shows the share of the population aged between 15 and 24 years with more than primary education from 1940 to 2010 in the data (Lee and Lee, 2016). It increased from 22.4% in 1940 substantially to 92.8% in 2010. The graph on the right-hand side shows the share of skilled children in the model. It is 18.5% around 1950 but increases to 80.0% around 2010.



Note: Data are from Lee and Lee (2016).

Fig. 8. Educational Attainment of Children

Fig. 9 shows the educational attainment of adults. The graph on the left-hand side shows the share of the population aged between 25 and 64 years with more than primary education from 1950 to 2010 in the data (Barro and Lee, 2013). It increased from about 4.2% in the 1950s to 71.9% in 2010. The graph on the right-hand side shows the share of skilled young and middle-aged adults in the model. It is 18.5% around 1950 but increases to 63.9% around 2010. Fig. 8 and 9 suggest that the model does a very good job of replicating the increasing trend in educational attainment in the data.



Note: Data are from Barro and Lee (2013).

Fig. 9. Educational Attainment of Adults

5 China's Demographic Transition

Now the model can be used to quantify how much the exogenous changes (mortality decline, changes in the TFP growth rates, and population policies) contributed to China's demographic transition and structural transformation. To this end, I conduct the following counterfactual experiments. First, I only allow mortality decline to play a role and check the transition path of the TFR and the share of agricultural employment. Second, I change the TFP growth rates on top of mortality decline. Next, I add the LLF Campaign. Finally, I add the OCP and the 3CP, which replicates the benchmark economy where all exogenous changes are included.[26]

The results are shown in Fig. 10. When I only allow the mortality rates to change, the TFR declines from 5.78 in 1941-1960 to 4.35 in 2001-2020. Mortality decline has a

[26]In Appendix E, I consider only one exogenous change each time and examine their effects separately.

strong effect on fertility until 2000. Afterward, the marginal effects of mortality decline become smaller. When the changes in the TFP growth rates are added, the TFR declines to a larger extent, from 5.78 in 1941-1960 to 2.65 in 2001-2020. The effect of the changes in the TFP growth rates is increasing over time and is particularly strong in 2001-2020. It accounts for 32.4% of the fertility decline in 1981-2000 and 37.9% in 2001-2020.

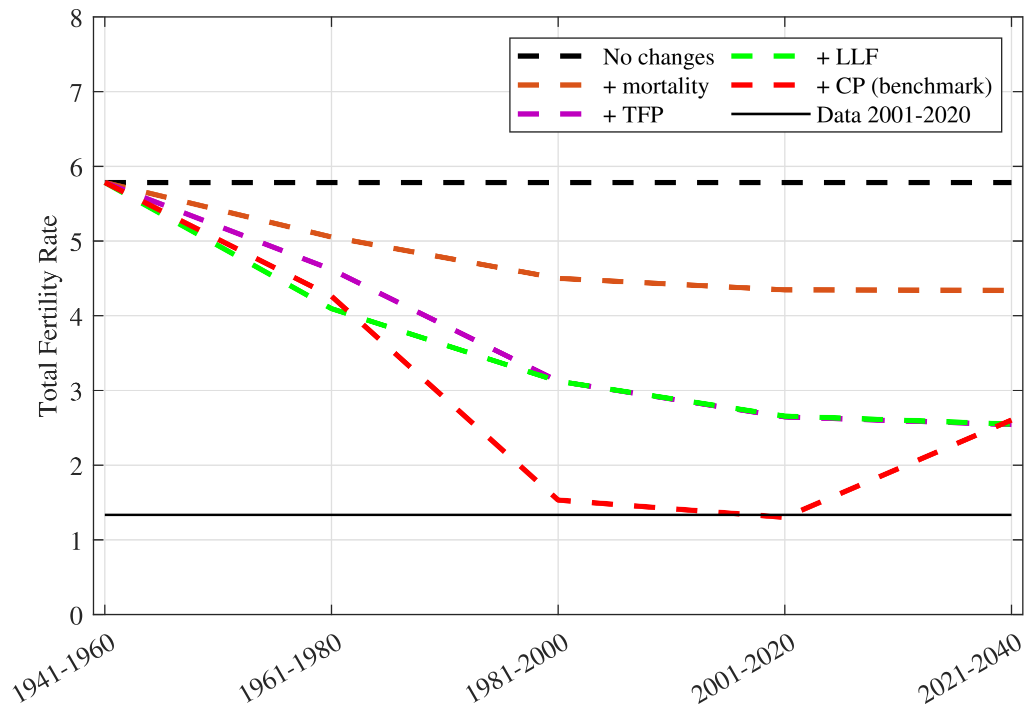


Fig. 10. TFR in the Model

What about the population policies? When the LLF Campaign is added, the TFR drops from 4.62 to 4.10 in the 1961-1980 period.[27] When the OCP is added, the TFR in 2001-2020 further drops to 1.30, which is very close to the data (1.33). The OCP has a stronger effect in 1981-2000, reducing the TFR from 3.12 to 1.53.

Finally, given the important role of the OCP, the model predicts that replacing it with

[27]The LLF Campaign was started in different years across provinces, and the average start year was 1972 if we give equal weights to each province. It was replaced with the OCP in 1979. So it was present for 7 years. In the model, we assume it is present for 20 years in the whole period 1961-1980, and we average the TFR over 20 years. Therefore, the actual effect of the LLF in the 7 years should be $0.52 \times 20/7 = 1.50$. The number is close to the estimate by Chen and Huang (2020), who suggest that the LLF reduced the TFR by 1.46 in their empirical study.

the 3CP in 2021-2040 has some positive effects on the fertility rate, increasing the TFR from 1.30 in 2001-2020 to 2.60 in 2021-2040. The quota restriction of three children per couple is not binding because of the increasingly large influence of productivity growth.[28]

Overall, the results show that there would still be a significant decline in the fertility rate even without any population policy, but the population policies were crucial for reducing the TFR to far below the replacement level and doing so in a short time. In the benchmark economy with all exogenous changes, the TFR declines from 5.78 in 1941-1960 to 1.30 in 2001-2020. The contributions from the mortality decline, the changes in the TFP growth rates, and the population policies are 32.1%, 37.9%, and 30.0%, respectively. Without the population policies, the TFR would be 2.65 instead of 1.30 in 2001-2020.

The structural transformation of the Chinese economy is shown in Fig. 11. In the benchmark, the share of agricultural employment decreases by 46.3 percentage points from 81.3% in 1940-1960 to 35.0% in 2001-2020. The main driving force is the changes in the sectoral TFP growth rates. It reduces the share of agricultural employment by 30.6 percentage points in 1981-2000 and 52.7 percentage points in 2001-2020, accounting for 115.6% and 113.8% of the total decline up to the corresponding periods, respectively.

By contrast, the effect of mortality decline on structural transformation is negligible, and the effects of the population policies are small or even negative. The LLF Campaign reduces the share of agricultural employment by 2.5 percentage points in 1981-2000, but the OCP increases it by 9.4 percentage points in 2001-2020.

[28] The prediction is qualitatively consistent with the empirical evidence that the relaxation of the OCP increased the fertility rate (Wu, 2022). However, the model may overestimate the effect. Three caveats should be noted. First, the model abstracts from some factors that have recently depressed fertility, including high housing prices (Pan and Xu, 2012). Second, the prediction of the fertility rate depends on the assumption of future productivity growth. The fertility rate in 2021-2040 will be lower if a higher rate of productivity growth in the skilled sector is assumed. Third, the model predicts that the fertility rate will decline continuously after the recovery until it reaches 2.30 on the new BGP.

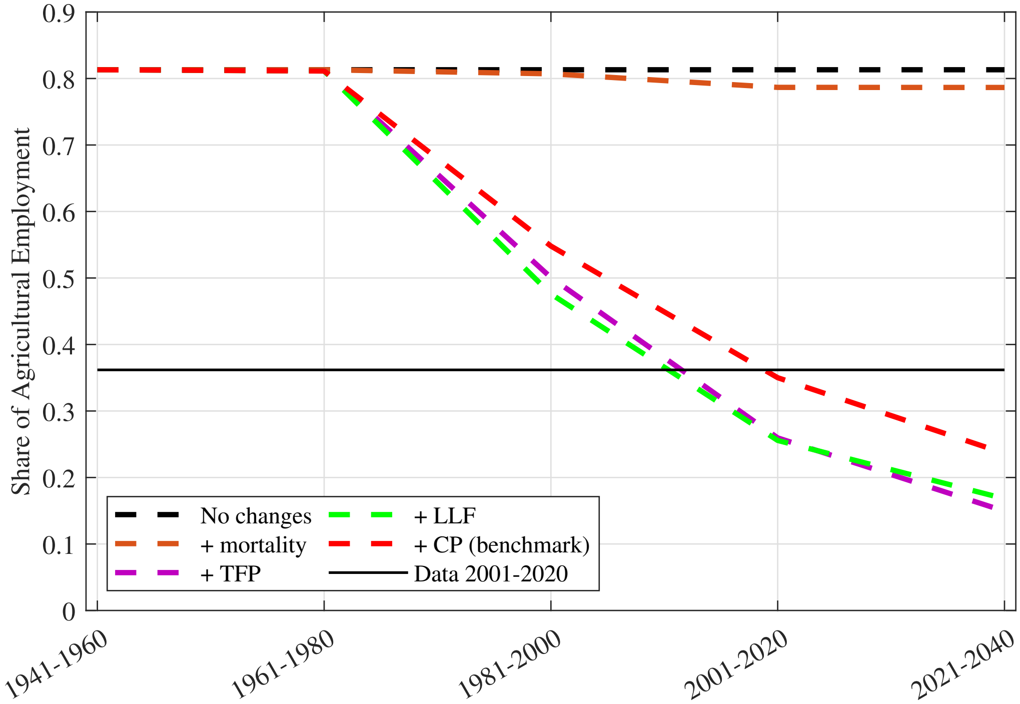


Fig. 11. Share of Agricultural Employment in the Model

In the above analysis, I assume that parents derive utility directly from the number of children and their wages in middle age. As I discussed in Section 3.2, this assumption captures both the altruistic and the old-age support motives for having children. In Appendix F, I model old-age support more explicitly by assuming that middle-aged children transfer a fraction of their income to their old parents. The basic findings presented above are robust to this extension.

6 Extension to Incorporate *Hukou*

An important feature of the Chinese economy that can affect fertility and sectoral allocation of labor is the *hukou* system. *Hukou* is the household registration system in China, which was initially used to collect vital statistics. From 1958 onward, it was also used to control migration. There were two types of *hukou*: rural/agricultural and urban/non-agricultural. People with rural *hukou* were supposed to work in agriculture, while those with urban *hukou* at non-agriculture. Children get the same *hukou* type as their parents at birth. Rural people could convert their *hukou* type to urban, subject to a quota restriction. The restriction has been relaxed since 1978, when the management of *hukou* conversion quota was gradually devolved to the local governments (Chan, 2015). Nowadays, rural people could obtain urban *hukou* more easily, or work at non-agriculture without urban *hukou*. In some provinces, rural and urban *hukou* are not distinguished any longer (Song, 2014). However, the barrier to rural-urban migration still exists since many migrant workers may still have difficulties getting urban *hukou*.

Hukou system has two features that may affect fertility and structural transformation. First, the child quota associated with the OCP is based on the *hukou* type. Non-agricultural workers with rural *hukou* were assigned a higher child quota than those with urban *hukou*. Second, local *hukou* holders are eligible for government-provided services, such as education, healthcare, and pension, which are financed through taxation on local workers. Therefore, workers who have left the countryside but have not obtained an urban *hukou* have to pay taxes but do not have access to the services.

In this section, I incorporate these two features into the model. First, I assume that only an exogenous fraction υ_t of skilled children from rural areas are entitled to an urban *hukou*. The others still hold rural *hukou*. The child quota of the OCP depends on the *hukou* type. Therefore, migrants with rural *hukou* are subject to a looser restriction. In this way, the *hukou* system will slow down the fertility transition. Notice that compared with the baseline model there is a new type of households, i.e., skilled parents with rural *hukou*.

Second, taxes and subsidies are introduced into the model. I adopt a similar strategy to Ngai et al. (2019). Workers with local *hukou* receive a lump-sum subsidy from the local government, which is financed through a lump-sum tax on local workers. The subsidy rate, or the ratio of the subsidies to the local output, is $\theta_{u,t}$ in rural areas and $\theta_{s,t}$ in urban areas. Notice that the taxes paid by agricultural workers are fully refunded to them. However, there are net transfers among manufacturing workers. Those with rural *hukou* have to pay taxes but receive no subsidies, while those with urban *hukou* receive more subsidies than paying taxes.

Since parents value children's quality in the form of their wage rate, the utility function is modified to take taxes and subsidies into account. More specifically, for parents with urban *hukou*, the utility from children's quality is $\chi log(w_{s,t+2} - T_{s,t+2} + B_{s,t+2})$, where $T_{s,t+2}$ is the lump-sum tax and $B_{s,t+2}$ is the lump-sum subsidy. For rural parents, the utility from children's quality is still $\chi log(w_{u,t+2})$ if the children are unskilled. However, if the children are skilled, the utility becomes $\nu_{t+1}\chi log(w_{s,t+2} - T_{s,t+2} + B_{s,t+2}) + (1 - \nu_{t+1})\chi log(w_{s,t+2} - T_{s,t+2})$, which reflects the fact that the children may or may not get urban *hukou*. Since the utility function is concave, this uncertainty discourages rural parents from providing their children with skills. Moreover, notice that native urban people receive more subsidies than they pay taxes, implying that migrant workers pay more taxes than they receive subsidies on average. This generates additional disincentives for rural parents to educate their children, which can slow down the structural transformation.

Before conducting any quantitative analysis, we need to know the *hukou* conversion quota, υ_t, and the subsidy rates, $\theta_{u,t}$ and $\theta_{s,t}$. Due to the complexity of the *hukou* system and lack of detailed data, an accurate estimate of υ_t is difficult to obtain. As a compromise, I make a rough but feasible estimate based on available data, for which the details are shown in Appendix G. I set υ to 1 in 1941-1960, 0.02 in 1961-1980, 0.27 in 1981-2000, and

0.50 in 2001-2020 and beyond. The subsidy rate in rural areas $\theta_{u,t}$ is set to 0 because it does not affect household decisions due to the lump-sum nature of the taxes and subsidies. For the subsidy rate in urban areas $\theta_{s,t}$, I compute the government expenditure on education, health care, pension, and other social assistance programs as a fraction of manufacturing output, following Ngai et al. (2019). The details for the data and computation are provided in Appendix H. The resulting subsidy rate is 0.024 in 1941-1980, 0.028 in 1981-2000, and 0.061 in 2001-2020 and beyond. These numbers are shown in Table 4. The estimated parameters are shown in Table 5.

Table 4: Sequence of Exogenous Changes about *Hukou*

	Description	Value	Source
		1941-, 1961-, 1981-, 2001-, 2021-, ...	
υ_t	*Hukou* conversion quota	{1, 0.02, 0.27, 0.50, 0.50, ...}	Appendix G
$\theta_{s,t}$	Urban subsidy rate	{0.024, 0.024, 0.028, 0.061, 0.061, ...}	Appendix H

Table 5: Estimated Parameters with *Hukou*

	Description	Value
$g_{u,0}$	Initial TFP growth rate in agriculture	1.1990
χ	Weight of utility from children	0.1332
c_0	Non-homothetic part of consumption	0.4691
q_0	Effect of the LLF Campaign	0.2706

Now the model can be used to quantify the impact of the *hukou* system in addition to the other factors. For this purpose, I take the *hukou* policy as a new exogenous force and add the exogenous changes one by one, i.e., mortality decline, changes in the sectoral TFP growth rates, the population policies and the *hukou* policy.

The results regarding fertility are shown in Fig. 12. The results before adding the *hukou* system are basically in line with the previous results. The new finding is that the *hukou* system increases the fertility rate. However, its effect is relatively small compared with the other factors. If the *hukou* system does not exist, the TFR would be reduced from 1.76 to 1.50 in 1981-2000 and from 1.50 to 1.27 in 2001-2020.[29]

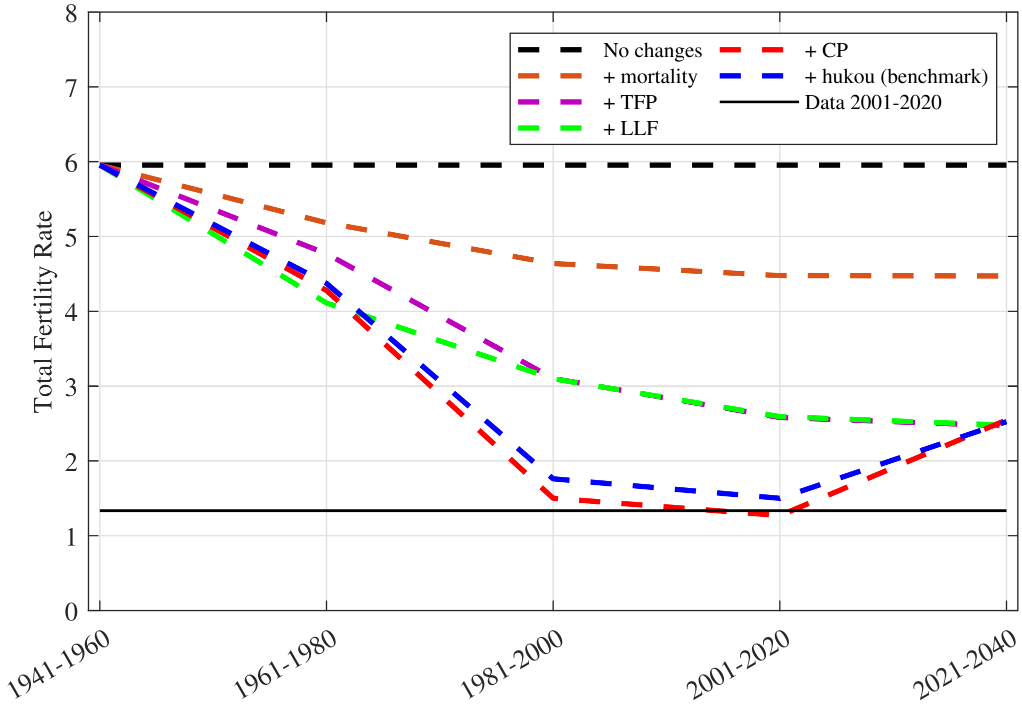


Fig. 12. TFR in the Model (with *Hukou*)

The results regarding structural transformation are shown in Fig. 13. First, the results before adding the *hukou* system remain largely unchanged. That is, productivity growth is the main driving force behind China's structural transformation. Second, the effects of the *hukou* system on structural transformation are small. The share of agricultural employment is increased by only 4.7 percentage points in 1981-2000 and 1.1 percentage points in 2001-2020. This finding is in contrast with the common wisdom that the *hukou* system seriously hinders China's structural transformation (e.g., Ngai et al., 2019). However, the results are not surprising. Although migrant workers need to pay taxes without receiving subsidies if they fail to get urban *hukou*, they can receive more subsidies than

[29]Note that since we recalibrate the model economy with the *hukou* system, the TFR is not identical to that in the benchmark economy.

paying taxes once they get it. As a result, the overall effect of the *hukou* system on the education decisions of unskilled parents can be quantitatively small. Moreover, the finding is in line with the observation that China's structural transformation was very fast despite the *hukou* system.

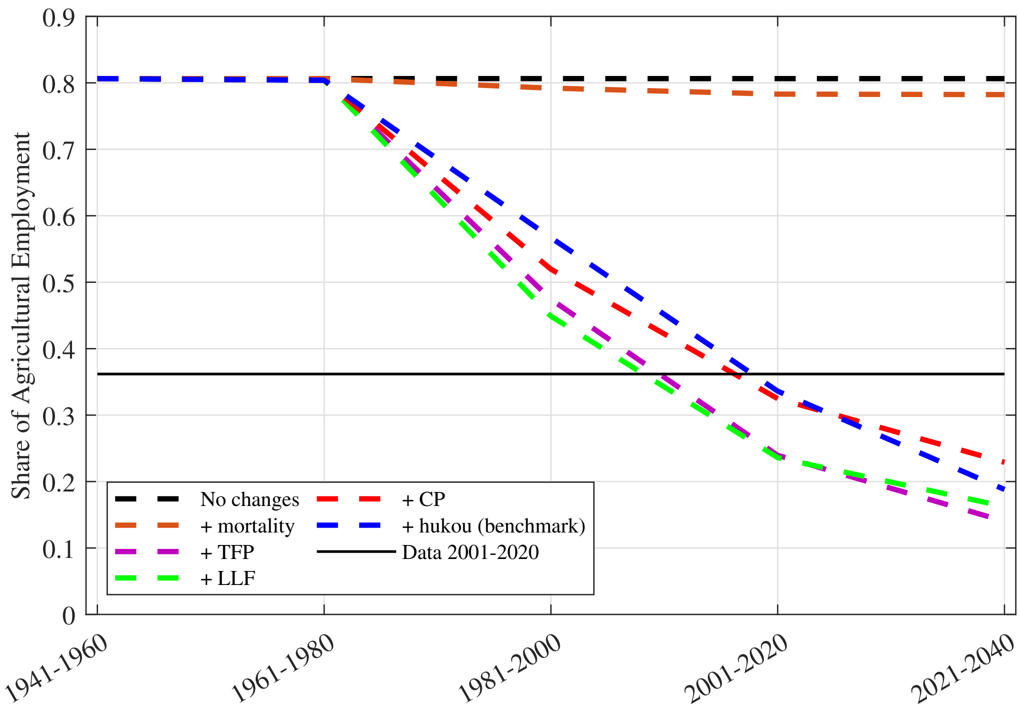


Fig. 13. Share of Agricultural Employment in the Model (with *Hukou*)

7 Conclusions

What has driven China's fast fertility decline? This study considers three most important factors, mortality decline which increases the expected cost of each newborn, changes in the productivity growth rates which lead to economic growth and structural transformation, and population control policies which either change people's preference for children or change the cost of children. To quantify the contribution of each factor to the fertility decline and also to structural transformation, this study builds a two-sector overlapping-generation model with the movement of workers from agriculture to manufacturing and endogenous fertility and education choices.

Counterfactual experiments are conducted by adding the exogenous changes one by one. The results on the fertility rate suggest that there would be a significant decline in fertility even without any population policy. In the benchmark economy with all exogenous changes, the TFR drops from 5.78 in 1941-1960 to 1.30 in 2001-2020. With only the mortality decline, the TFR would be 4.35 in 2001-2020. If we further add the TFP growth, the TFR would drop to 2.65. Hence, these two factors alone can account for 70.0% of the total decline in the number of children.

However, the population policies were crucial for reducing the TFR to far below the replacement level in a short time. The LLF Campaign has a small effect by reducing the TFR in 1961-1980 from 4.62 to 4.10. The impact of the OCP is much stronger. Adding the OCP reduces the TFR from 3.12 to 1.53 in 1981-2000 and from 2.65 to 1.30 in 2001-2020, accounting for 30.0% of the total decline.

The results on structural transformation suggest that productivity growth is the main driving force behind China's structural transformation. In the benchmark economy, the share of agricultural employment declines from 81.3% in 1941-1960 to 35.0% in 2001-2020, and all of the decline can be accounted for by productivity growth. By contrast, the effect of mortality decline on structural transformation is negligible, and the effects of the population policies are small or even negative.

The baseline model is further extended to incorporate the *hukou* system, considering that different *hukou* types are linked to different child quotas and government transfers. The extended model suggests that if the *hukou* system does not exist, the TFR would decrease slightly from 1.76 to 1.50 in 1981-2000 and from 1.50 to 1.27 in 2001-2020, and the share of agricultural employment would decrease by 4.7 percentage points in 1981-2000 and 1.1 percentage points in 2001-2020.

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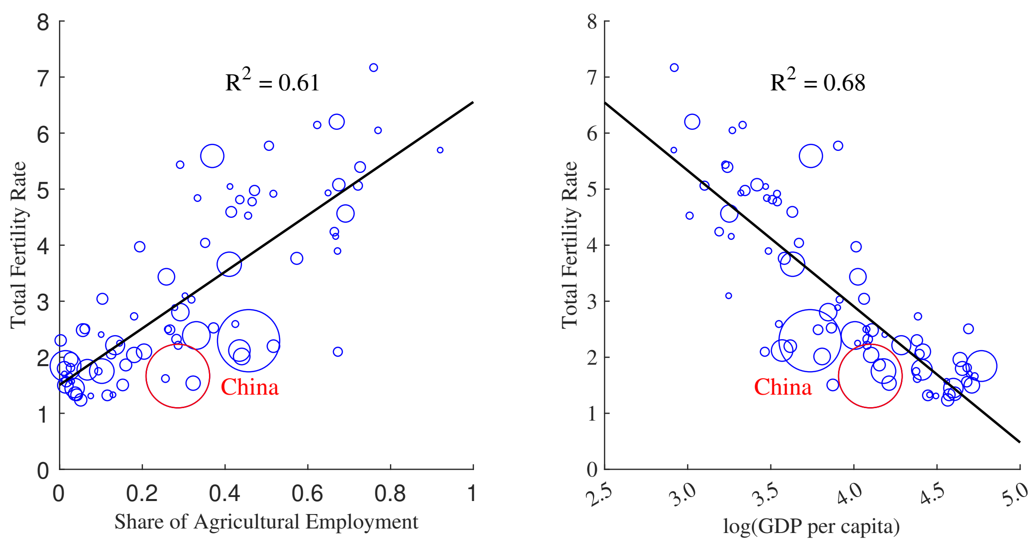
Appendices

A Some Facts in the Global Context

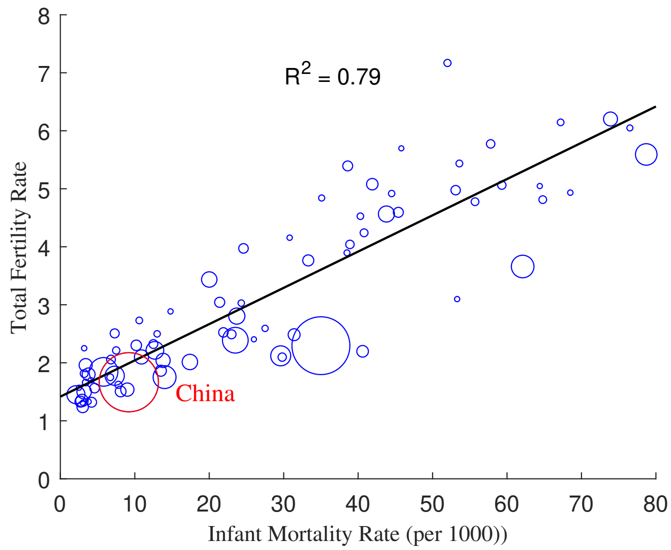
Fig. 3 in the main text shows that, for China in the period 1950-2019, there was a persistent fertility gap between rural and urban areas, and the TFR dropped over time in both areas. At the same time, China experienced fast structural transformation and economic growth, suggesting a strong correlation between economic development and fertility rate. This relationship is also supported by cross-country evidence. In Fig. A.1, I plot the TFR against the share of agricultural employment and log(GDP per capita) for a set of large countries in 2015. A striking pattern is that the TFR is significantly higher in countries where more people work in agriculture and where GDP per capita is low.



Note: Data used are cross-country data in 2015 with a population > 10 million from the World Bank. The size of the circle is proportional to the population.

Fig. A.1. Economic Development and TFR in the Global Context

The TFR and IMR are strongly correlated in China in the period 1950-2020 (Fig. 4 in the main text). This relationship is not unique to China but holds in the global context. In Fig. A.2, I plot the TFR against the IMR for a set of large countries in 2015. Obviously, for countries with high IMR, the TFR is higher as well.

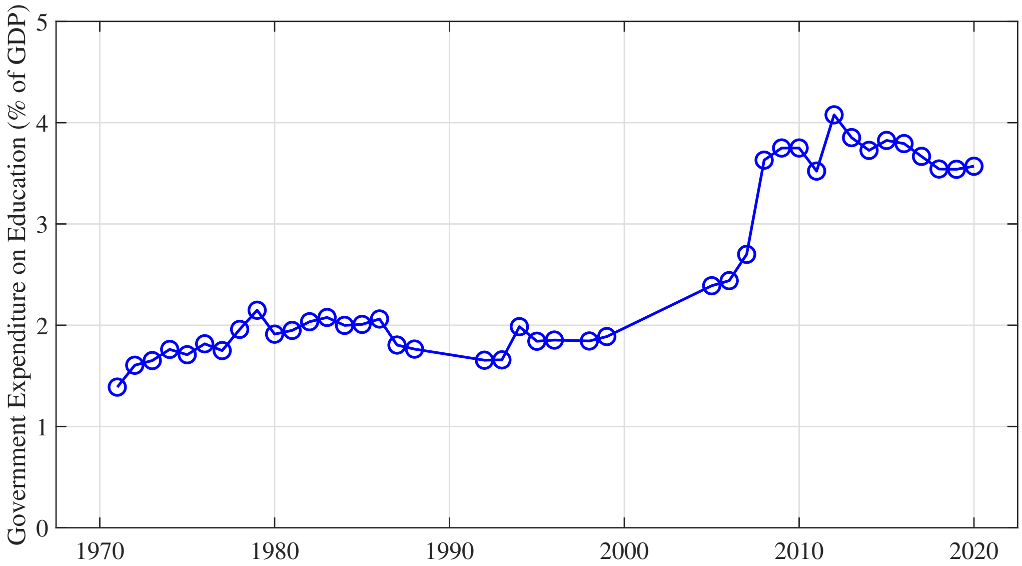


Note: Data used are cross-country data in 2015 with a population > 10 million from the World Bank. The size of the circle is proportional to the population.

Fig. A.2. Infant Mortality and Fertility in the Global Context

B Government Spending on Education

Fig. A.3 shows government spending on education as a percentage of GDP in China since the 1970s. In 1970-2000, it was quite flat, often below 2%. After 2000, it increased substantially, reaching 3.5% in 2020. This trend contrasts with that of the secondary school enrollment rate. As shown in Fig. 8, the increase in the share of the population aged 15-24 years with more than primary education occurred mainly before 2000. It started to increase around 1960, from less than 25%. By 2000, this rate had reached 83%. Although it continued to increase after 2000, the change between 2000 and 2010 (9.6%) is much smaller than the change between 1950 and 2000 (59.7%).



Note: Data are from the World Bank.

Fig. A.3. Government Spending on Education in China

C Balanced Growth Paths

This appendix characterizes the three types of balanced growth paths (BGPs). To simplify the analysis, I assume that there are no population policies. Since the survival rates are constant, their time subscripts can be dropped, so we have $\{s^c, s^y, s^m\}$. In addition, denote the TFP growth rate in the skilled and unskilled sectors by g_s and g_u, respectively.

First, note that if the wage growth rate $g_w \in \{g_{w,u}, g_{w,s}\}$ is positive, the non-homothetic term c_0 in the utility function can be ignored in the long run. Then, Equation (10) implies that the preferred number of children is

$$Q_t = \frac{\chi}{1 + \beta s^y + \beta^2 s^y s^m + \chi} \frac{1 + \lambda g_w s^y / R}{\tau_0 + s^c(\tau_1 + e_{t+1}\tau_2)}. \tag{A.1}$$

which remains unchanged over time conditional on the choice of education. In addition, it can be shown that household consumption grows at the same rate as wages.

C.1 Skilled BGP

On a skilled BGP, the fraction of unskilled households converges to 0, and wages grow at a positive rate. To have a skilled BGP, we need productivity in the skilled sector to grow at a positive rate. Below I explain how to derive the wage rates $\{w_{s,t}, w_{u,t}\}$, the population growth rate g_n, and the fraction of unskilled workers who educate their children h.

First, I explain how to derive the wage rates. Equation 3 shows that the skilled wage is equal to the productivity in the skilled sector, i.e., $w_{s,t} = A_{s,t}$. Therefore, the skilled wage grows at the same rate as the productivity growth rate in the skilled sector, i.e., $g_{w,s} = g_s$. In addition, the unskilled wage grows at the same rate, i.e., $g_{w,u} = g_s$. Suppose that the unskilled wage grows faster, then at some point the unskilled wage will exceed the skilled wage. As a result, no parents will educate their children and no workers will work in the skilled sector. This cannot be a skilled BGP. In contrast, suppose that the unskilled wage grows more slowly, then at some point the skilled wage will exceed the unskilled wage. As a result, all parents will educate their children and no workers will work in the unskilled sector.[30] This is impossible because it will drive the unskilled wage to infinity. In summary, we have the following equation for the wage growth rate,

$$g_{w,u} = g_{w,s} = g_s. \tag{A.2}$$

Given the growth rate of wages, we can obtain the number of children in each type of household from Equation (A.1). It can be shown that $Q_{ss} = Q_{us} < Q_{uu}$.

On a skilled BGP, the fraction of unskilled parents who educate their children is on

[30] To simplify the analysis, I now assume that skilled parents can choose whether or not to educate their children.

the interval $(0,1)$, i.e., $h \in (0,1)$. Suppose $h = 1$, then there will be no workers in the unskilled sector in subsequent periods, driving the unskilled wage to infinity. In contrast, suppose that $h = 0$. Since $Q_{ss} < Q_{uu}$, the share of workers in the unskilled sector will increase over time. This cannot be a skilled BGP. Therefore, h must be on the interval $(0,1)$. This in turn implies that unskilled parents are indifferent between educating their children and not educating them. I now show how this condition can determine the level of the unskilled wage. In solving household problems, one can find that type-uu and type-us households make the same decisions on consumption but different decisions on fertility and education. Indeed, from Equation (A.1), we have

$$Q_{uu} = \frac{\tau_0 + s_c(\tau_1 + \tau_2)}{\tau_0 + s_c \tau_1} Q_{us}. \tag{A.3}$$

Since unskilled parents are indifferent between educating their children and not educating them, from their utility function we can get

$$w_{u,t} = \frac{\tau_0 + s_c \tau_1}{\tau_0 + s_c(\tau_1 + \tau_2)} w_{s,t}. \tag{A.4}$$

This equation suggests that the unskilled wage is a constant proportion of the skilled wage. The proportion is equal to the ratio of the expected cost of a newborn who will not receive an education if she survives to the expected cost of a newborn who will receive an education if she survives. Now we have derived wages and their growth rate.

Next, since u is as close to 0 as possible, the population growth rate,

$$g_n = Q_{ss} s_c, \tag{A.5}$$

where Q_{ss} is given by Equation (A.1).

Finally, we can derive the fraction of unskilled parents who educate their children, h.

Since a fraction $1-h$ of unskilled parents do not educate their children, the growth rate of the unskilled labor force is $(1-h)Q_{uu}s_c$. Equation (7) implies that the growth rate of the unskilled wage is

$$g_{w,u} = g_u[(1-h)Q_{uu}s_c]^{-\alpha}. \tag{A.6}$$

Plugging it into Equation (A.2), we have

$$g_u[(1-h)Q_{uu}s_c]^{-\alpha} = g_s. \tag{A.7}$$

This equation states that labor productivity should grow at the same rate in both sectors. From this we can derive the value of h.

C.2 Unskilled BGP

On an unskilled BGP, the fraction of unskilled households is 1, and the unskilled wage grows at a constant non-negative rate. To have such a BGP, we need productivity in the unskilled sector to grow at a non-negative rate, and labor productivity in the unskilled sector to grow faster than in the skilled sector. In the following, I focus on an unskilled BGP where g_u is sufficiently large that the growth rate of the unskilled wage $g_{w,u}$ is positive. Now I explain how to derive $g_{w,u}$ and the population growth rate g_n.

Since only the unskilled sector is active, there are only type-uu households. Given $g_{w,u}$ (which is to be solved), we can get the fertility rate of these households from Equation (A.1),

$$Q_{uu} = \frac{\chi}{1+\beta s^y + \beta^2 s^y s^m + \chi} \frac{1+\lambda g_{w,u} s^y/R}{\tau_0 + s^c \tau_1}. \tag{A.8}$$

Therefore, the population growth rate is

$$g_n = Q_{uu}s_c. \tag{A.9}$$

Since all workers are in the unskilled sector, g_n is also the growth rate of the unskilled labor force. As a result, Equation (7) implies that the growth rate of the unskilled wage is

$$g_{w,u} = g_u g_n^{-\alpha}. \tag{A.10}$$

Clearly, (A.8)-(A.10) are three equations with three unknowns, $g_{w,u}$, Q_{uu}, and g_n.

C.3 Skilled-unskilled BGP

On a skilled-unskilled BGP, the fraction of unskilled households is a constant on the interval $(0, 1)$, and wages grow at a constant non-negative rate. To have such a BGP, we need productivity in the skilled sector to grow at a non-negative rate. Now I explain how to derive the wage rates $\{w_{s,t}, w_{u,t}\}$, the population growth rate g_n, the fraction of unskilled households u, and the fraction of unskilled households that educate their children h.

First, as in the case of a skilled BGP, we can show that the skilled wage is equal to the productivity in the skilled sector (i.e., $w_{s,t} = A_{s,t}$), and that wages grow at the productivity growth rate in the skilled sector (i.e., $g_{w,u} = g_{w,s} = g_s$). Therefore, $g_s > 1$ implies a positive growth rate of wages, and $g_s = 1$ implies constant wages.

If $g_s > 1$, we can get the number of children for each household type from Equation (A.1) and show that $Q_{ss} = Q_{us} < Q_{uu}$. If $g_s = 1$, we can compute the number of children of type-ss parents, but not of type-uu or type-us parents, since we do not yet know the unskilled wage. However, since the unskilled wage is lower than the skilled wage, Equation (10) suggests that $Q_{ss} < Q_{us} < Q_{uu}$.

Given $Q_{ss} < Q_{uu}$, we can show that the fraction of unskilled parents who educate their children is on the interval $(0,1)$, using a similar argument as in the case of a skilled BGP. This implies that unskilled parents are indifferent between educating their children or not. With this condition, we can show that the unskilled wage is given by Equation (A.4). Now we have derived the wages and their growth rate. Then, we can compute Q_{uu} and Q_{us} even in the case of $g_s = 1$.

Next, I explain how to derive the population growth rate, g_n. Since u is constant, the unskilled labor force grows at the same rate as the population. Equation (7) implies that the growth rate of the unskilled wage is

$$g_{w,u} = g_u g_n^{-\alpha}. \tag{A.11}$$

Plugging it into Equation (A.2), we have

$$g_u g_n^{-\alpha} = g_s. \tag{A.12}$$

This is an equation with one unknown. From this we can derive g_n.

Dropping the time subscript in Equation (13), we have the population growth rate,

$$g_n = [u(1-h)Q_{uu} + uhQ_{us} + (1-u)Q_{ss}]s^c. \tag{A.13}$$

This is an equation connecting u and h.

Dropping the time subscript in Equation (16), we have the share of unskilled households,

$$u = u(1-h)Q_{uu}/[u(1-h)Q_{uu} + uhQ_{us} + (1-u)Q_{ss}]. \tag{A.14}$$

This is another equation connecting u and h. From the two equations (A.13)-(A.14), we can get the values of u and h.

D Model Fit without Dropping Abnormal Values in the Data

The share of agricultural employment was very low in the Great Leap Forward period (1958-1960), and the TFR was very low in the Great Famine period (1959-1961). When I calibrate the parameters, the abnormal numbers in these years are dropped. Fig. A.4 shows the model fit if these abnormal numbers are included. In this figure, the TFR and share of agricultural employment from the model are the same as in Fig. 7. However, the moments from the data are different. The TFR in both rural and urban areas are lower in 1941-1960. The share of agricultural employment is also lower in 1941-1960.

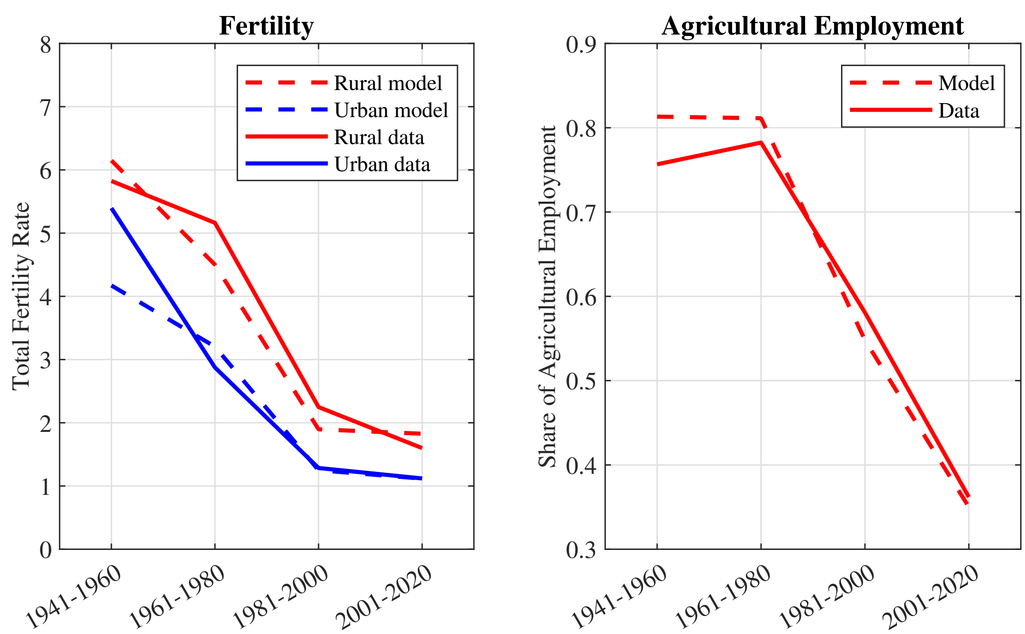


Fig. A.4. Model and Data (without Dropping Abnormal Values)

E Alternative Counterfactual Experiments

In the main analysis, the exogenous changes are added one after another: first, mortality decline; next, changes in the TFP growth rates; and finally, the population policies. The rationale for this order is that the mortality decline happened before the fast TFP growth in the data and the population policies were imposed additionally by the government. An alternative analysis is to consider only one change each time and examine their effects separately. The results are shown in Fig. A.5 and A.6.

Fig. A.5 shows that mortality decline and TFP growth have large effects on the TFR. Mortality decline can reduce the TFR from 5.78 in 1941-1960 to 4.35 in 2001-2020 (the same as in Fig. 10), and TFP growth can reduce the TFR to 3.50. The LLF Campaign can reduce the TFR in 1961-1980 by 0.64. The magnitudes of the effects of these factors are in line with the findings in Fig. 10. One different finding is that the effects of the OCP are even larger. If there are only the OCP and the 3CP, the TFR can drop to 1.92 in 1981-2000 and 1.95 in 2001-2020. However, this is not surprising considering the harsh punishment in case of violation.

Fig. A.6 shows that changes in the sectoral TFP growth rates have very large effects on structural transformation. It can reduce the share of agricultural employment substantially from 81.3% in 1941-1960 to 27.0% in 2001-2020. However, the OCP also has large effects. If there are only the OCP and the 3CP, the share of agricultural employment would decline to 18.8% in 2001-2020.[31] By contrast, the effects of mortality decline and the LLF Campaign are very small. Overall, the findings support that changes in the sectoral TFP growth rates have important effects on China's structural transformation.

[31] It is noteworthy that this is only a short-run effect on the transition path. The reduced labor force in agriculture as a result of the OCP will lead to an increase in unskilled wages and impede rural-urban migration in the following periods.

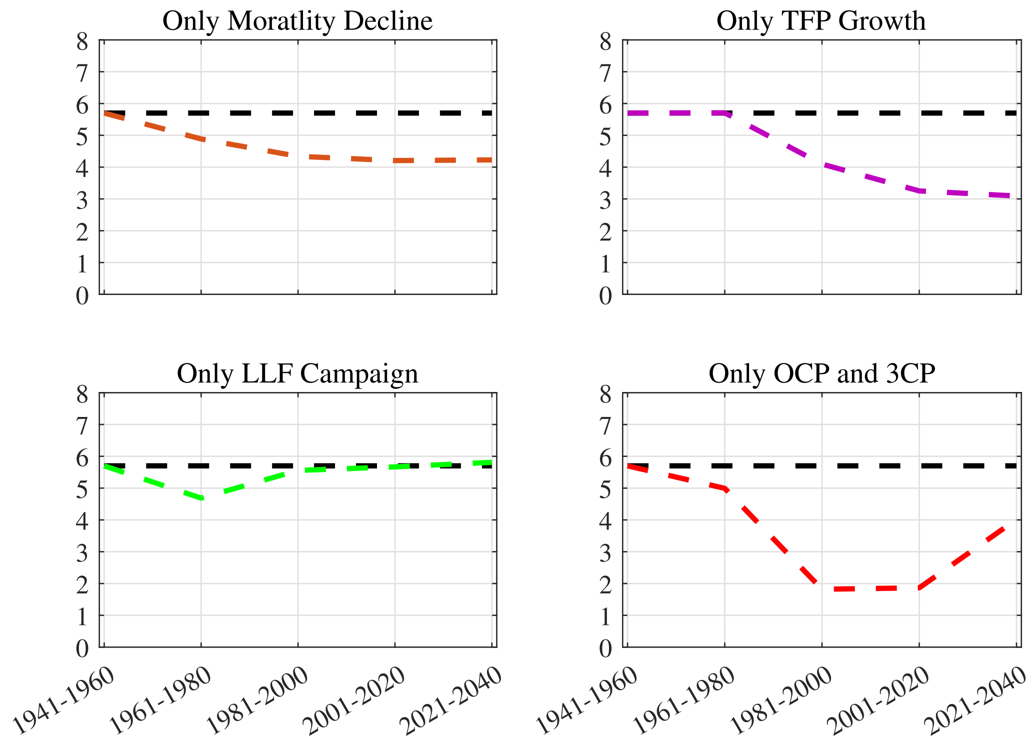


Fig. A.5. TFR in the Model

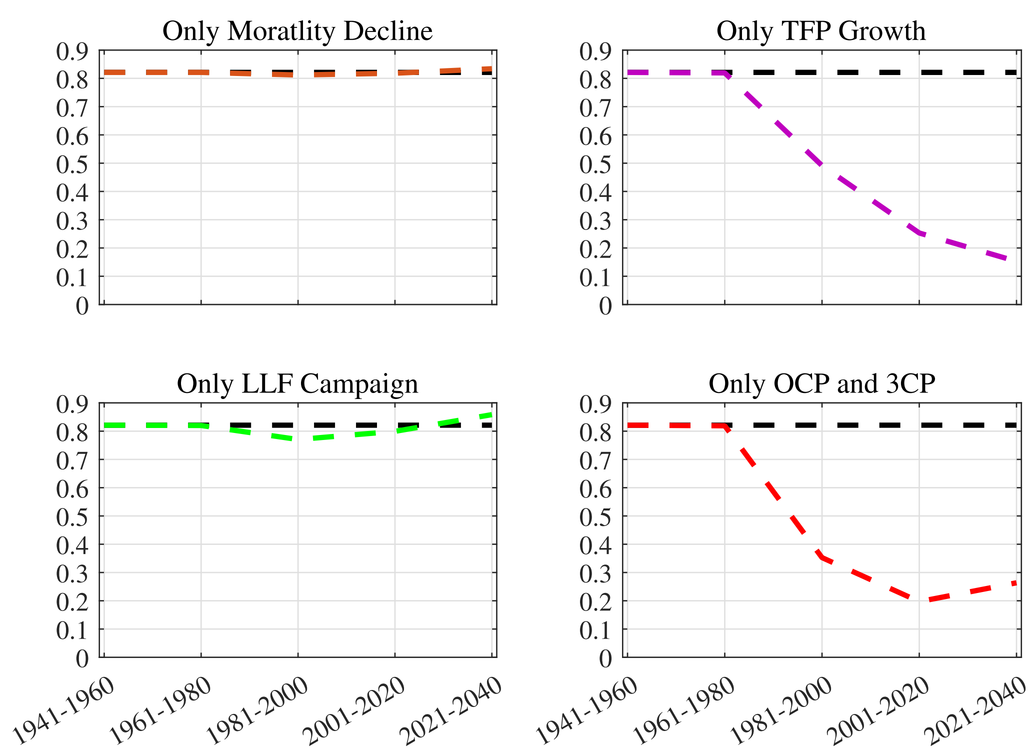


Fig. A.6. Share of Agricultural Employment in the Model

F Role of Old-age Support

In the baseline model for the main analysis, I assume that parents derive utility directly from the number of children and their wages in middle age. This specification captures two motives for having children. First, parents are altruistic and care about their children's welfare, which depends on their children's wages. Second, parents may receive old-age support from their children, which is related to the children's wages in middle age. Alternatively, the old-age support motive can be modeled more explicitly. To this end, I assume that each middle-aged child needs to transfer an exogenous fraction ζ of her income to her parent.[32] In this way, parents care about their children's total earnings in middle age because they can directly affect parental consumption in old age. Meanwhile, parents also care about their children's income for the altruistic motive, as specified in the baseline model.

The expected lifetime utility function for a young adult remains the same, i.e.,

$$\begin{aligned} &V(c_t^y, c_{t+1}^m, c_{t+2}^o, Q_t, e_{t+1}) \\ &\quad = log(c_t^y + c_0) + \beta s_t^y log(c_{t+1}^m + c_0) + \beta^2 s_t^y s_{t+1}^m log(c_{t+2}^o + c_0) \\ &\qquad + \chi log(Q_t s_t^c) + \chi log[e_{t+1} w_{s,t+2} + (1 - e_{t+1}) w_{u,t+2}]. \end{aligned} \tag{A.15}$$

where $\chi log(Q_t s_t^c) + \chi log[e_{t+1} w_{s,t+2} + (1 - e_{t+1}) w_{u,t+2}]$ captures only the altruistic motive for having children now.

[32] Middle-aged parents may not survive to the next period and therefore cannot receive the transfer. I assume that transfers to deceased parents are distributed to other surviving parents. This assumption is analogous to the assumption of an actuarially fair interest rate.

The period budget constraints become

$$
\begin{aligned}
c_t^y + Q_t[\tau_0 + s_t^c(\tau_1 + e_{t+1}\tau_2)]w_t + i_t^y &\le w_t, \\
c_{t+1}^m + i_{t+1}^m &\le \lambda w_{t+1}(1-\zeta) + i_t^y R/s_t^y, \qquad \text{(A.16)} \\
c_{t+2}^o \le i_{t+1}^m R/s_{t+1}^m + Q_t s_t^c s_{t+1}^y \lambda[e_{t+1}w_{s,t+2} &+ (1-e_{t+1})w_{u,t+2}]\zeta/s_{t+1}^m.
\end{aligned}
$$

In the analysis, the fraction of income transferred to parents ζ is set to 4%, following Curtis et al. (2015). Next, the parameters are estimated, which are shown in Table A.1. In the model with old-age support, c_0 becomes smaller while q_0 becomes larger. To understand the changes, suppose that the parameters have the same values as in the baseline model. Due to the old-age support motive, parents in the model now want more children, which does not fit the data well. In addition, since the supply of land in agriculture is fixed, a larger share of labor would be allocated to the manufacturing sector, which also does not fit the data. To have a lower fertility rate in the model, we need c_0 to be smaller, which increases the marginal utility of consumption and thus the opportunity cost of raising children. In addition, a smaller c_0 leads to a smaller decline in the fertility rate in 1961-1980. To match the fertility change in the data, q_0 becomes larger.

Table A.1: Estimated Parameters

	Description	Baseline	Old-age support
$g_{u,0}$	Initial TFP growth rate in agriculture	1.1908	1.1816
χ	Weight of utility from children	0.1407	0.1402
c_0	Non-homothetic part of consumption	0.3731	0.2416
q_0	Effect of the LLF Campaign	0.2127	0.4819

Finally, the counterfactual analysis is repeated. The results are shown in Fig. A.7 and Fig. A.8, which are basically in line with the results in the main analysis. One small difference is that the changes in the productivity growth rates now play a slightly smaller role in the fertility decline than in the main analysis, while the population policies have a larger effect. In the benchmark economy with all exogenous changes, the TFR drops from 5.60 in 1941-1960 to 1.33 in 2001-2020. With only the decline in mortality, the TFR would be 4.28 in 2001-2020. If we further add the changes in productivity growth rates, the TFR would drop to 2.95. The LLF Campaign reduces the TFR in 1961-1980 from 5.26 to 4.25, and the OCP reduces it from 3.40 to 1.52 in 1981-2000 and from 2.97 to 1.33 in 2001-2020. The reason for the smaller effect of TFP growth is that income growth in the future increases the value of children and motivates parents to have more children.

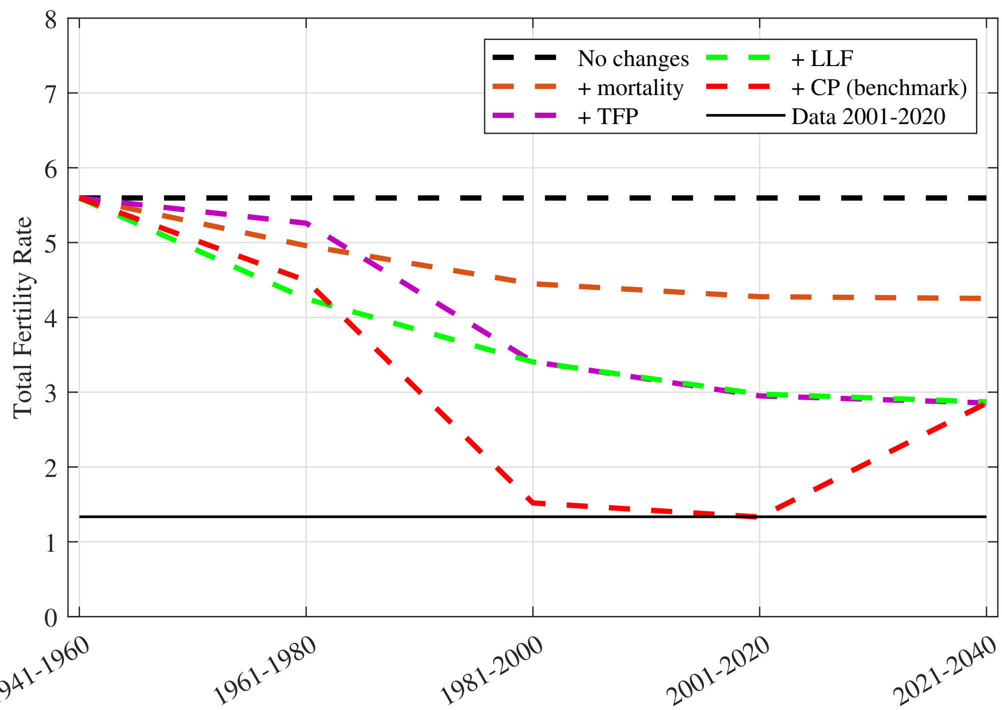


Fig. A.7. TFR in the Model (with Old-age Support)

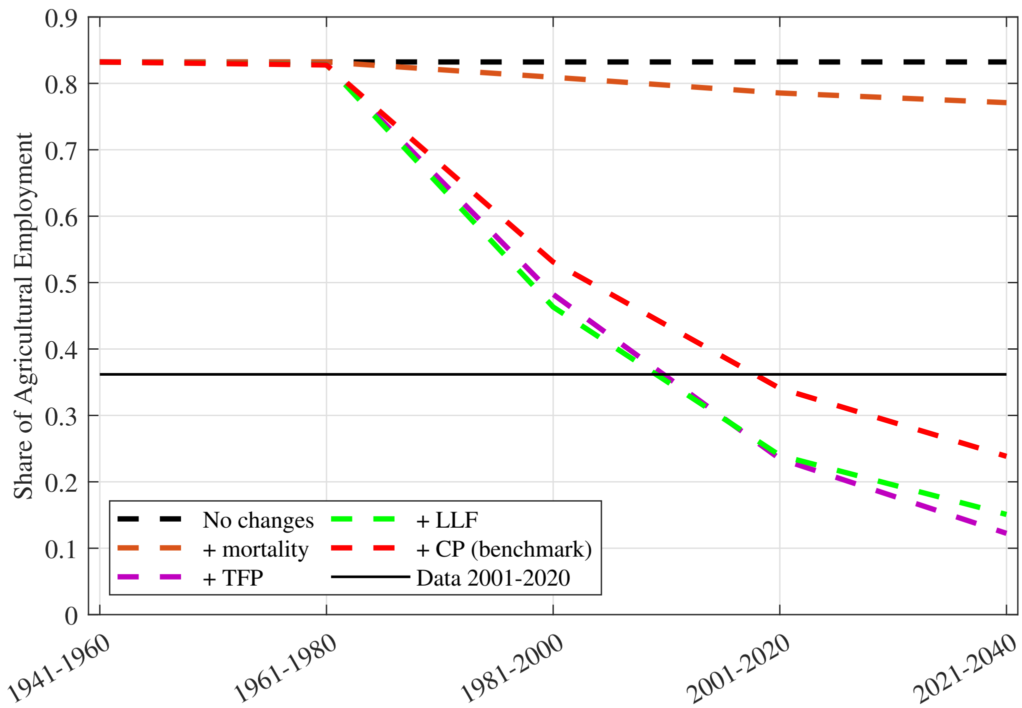


Fig. A.8. Share of Agricultural Employment in the Model (with Old-age Support)

G Estimation of *Hukou* Conversion Quota

Due to the complexity of *hukou* system and lack of data, accurate estimation of the conversion quota is hard to make. As a compromise, I make a rough but feasible estimate based on available data. First, for each model period, I predict the urban population size given the size in the previous period, assuming that it grows at the national growth rate and that there is no *hukou* conversion. This number, by construction, is smaller than the actual urban population size, since there are *hukou* conversions in reality. The difference between the predicted and actual numbers can be taken as the number of conversions. Denote it by N_c. Next, I estimate the urban population with rural *hukou*, assuming that the share of the urban population is equal to the share of non-agricultural employment. These people are just those who failed to convert their *hukou* type. Denote this population size by N_f. Therefore, for every $N_c + N_f$ urban people from rural areas, N_c people can obtain *hukou*. Hence, the conversion quota can be computed as $\upsilon = N_c/(N_c + N_f)$. In the data, υ is 1 before 1958, 0.02 in 1963-1980, 0.27 in 1981-2000, and 0.23 in 2001-2014. Following a reform in 2014, *hukou* conversion is increasingly easy, but no *hukou* registration data are provided any longer. In the model, I set υ to 1 in 1941-1960, 0.02 in 1961-1980, 0.27 in 1981-2000, and 0.50 in 2001-2020 and beyond.

For this estimation, the data on the population with rural and urban *hukou* are from *China Population Statistical Yearbook* (NBSC, 1995-2021) for the years 1955-2014 and *China Statistical Yearbook* (NBSC, 2016-2019) for the years 2015-2018. The data on employment in agriculture and non-agriculture are from *New China 65 Years* (NBSC, 2014) and *China Statistical Yearbook* 2021 (NBSC, 2021).

H Estimation of the Subsidy Rate

Following Ngai et al. (2019), the subsidy rate is computed as government expenditure as the fraction of the non-agricultural output. The social services related to *hukou* include education, healthcare, pensions, and other social assistance programs. I compute the ratio of government expenditure to non-agricultural GDP for each item and aggregate the ratios together. The details for each item are shown below.

The data on government expenditure on education are from *China Educational Finance Statistical Yearbook* (Ministry of Education of China and National Bureau of Statistics of China, 2016-2019), which provides such information for various education levels in 1995-2018. I only consider the spending on nine years of compulsory education, for which separate data are available for rural areas and I can derive the data for urban areas. For each year in 1995-2018, I compute the ratio of government expenditure on education in urban areas to the non-agricultural GDP. Since such information is not available before 1995 and the ratio is quite flat in 1995-2000, I extend the ratio in 1995 to the previous years and average the numbers to each model period.

The data on expenditure on health are from *China Health Statistical Yearbook* (Ministry of Health of China, 2019). The yearbook provides information on the total government spending on health in 1990-2016. However, no separate data are available for rural and urban areas. Instead, total health spending can be observed for the two areas, which includes altogether the spending from the government, social entities, and individuals. I, therefore, assume that the distribution of rural and urban spending is the same in total health spending and government health spending, following Ngai et al. (2019). Afterward, I compute the ratio of government expenditure on health in urban areas to the non-agricultural GDP. Since the number can only be computed for the years 1990-2016 and there is no clearly increasing, decreasing, or flat trend, I average the ratio over the years and use the same number for each model period.

The data on government expenditure on pensions and other social assistance programs (unemployment insurance, work injury insurance, medical insurance, and maternity insurance) are from *Finance Yearbook of China* (Ministry of Finance of China, 2019), which provide such information in 1990, 1995, 2000-2018. For the years with available information, I compute the ratio of total government spending to the non-agricultural GDP. Next, I interpolate the numbers for the skipped years and extend the number in 1990 to the previous years. Finally, I average the ratio to each model period.