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# China's Demographic Transition: A Quantitative Analysis

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**Abstract**

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 6.40 children around 1950 to 2.85 children around 2010. However, the population policies were critical for 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 2.85 to 1.34 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 minor.

JEL Codes: D1, J13, O41.

Keywords: Demographic transition, structural transformation, population policies, productivity growth, mortality, China.

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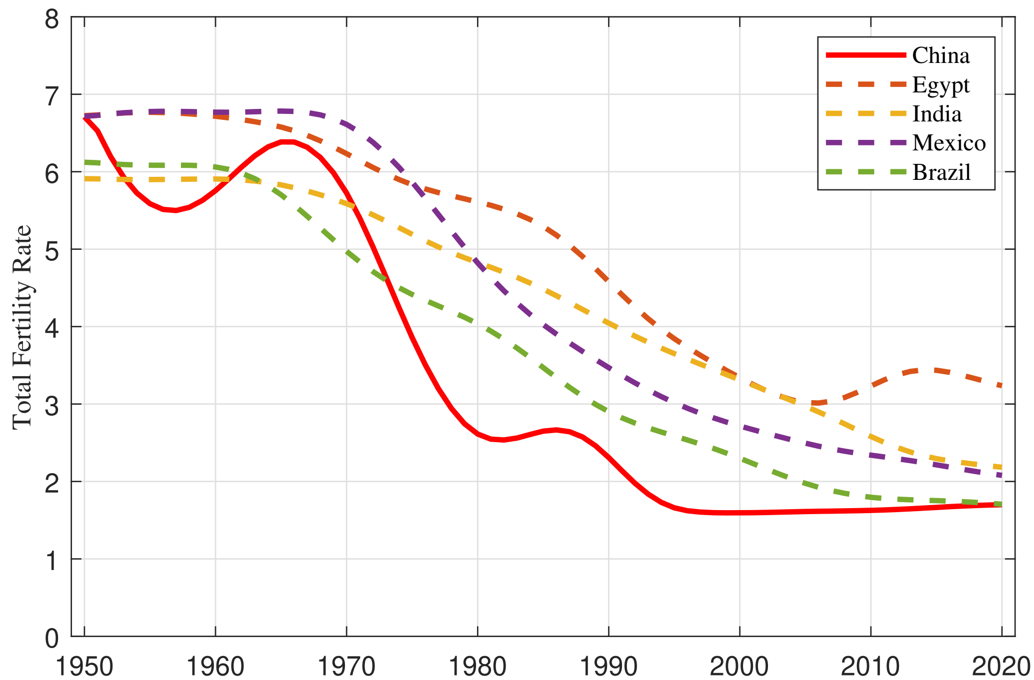
# 1 Introduction

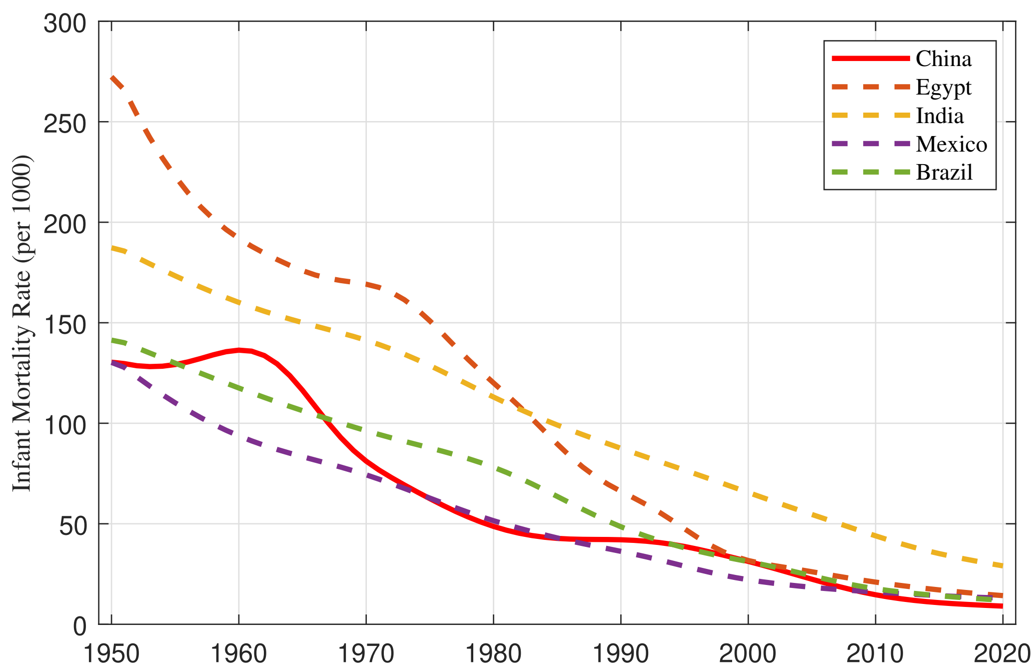
China's demographic transition was very fast. The total fertility rate (TFR) declined from about 6 in the 1950s to about 1.5 in the late 1990s. The decline was much faster than other middle-income countries. Fig. 1 shows the TFR for several middle-income countries since 1950. While it took about 50 years for TFR to drop from above 6 to the replacement level (2.1) in the other countries, Chinese 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 in 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 further 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 by speeding up the movement of people out of agriculture? To answer these questions, I build a two-sector overlapping-generation model with endogenous fertility and education choices. The fundamental driving forces behind fertility decline are mortality decline, productivity growth, and population policies. In the model, there are two sectors, agriculture (rural) and non-agriculture (urban, manufacturing). Agricultural goods are produced with capital and unskilled labor, while non-agricultural goods are produced with capital and skilled labor. Individuals derive utility from consumption of both goods with non-homothetic preferences. Finally, individuals care about the quantity and quality of their children. Raising children implies a time cost of parents, and providing them with skills requires an additional time cost. If children are endowed with skills, they can work in non-agriculture and earn a higher wage. Otherwise, they work in agriculture as unskilled workers.

In the model, total factor productivity (TFP) growth affects fertility and structural transformation through three channels. First, TFP growth increases wages. Since people's preferences are non-homothetic, as the economy gets richer, people consume relatively more non-agricultural goods. As a result, more skilled labor is demanded, which raises skill premium and encourages parents to have fewer but better-educated children. Second, if TFP does not grow at the same rate in the two sectors and if the two goods are complements in the utility function, increased production in the sector with faster productivity growth will lead to a more than proportional decline in its relative price, inducing a reallocation of labor away from this sector. Third, since non-agricultural goods are luxury, households with increasing income tend to substitute children for non-agricultural consumption, leading to a lower fertility rate and less agricultural labor.

Finally, the 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. When people raise fewer children, they educate them more. As a result, more skilled workers will be supplied in the non-agricultural sector. This effect does not depend on the type of the population policies, and operates whether the reduction in the number of children is voluntary (in the case of the LLF Campaign) or involuntary (in the case of the OCP).

The model is calibrated to the time path of the Chinese economy since 1950. The exogenous driving forces in the model are decline in the mortality rates, productivity growth in the two sectors and the population policies. The model is then contrasted with the data on TFR in rural and urban areas and the share of agricultural employment. The model does a good job replicating the changes in the data. To quantify the effects of each factor on 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 TFP growth in addition to mortality decline. Finally, I add the LLF Campaign and the OCP (and its descendent, current Three-Child Policy) one after the other.

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 6.40 around 1950 to 1.34 around 2010. With only the decline in mortality, the TFR would be 4.27 in 2010. If we also add the TFP growth, the TFR is 2.85 around 2010. Hence, these two forces alone can account for 70% of the decline in the number of children.

However, the population policies are critical for reducing the TFR to far below the replacement level and doing so in a short window. The effect of the LLF campaign is small. Adding the LLF campaign to the decline in mortality and the TFP growth reduces the TFR from 4.83 to 3.77 around 1970. The impact of the OCP is much more significant. Adding the OCP to mortality decline and TFP growth reduces the TFR from 3.81 to 1.65 around 1990 and from 2.77 to 1.34 around 2010. This is 30.0% of the total decline in the TFR.

Given the important role of the OCP, the model predicts that the TFR will rebound to 2.17 after it is replaced with the 3CP after 2020. The quota restriction of three children per couple will not be binding because of the increasingly large influence of productivity growth.

The results also reveal that productivity growth is the main driving force behind China's structural transformation. In the benchmark economy, the share of agricultural employment declines from 74.9% around 1950 to 39.0% around 2010. The bulk (86.3%) of the decline can be accounted for by productivity growth. Mortality decline and the population policies also play some roles in the structural transformation, but their effects are very small. Mortality decline reduces the share of agricultural employment by 3.5 percentage points during this period, and the OCP leads to another decline of 1.8 percentage points. In addition, the LLF Campaign reduces the share of agricultural employment around 1990 by 1.6 percentage points.

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 around 1990 from 1.79 to 1.64 and the TFR around 2010 from 1.53 to 1.34. However, the *hukou* system only has a negligible effect on structural transformation by increasing the share of agricultural employment by about 0.4 percentage points around 1990 and 0.1 percentage points around 2010.

This study contributes to the literature on fertility and development. Many studies investigate the joint evolution of economic development and demographic changes, emphasizing the role of technological progress and movement of people from agriculture (rural) to manufacturing (urban) (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 (Kalemli-Ozcan, 2002, 2003; Bar and Leukhina, 2010) and education policies (Doepke, 2004). Some recent studies examine how family planning policies affect 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) analyze how population control policies aimed at altering family-size norms could accelerate the fertility decline in developing countries. Cavalcanti et al. (2021) investigate how family planning interventions affect living standards by reducing unwanted fertility. My study is very related to but different 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 changing people's preference. 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 child mortality rate declined fast at the same time of 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 increase investment in education of children, which may lead to higher income in the long run. In this study, I make use of a general equilibrium framework 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.

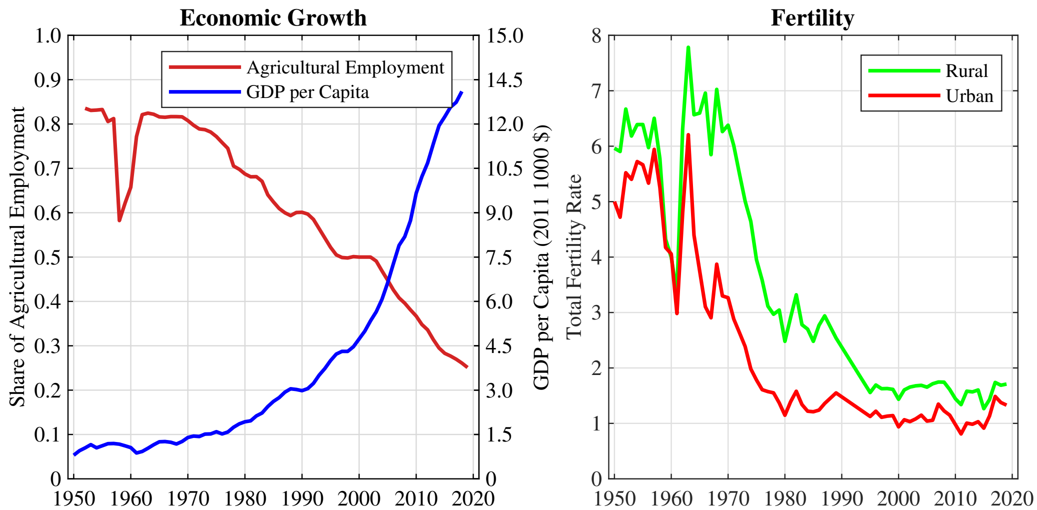
## 2 Facts

***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), 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 incentive 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 polices 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 non-agriculture sectors 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 1950-2019 period. The share of agricultural employment was about 70% in 1978, but dropped to below 30% in 2019.[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 Labor Statistical Yearbook 2020* (NBSC, 2020). 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 1994-2019 are computed by the author based on the age-specific fertility rates from *China Population Statistics Yearbook* (NBSC, 1995-2020).

**Fig. 3** Economic Growth and Total Fertility Rate

During the same period, the TFR dropped in both rural and urban areas, as shown in the graph 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.[3]

Overall, Fig. 3 highlights how structural transformation of the Chinese economy might have affected the TFR. First, as many rural people migrate to urban areas and work at

[2]The share of agricultural employment was very low in the period 1958-1960 due to the "Great Leaping Forward" Economic Campaign.

[3]The TFR was very low in 1959-1961, because there was a great famine.

non-agriculture, 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.[4]

***Fact 2. China achieved fast child mortality decline.***

Fig. 4 plots the infant mortality rate against the total fertility rate.[5,6] 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 in 1950-1980, including sanitation campaigns, childhood vaccination programs 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.

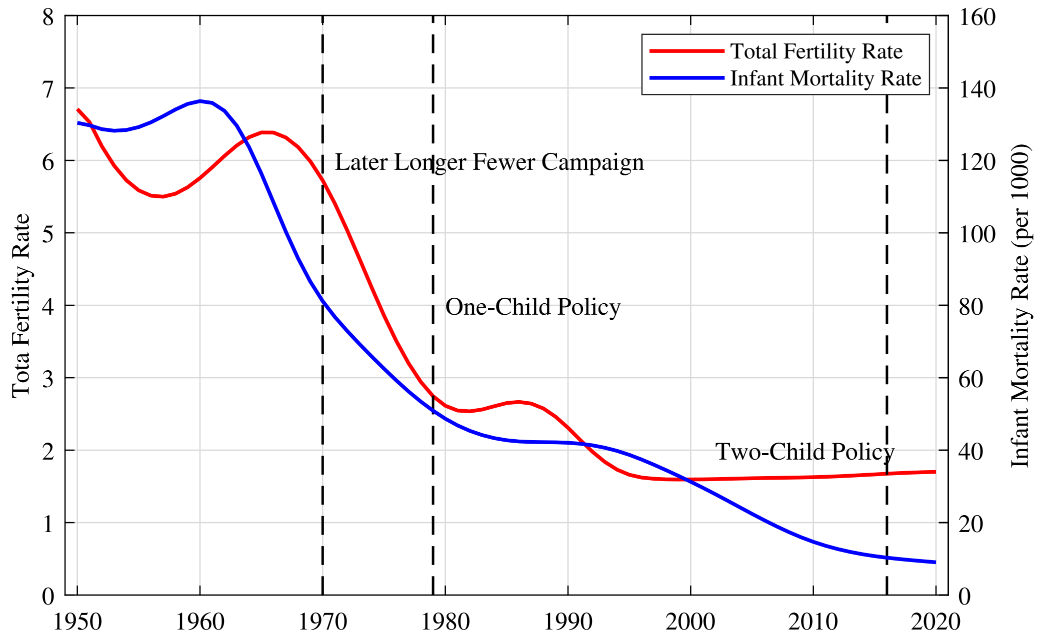
***Fact 3. China implemented strict population control policies.***

China was one of the first countries that implemented population control policies. After the great famine during 1958-1959, 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" in order to control population growth (Peng, 1997). In 1964, the family planning commissions were gradually established firstly at the national level and afterwards at the province, prefecture and

[4]Fig. 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.

[5]Infant mortality is a narrower concept than child mortality, but the two rates are highly correlated. For the sake of illustration, I use infant mortality rate since its annual data are available.

[6]Fig. 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

county levels. However, the Cultural Revolution in 1966 promptly shut down most of the institutions (Chen and Huang, 2020).

At the end of 1960s, China's population exceeded 800 million due to the high birth rate in the earlier years. Meanwhile, the 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 1970 in Shandong and Guangdong provinces, 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 preference and large ideal family size. After a coercive abortion campaign in 1983 which 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 parents were subject to a looser restriction compared with their urban counterparts.[7] On average, urban parents were limited to have about 1.0 children, while rural parents were allowed to have about 1.8 children. In addition, parents

[7] According to Ebenstein (2010), provinces can be simply grouped into three categories, 1-child zones, 1.5-child zones, 2-child zones. In the 1-child (2-child) zones, parents were limited to have at most 1 (2) children. In the 1.5-child zones, rural parents were allowed to have a second child if the first was a daughter.

in remote areas and other various groups, including ethnic minorities, could have a second or third child or even be exempted from such restrictions (Zhang, 2017).

Chinese government has been increasingly aware of 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

The model economy has two sectors: agriculture (rural) and non-agriculture (manufacturing, urban). Agricultural goods are produced with capital and unskilled labor, while non-agricultural goods are produced with capital and 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 of both goods with non-homothetic preferences. There is a subsistence level of agricultural consumption as well as a basic amount of non-agricultural goods that can be produced domestically. Finally, adults give births 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 non-agriculture 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 few and well-educated ones.

### 3.1 Firms

There are two sectors, agriculture and non-agriculture. Non-agricultural goods are produced with capital and skilled labor using a Cobb-Douglas technology

$$Y_{m,t} = z_t K_{m,t}^{\mu} S_{m,t}^{1-\mu}, \tag{1}$$

where $z$ is the total factor productivity, and $K_m$ and $S_m$ are the inputs of capital and skilled labor. The subscript $t$ indicates the time period.

Agricultural goods are produced with capital and unskilled labor also using a Cobb-Douglas technology

$$Y_{a,t} = x_t K_{a,t}^{\alpha} U_{a,t}^{1-\alpha}, \tag{2}$$

where $x$ is the total factor productivity, and $K_a$ and $U_a$ are the inputs of capital and unskilled labor. Note that unskilled labor is used only in the agricultural sector, while skilled labor is used only in the non-agricultural sector.

Agricultural goods can only be consumed, while non-agricultural output can be either consumed or accumulated as capital. In each period, a fraction $\delta$ of capital depreciates. The price of non-agricultural goods is normalized to 1, and the relative price of agricultural goods is denoted by $p_t$. In addition, the gross interest rate is denoted by $R_t$, the skilled wage by $w_{m,t}$, and unskilled wage by $w_{a,t}$. Profit-maximizing firms solve the following problems

$$\max_{K_{m,t},S_{m,t}} z_t K_{m,t}^{\mu} S_{m,t}^{1-\mu} - (R_t + \delta - 1)K_{m,t} - w_{m,t}S_{m,t}, \tag{3}$$

and

$$\max_{K_{a,t},U_{a,t}} p_t x_t K_{a,t}^{\alpha} U_{a,t}^{1-\alpha} - (R_t + \delta - 1)K_{a,t} - w_{a,t}U_{a,t}. \tag{4}$$

The first order conditions associated to these problems determine factor prices.

## 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 adults. 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 consume agricultural and non-agricultural goods. 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 endow them with skills, $e_{t+1} \in \{0, 1\}$. There is a fixed time cost $\tau_0$ associated with each newborn whether she survives or not. If the newborn survives, there is an extra time cost $\tau_1$. 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 endows the child with skills, there is another time cost $\tau_2$.

A middle-aged adult has $\lambda$ ($< 1$) unit of time. She works, consumes and saves for the old age. An old adult does not work and only consumes. Finally, I assume that the savings of deceased adults are distributed evenly to the survivors in the next generation as bequests.

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

$$
\begin{aligned}
&U(a_t^y, m_t^y, a_{t+1}^m, m_{t+1}^m, a_{t+2}^o, m_{t+2}^o, Q_t, e_{t+1}) \\
&\quad = log\{[(1-\psi)(a_t^y - a_0)^{\frac{\epsilon-1}{\epsilon}} + \psi(m_t^y + m_0)^{\frac{\epsilon-1}{\epsilon}}]^{\frac{\epsilon}{\epsilon-1}}\} \\
&\qquad + \beta s_t^y log\{[(1-\psi)(a_{t+1}^m - a_0)^{\frac{\epsilon-1}{\epsilon}} + \psi(m_{t+1}^m + m_0)^{\frac{\epsilon-1}{\epsilon}}]^{\frac{\epsilon}{\epsilon-1}}\} \\
&\qquad + \beta^2 s_t^y s_{t+1}^m log\{[(1-\psi)(a_{t+2}^o - a_0)^{\frac{\epsilon-1}{\epsilon}} + \psi(m_{t+2}^o + m_0)^{\frac{\epsilon-1}{\epsilon}}]^{\frac{\epsilon}{\epsilon-1}}\} \\
&\qquad + \chi log(Q_t s_t^c) + \chi log[e_{t+1} w_{m,t+1} + (1-e_{t+1}) w_{a,t+1}].
\end{aligned}
\tag{5}
$$

Here $a_0$ ($\geq 0$) is the subsistence level of consumption of agricultural goods, and $m_0$ ($\geq 0$) is the basic amount of non-agricultural goods that can be produced domestically instead of bought in the market. $a^y$, $a^m$ and $a^o$ denote the individual's consumption of agricultural goods when young, middle-aged and old, while $m^y$, $m^m$ and $m^o$ represent consumption of non-agricultural goods. $\psi$ indicates the importance of non-agricultural consumption relative to agricultural consumption, and $\epsilon$ governs the elasticity of substitution between the two goods. If $\epsilon > 1$, the two goods are substitutes, and if $\epsilon < 1$, they are complements. The utility from consumption when middle-aged and old is discounted by both the discount factor $\beta$ 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.[8] Quality is measured by the wage children will earn as young adults. $e_{t+1}$ indicates whether the children are endowed with skills or not. Skilled children ($e_{t+1} = 1$) will earn $w_{m,t+1}$ when they grow up, while unskilled children ($e_{t+1} = 0$) will receive $w_{a,t+1}$.

[8]When referring to the number of surviving children, I assume that the law of large number applies. I do not consider the uncertainty in the number of surviving children as Kalemli-Ozcan (2002, 2003). In fact, in most cases, deceased children die at a very young age, and replacement of non-surviving children can be strong.

Let $w_t \in \{w_{a,t}, w_{m,t}\}$ denotes the wages at time $t$ for parents. Then, the budget constraints are given by

$$p_t a_t^y + m_t^y + Q_t[\tau_0 + s_t^c(\tau_1 + e_{t+1}\tau_2)]w_t + i_t^y \leq w_t + b_t^y,$$
$$p_{t+1}a_{t+1}^m + m_{t+1}^m + i_{t+1}^m \leq \lambda w_{t+1} + i_t^y R_{t+1} + b_t^m, \tag{6}$$
$$p_{t+2}a_{t+2}^o + m_{t+2}^o \leq i_{t+1}^m R_{t+2},$$

where $i^y$ and $i^m$ are the savings when young and middle-aged, and $b^y$ and $b^m$ are the bequests received.

In each period, some households work in agriculture and the others work in non-agriculture. I interpret households that work in agriculture as residing in rural areas and the others in urban areas. Hence, when a parent who works in agriculture decides to educate their children, the children move to urban areas and work in non-agriculture. In addition, it turns out that parents in non-agriculture always choose to educate their children, so there is no movement of labor from non-agriculture to agriculture.

## 3.3 Fertility Decisions

Assuming an interior solution, the optimal number of children is

$$Q_t = \frac{\chi}{1 + \beta s_t^y + \beta^2 s_t^y s_{t+1}^m + \chi} \frac{w_t + \lambda w_{t+1}/R_{t+1} + b + c_0}{[\tau_0 + s_t^c(\tau_1 + e_{t+1}\tau_2)]w_t}, \tag{7}$$

where the term $c_0 = m_0 - p_t a_0 + (m_0 - p_{t+1}a_0)/R_{t+1} + (m_0 - p_{t+2}a_0)/R_{t+1}/R_{t+2}$ appears due to non-homotheticity, and the term $b = b^y + b^m/R_{t+1}$ is the present value of bequests. The right-hand side of Equation (7) is product of two terms. The first term is the share of resources allocated to raising children. The numerator of the second term is the total resources, i.e., the life-time income adjusted for non-homotheticity and bequests, while the denominator is the expected cost of a newborn.

What does Equation (7) imply about the optimal 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. In addition, the optimal number of children is decreasing in the survival rates of young and middle-aged adults $s_t^y$ and $s_{t+1}^m$. When people are more likely to survive, they value future consumption more and tend to reduce the number of children.

Second, the number of children is smaller if parents decide to educate them ($e_{t+1} = 1$). Obviously, skilled children require more time commitment of parents, and therefore, parents tend to have fewer children if they are going to educate them. This is basically the quantity-quality trade-off. As a result, if there is a structural transformation with more skilled labor in non-agriculture, the overall fertility rate will decline. This allows TFP growth to play a role in two ways. First, TFP growth increases wages. Since the utility function is non-homothetic, people with raising income will spend more on non-agricultural goods relative to agricultural goods, which leads to a larger non-agricultural sector (Kongsamut et al., 2001). Second, if the two goods are complements in the utility function, which is the case in our calibration, the income elasticity of demand will be smaller than one. Therefore, if TFP grows at different rates in the two sectors, increased production in the sector with faster growth will lead to a more than proportional decline in its relative price, inducing a reallocation of labor away from this sector to the other sector (Ngai and Pissarides, 2007).

Finally, supposing $w_t = w_{t+1}$, the optimal number of children is decreasing in wage rate if $b + c_0 > 0$.[9] The underlying reason is that with a higher wage rate, parents shifts

[9] A sufficient but not necessary condition is that $m_0 > 0$ and $a_0 = 0$.

their demand from the number of children toward the luxury non-agricultural good.[10] This implies that TFP can also affect fertility through 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 preference. 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 the LLF Campaign into the model in the following way. Without the policy, the utility from children is $\chi log(Q_t s_t^c) + \chi log[(1 - e_{t+1})w_{a,t+1} + e_{t+1}w_{m,t+1}]$. But if the LLF Campaign is present, the utility from children becomes

$$\chi log(Q_t s_t^c + q_0) + \chi log[(1 - e_{t+1})w_{a,t+1} + e_{t+1}w_{m,t+1}], \tag{8}$$

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

$$Q_t[\tau_0 + s_t^c(\tau_1 + e_{t+1}\tau_2)]w_t + max\{Q_t s_t^c - \bar{q}, 0\}f w_t, \tag{9}$$

[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).

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

In the model, the population policies also affect structural transformation. 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 utility of consumption implies that some of the extra time will be invested to children's education as well. As a consequence, more skilled workers will be supplied to the non-agricultural sector. This effect does not depend on the type of the population policies, and operates whether the reduction in the number of children is voluntary (in the case of the LLF Campaign) or involuntary (in the case of the OCP).

## 3.5 Equilibrium and Steady State

There are three types of households: ($uu$) 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 in order to work in agriculture people need to have a piece of land, which is hard to obtain if the parents work in non-agriculture.

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

$$g_{n,t+1} = [u_t^y(1 - h_t^y)Q_{uu,t} + u_t^y h_t^y Q_{us,t} + (1 - u_t^y)Q_{ss,t}]s_t^c. \tag{10}$$

The term in the bracket is the average number of children of the young adults in period $t$, where $Q_{uu,t}$, $Q_{us,t}$ and $Q_{ss,t}$ are the number of children of the type-$uu$, type-$us$ and type-$ss$ households, respectively. 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

$$n_{t+1}^y = n_t^y g_{n,t+1}, \tag{11}$$

and

$$n_{t+2}^m = n_{t+1}^y s_{t+1}^y; \; n_{t+3}^o = n_{t+2}^m s_{t+2}^m. \tag{12}$$

The first equation states that the number of young adults in each period equals the number of young adults in 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 equals the number of young (or middle-aged) adults in last period multiplied by their survival rate.

In equilibrium, several market clearing conditions should hold. First, the markets of agricultural goods and non-agricultural goods should clear,

$$n_t^y a_t^y + n_t^m a_t^m + n_t^o a_t^o = Y_{a,t}, \tag{13}$$

and

$$n_t^y m_t^y + n_t^m m_t^m + n_t^o m_t^o = Y_{m,t}, \tag{14}$$

where $a_t^j = u_t^j(1 - h_t^j)a_{uu,t}^j + u_t^j h_t^j a_{us,t}^j + (1 - u_t^j)a_{ss,t}^j$ is the average consumption of agricultural goods by age-$j$ adults in period $t$ with $j \in \{y, m, o\}$, and $m_t^j = u_t^j(1 - h_t^j)m_{uu,t}^j +$

$u_t^j h_t^j m_{us,t}^j + (1-u_t^j) m_{ss,t}^j$ is the average consumption of non-agricultural goods.

Second, the markets for skilled labor and unskilled labor should clear,

$$U_{a,t} = n_t^y u_t^y (1-h_t^y)[1-Q_{uu,t}(\tau_0+s_t^y\tau_1)] + n_t^y u_t^y h_t^y \{1-Q_{us,t}[\tau_0+s_t^y(\tau_1+\tau_2)]\} + n_t^m u_t^m \lambda, \quad (15)$$

and

$$S_{m,t} = n_t^y (1-u_t^y)\{1-Q_{ss,t}[\tau_0+s_t^y(\tau_1+\tau_2)]\} + n_t^m (1-u_t^m)\lambda, \quad (16)$$

where young adults, skilled or unskilled, supply their labor endowment net of childcare time.

Third, the capital market should clear

$$K_{a,t} + K_{m,t} = n_{t-1}^y i_{t-1}^y + n_{t-1}^m i_{t-1}^m, \quad (17)$$

where $i_{t-1}^y = u_{t-1}^y(1-h_{t-1}^y) i_{uu,t-1}^y + u_{t-1}^y h_{t-1}^y i_{us,t-1}^y + (1-u_{t-1}^y) i_{ss,t-1}^y$ is the average savings of young adults at the end of period $t-1$, $i_{t-1}^m = u_{t-1}^m(1-h_{t-1}^m) i_{uu,t-1}^m + u_{t-1}^m h_{t-1}^m i_{us,t-1}^m + (1-u_{t-1}^m) i_{ss,t-1}^m$ is the average savings of middle-aged adults at the end of period $t-1$. So this equation states that the total capital demand in agriculture and non-agriculture equals the capital supply of the young adults and middle-aged adults at the end of last period.

To close the model, we need the bequests to be consistent with household decisions, i.e.,

$$b_t^y = i_{t-1}^y R_t (1-s_{t-1}^y)/g_{n,t}, \quad (18)$$

and

$$b_{t+1}^m = i_t^m R_{t+1} s_{t-1}^y (1-s_t^m)/(g_{n,t} s_t^y). \quad (19)$$

*Definition of equilibrium*: Given a sequence of the TFP in agriculture and non-agriculture, survival rates and population policies, $\{x_t, z_t, s_t^c, s_t^y, s_t^m, LLF_t, OCP_t, 3CP_t\}_{t=1}^{\infty}$, a competitive equilibrium is a sequence of price of agricultural goods, wages and interest rate $\{p_t, w_{a,t}, w_{m,t}, R_t\}_{t=1}^{\infty}$, a sequence of bequests $\{b_t^y, b_t^m\}_{t=1}^{\infty}$, a sequence of allocations of firms $\{K_{a,t}, U_{a,t}\}_{t=1}^{\infty}$ and $\{K_{m,t}, S_{m,t}\}_{t=1}^{\infty}$ and a sequence of allocations of households $\{a_{uu,t}^y, m_{uu,t}^y, a_{uu,t+1}^m, m_{uu,t+1}^m, a_{uu,t+2}^o, m_{uu,t+2}^o, Q_{uu,t}\}_{t=1}^{\infty}$, $\{a_{us,t}^y, m_{us,t}^y, a_{us,t+1}^m, m_{us,t+1}^m, a_{us,t+2}^o, m_{us,t+2}^o, Q_{us,t}\}_{t=1}^{\infty}$, and $\{a_{ss,t}^y, m_{ss,t}^y, a_{ss,t+1}^m, m_{ss,t+1}^m, a_{ss,t+2}^o, m_{ss,t+2}^o, Q_{ss,t}\}_{t=1}^{\infty}$ such that

1. Given the prices, wage rates, interest rates and bequests, households maximize their utility.

(a) $\{a_{uu,t}^y, m_{uu,t}^y, a_{uu,t+1}^m, m_{uu,t+1}^m, a_{uu,t+2}^o, m_{uu,t+2}^o, Q_{uu,t}\}$ maximizes the utility of unskilled parents conditional on that they will not educate their children.

(b) $\{a_{us,t}^y, m_{us,t}^y, a_{us,t+1}^m, m_{us,t+1}^m, a_{us,t+2}^o, m_{us,t+2}^o, Q_{us,t}\}$ maximizes the utility of unskilled parents conditional on that they will educate their children.

(c) $\{a_{ss,t}^y, m_{ss,t}^y, a_{ss,t+1}^m, m_{ss,t+1}^m, a_{ss,t+2}^o, m_{ss,t+2}^o, Q_{ss,t}\}$ maximizes the utility of skilled parents.

(d) Unskilled parents choose between educating their children and not.

2. Given the price, wage rates and interest rate, firms maximize their profits.

(a) $\{K_{a,t}, U_{a,t}\}$ maximizes the profit of agricultural firms.

(b) $\{K_{m,t}, S_{m,t}\}$ maximizes the profit of non-agricultural firms.

3. All markets clear.

4. The bequests received by surviving individuals equal to the savings of non-surviving individuals.

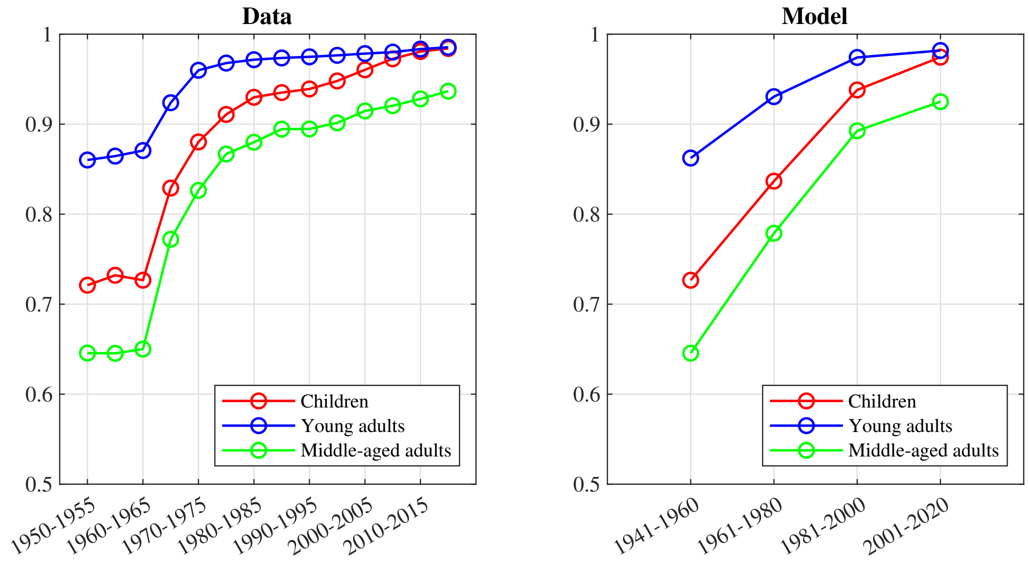
*Definition of steady state*: Given constant productivity, surviving rates and population policies, a steady state is a competitive equilibrium where a set of variables are constant, including the price, wage rates and interest rate $\{p_t, w_{u,t}, w_{s,t}, R_t\}$, the fraction of unskilled young adults $u_t$, the fraction of unskilled young adults endowing their children with skills $h_t$, the choices of three types of households $\{a_t^y, m_t^y, a_{t+1}^m, m_{t+1}^m, a_{t+2}^o, m_{t+2}^o, Q_t\}$, and capital per worker in the two firms $\{K_{m,t}/S_{m,t}, K_{a,t}/U_{a,t}\}$.

# 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 treat the economy during 1941-1960 as being in an initial steady state. With exogenous changes of mortality rate, TFP and population policies in the following periods, the economy transits from the initial steady state to a new one. The quantitative analysis focuses on the 1941-1960, 1961-1980, 1981-2000, 2001-2020 and 2021-2040 periods.

## 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). But 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.




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

**Fig. 5** Survival Rates

Next, I borrow TFP estimates from the literature. Between 1952 and 1978, there was very little growth in the aggregate TFP 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 the TFP growth in each sector to the aggregate TFP estimates, and assume that there is no TFP growth in the model between 1941 and 1978.

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 non-agriculture.[11] However, Young (2003) shows that taking into account improvement in education attainment can reduce the growth rate of non-agricultural

[11]Dekle and Vandenbroucke (2012) also divide non-agriculture 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 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 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%.

TFP from 3.0% to 1.4% in 1978-1998.[12] For agriculture, I take the estimate by Dekle and Vandenbroucke (2012). For non-agriculture, I take the estimate by Young (2003). Therefore, I set the TFP growth rate in agriculture to 1% in 1961-1980 (0.06% per year), 65% in 1981-2000 (2.54% per year) and 107% in 2001-2020 (3.70% per year), and in non-agriculture to 0% in 1961-1980 (0.00% per year), 21% in 1981-2000 (0.94% per year) and 32% in 2001-2020 (1.40% per year). Since the model does not have a balanced growth path with persistent TFP growth, I assume that TFP in the two sectors continues to grow at 3.7% and 1.4% per year for 2 more periods (40 years), respectively.[13]

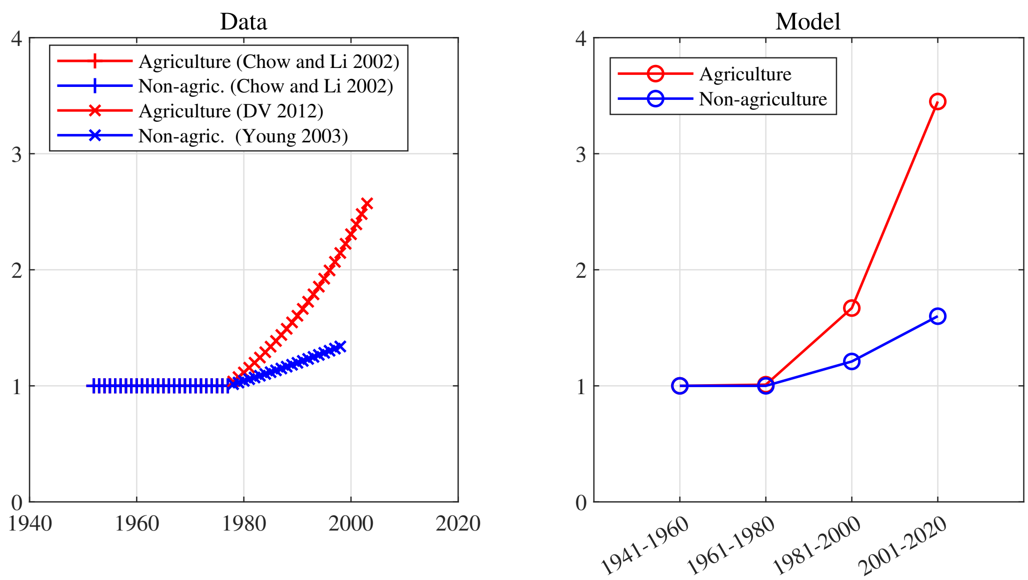



**Fig. 6** Cumulative TFP Gowth Rates

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

[12]Young (2003) does not conduct similar analyses for the TFP growth in agriculture. However, the analysis on output per worker suggests that it is likely there is no big issue with agriculture. After adjustment, the growth rate of output per worker decreases from 6.9% to 5.2% for the whole economy, which is mainly driven by the change in non-agriculture (from 6.1% to 3.6%).

[13]TFP growth in the far future has little effect on the quantitative analysis in the focused periods.

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.

**Table 1** Sequence of Exogenous Changes

| | Description | Value | Source |
|---|---|---|---|
| | | 1941-, 1961-, 1981-, 2001-, 2021-, ... | |
| $s_t^c$ | Survival rate of children | {0.727, 0.837, 0.938, 0.974, 0.974, ...} | UN (2019) |
| $s_t^y$ | Survival rate of young adults | {0.862, 0.931, 0.974, 0.982, 0.982, ...} | UN (2019) |
| $s_t^m$ | Survival rate of middle-aged adults | {0.646, 0.779, 0.893, 0.925, 0.925, ...} | UN (2019) |
| $x_t$ | TFP in agriculture | $\{x_0$, $1.01x_0$, $1.67x_0$, $3.45x_0$, $7.14x_0$, ...} | Literature |
| $z_t$ | TFP in non-agriculture | $\{z_0$, $1.00z_0$, $1.21z_0$, $1.60z_0$, $2.11z_0$, ...} | 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: The TFP estimates are taken from Chow and Li (2002), Dekle and Vandenbroucke (2012), and Young (2003). See the text for further details.

## 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 0.94, a standard value in the macroeconomics literature. The non-homothetic part of agricultural consumption $a_0$ is normalized to 0, while its counterpart for non-agricultural consumption $m_0$ will be estimated in the model.[14] The elasticity of substitution between agricultural and non-agricultural goods is from Yao and Zhu (2021) and set to 0.197, suggesting that agricultural and non-agricultural goods are complements. As a result, faster TFP growth in agriculture will move labor away from agriculture to non-agriculture.[15]

[14] A positive $m_0$ and a positive $a_0$ lead to similar income effects on structural transformation. In this sense, only one parameter can be identified. However, $m_0 > 0$ is also important for the positive effect of wages on fertility. So I keep $m_0 > 0$ and set $a_0$ to 0.

[15] In Appendix B, I show the results with a Cobb-Douglas specification with a unit elasticity. The model performs worse in fitting the data, but the main findings are largely unchanged.

Capital share in agriculture is from Cao and Birchenall (2013), who estimate that the shares of capital, labor and land are 0.26, 0.39 and 0.35. Since I abstract from land in the production of agricultural goods, land share is split to capital and labor proportionally, which leads to a capital share of 0.40.[16] Capital share in non-agriculture is from Young (2003), which is 0.54. This number is computed based on the national account, and is widely used in other studies (e.g., Dekle and Vandenbroucke, 2012; Cao and Birchenall, 2013). The annual depreciation rate of capital $\delta$ is set to 0.06, following Chow and Li (2002). The initial productivity in agriculture and non-agriculture is normalized to 1.

There are three costs associated with children, the cost of a newborn whether she survives or not, $\tau_0$, the extra cost if a newborn survives to adult, $\tau_1$, and the cost of endowing a child with skills, $\tau_2$. These costs come from two parts, basic living cost and education cost. I assume that living cost is proportional to survival years, and that 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),[17] so the living cost amounts to $\tau_0 = 3.4/20 * 0.025 = 0.0043$. 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 $16.6/20 * 0.025 = 0.0208$. Since one year of schooling costs 17.7% of the annual income of a parent (Chi and Qian, 2016), the extra education cost is $6.2 * 0.177/20 = 0.0549$.[18] Note that we have 20 as the denominator

[16] Both 0.26 and 0.40 are much larger than the number based on the national account, which is about 0.12. However, as argued by Cao and Birchenall (2013), labor income in the national account includes income from various activities associated with production in rural areas, which results in an overestimated labor share and an underestimated capital share.

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

[18] Based on the population census data in 1982, 1990, 2000 and 2010 (State Council and State Statis-

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 receive 3.4 more years of education, implying that the extra education cost of a skilled child is $\tau_2 = 3.4 * 0.177/20 = 0.0301$.[19]

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 time cost. For instance, a couple would be fined with 1.29 times their annual income for each above-quota child in Shanxi Province in 2000. Since each houshold has only one parent in the model, I compute the cost for one parent, which is $1.29 * 2 = 2.58$ times her annual income. As young adults work for 20 years, the equivalent time cost is $2.58/20 = 0.129$. Next, considering that the fine rate varies over time, I compute the average cost for each province during 1979-2000 based on the data of Ebenstein (2010). Finally, since the fine rate varies across space as well, I weight the cost at the province level with the employments in each province in 1982. This gives a fine rate of 0.1594.[20]

The child quota of the OCP is different for rural and urban couples. Although the policy is named "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, 2-child zones. In the

tical Bureau of China, 1985, 1993, 2002, 2012), agricultural (or unskilled) workers receives 6.2 years of education on average, and non-agricultural (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.

[19]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%.

[20]If $f$ is computed for rural and urban areas respectively, the values are very similar.

**Table 2** Parameters Chosen outside the Model

| | Description | Value | Source |
|---|---|---|---|
| $T$ | Model period | 20 | |
| $\beta$ | Discount factor (yearly) | 0.94 | Standard |
| $a_0$ | Non-homothetic part of agricultural consumption | 0 | |
| $\epsilon$ | Elasticity of substitution | 0.197 | Yao and Zhu (2021) |
| $\mu$ | Capital share in non-agriculture | 0.54 | Young (2003) |
| $\alpha$ | Capital share in agriculture | 0.40 | Cao and Birchenall (2013) |
| $\delta$ | Depreciation factor (yearly) | 0.06 | Chow and Li (2002) |
| $x_0$ | Initial TFP in agriculture | 1 | Normalization |
| $z_0$ | Initial TFP in non-agriculture | 1 | Normalization |
| $\tau_0$ | Fixed time cost of each child | 0.0043 | de Silva and Tenreyro (2020) |
| $\tau_1$ | Extra time cost of each surviving child | 0.0757 | United Nations (2019) and Chi and Qian (2016) |
| $\tau_2$ | Time cost of educating each child | 0.0302 | Chi and Qian (2016) |
| $f$ | Fines on each above-quota child | 0.1594 | Ebenstein (2010) |
| $\bar{q}_a$ | OCP child quota of rural parents | 1.7794/2 | Ebenstein (2010) |
| $\bar{q}_m$ | OCP child quota of urban parents | 1.0374/2 | Ebenstein (2010) |
| $\bar{q}_{a,m}$ | 3CP child quota | 3/2 | |
| $\lambda$ | 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.

1-child (or 2-child) zones, each couple was limited to have 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 are weighted with employments 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, $\lambda$, is set to 0.75, since workers retire at age 55. The parameters chosen outside the model are summarized in Table 2.

## 4.3 Estimated Parameters

We are left with four parameters governing household preference: $\psi$, $\chi$, $m_0$ and $q_0$. $\psi$ is the weight of non-agricultural consumption, $\chi$ is the weight of children, and $m_0$ is the non-homothetic part of non-agricultural consumption. Finally, $q_0$ captures the effect of the LLF Campaign. These parameters are calibrated to match (1) the TFR in rural and urban areas (Yao and Yin, 1994, NBSC, 1995-2020) and (2) the share of agricultural employment (NBSC, 2014, 2020) for the 1950-2019 period.[21] The economy is assumed to be in a steady state with constant mortality rates and TFP and no population policies in the period 1941-1960. The economy starts its transition in the second period, and will reach a new steady state after sufficiently many periods. The parameters are chosen such that the model-generated variables are as close as possible to the actual data. Overall, I

[21] The share of agricultural employment was very low in the Great Leaping 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. 7 in Appendix C shows the data without dropping these numbers.

have 12 data points to pin down four parameters.

The estimated parameters are shown in Table 3. The value of $q_0$ indicates that the LLF Campaign would reduce the TFR by around 1.1, since parents still enjoy $q_0$ children even if they do not have any child. The moments from the data and 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 |
|---|---|---|
| $\psi$ | Weight of utility from non-agricultural goods | 0.3551 |
| $\chi$ | Weight of utility from children | 0.1117 |
| $m_0$ | Non-homothetic part of non-agricultural consumption | 0.0260 |
| $q_0$ | Effect of the LLF Campaign | 0.5659 |

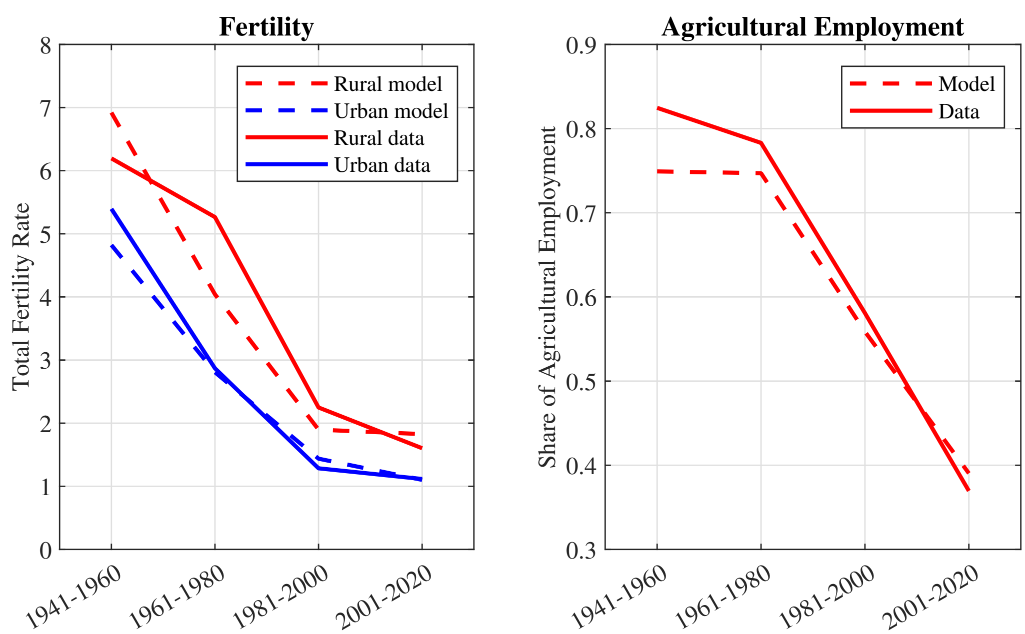



**Fig. 7** Model and Data

# 5 Results

Now the model can be used to quantify how much the exogenous changes (mortality decline, TFP growth 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 add the TFP growth on the 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.[22]

The results are shown in Fig. 8. When I only allow mortality rates to change, the TFR declines from 6.40 in 1941-1960 to 4.27 in 2001-2020. Mortality decline has a strong effect on fertility until 2000. Afterwards, the marginal effects of mortality decline become smaller. When the TFP growth is further added, the TFR declines to a larger extent from 6.40 in 1941-1960 to 2.85 in 2001-2020. The effect of TFP growth is increasing over time and particularly strong in 2001-2020. It accounts for only 12.8% of the fertility decline in 1981-2000 but 28.2% in 2001-2020.

What about the population polices? When the LLF Campaign is added, the TFR drops from 4.83 to 3.77 in the 1961-1980 period. When the OCP is added, the TFR in 2001-2020 further drops to 1.34, which is the same as in the data. The OCP has a stronger effect in 1981-2000, reducing the TFR from 3.81 to 1.65.

Finally, given the important role of the OCP, the model predicts that replacing it with the 3CP in 2021-2040 has some positive effects on the fertility rate, increasing the TFR

[22] In Appendix D, I consider only one exogenous change each time and examine their effects separately. The findings are in line with those presented here.

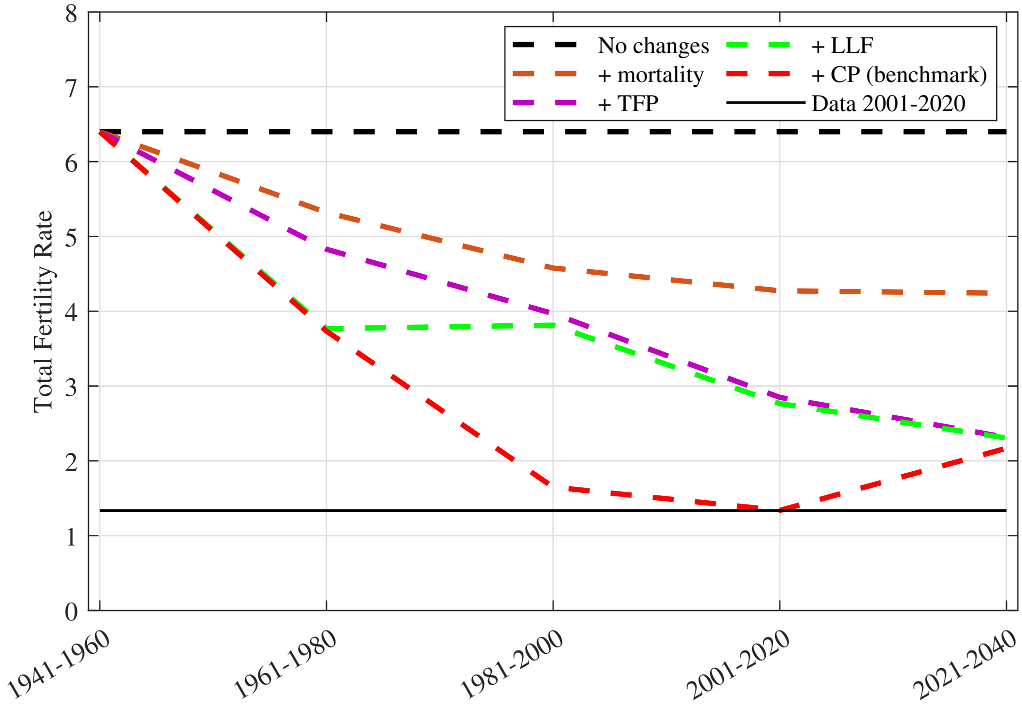



**Fig. 8** TFR in the Model

from 1.34 in 2001-2020 to 2.17 in 2021-2040. The quota restriction of three children per couple is not binding because of the increasingly large influence of productivity growth.

Overall, the results show that there would still be a significant decline in fertility rate even without any population policy, but the population policies are critical for reducing the TFR to far below the replacement level. In the benchmark economy with all exogenous changes, the TFR declines from 6.40 in 1941-1960 to 1.34 in 2001-2020. The contributions from mortality decline, the TFP growth and the population policies are 42.0%, 28.0% and 30.0%, respectively. Without the population policies, the TFR would be 2.85 instead of 1.34 in 2001-2020. Finally, replacing the OCP with the 3CP after 2020 can raise the TFR to 2.17.

The structural transformation of the Chinese economy is shown in Fig. 9. In the benchmark, the share of agricultural employment decreases by 35.9 percentage points from 74.9% in 1940-1960 to 39.0% in 2001-2020. Obviously, the TFP growth is the main driving force, and its role becomes more important over time. The TFP growth reduces the share of agricultural employment by 15.1 percentage points in 1981-2000 and 31.0 percentage points in 2001-2020, accounting for 79.2% and 86.3% of the total decline up to the corresponding periods, respectively.

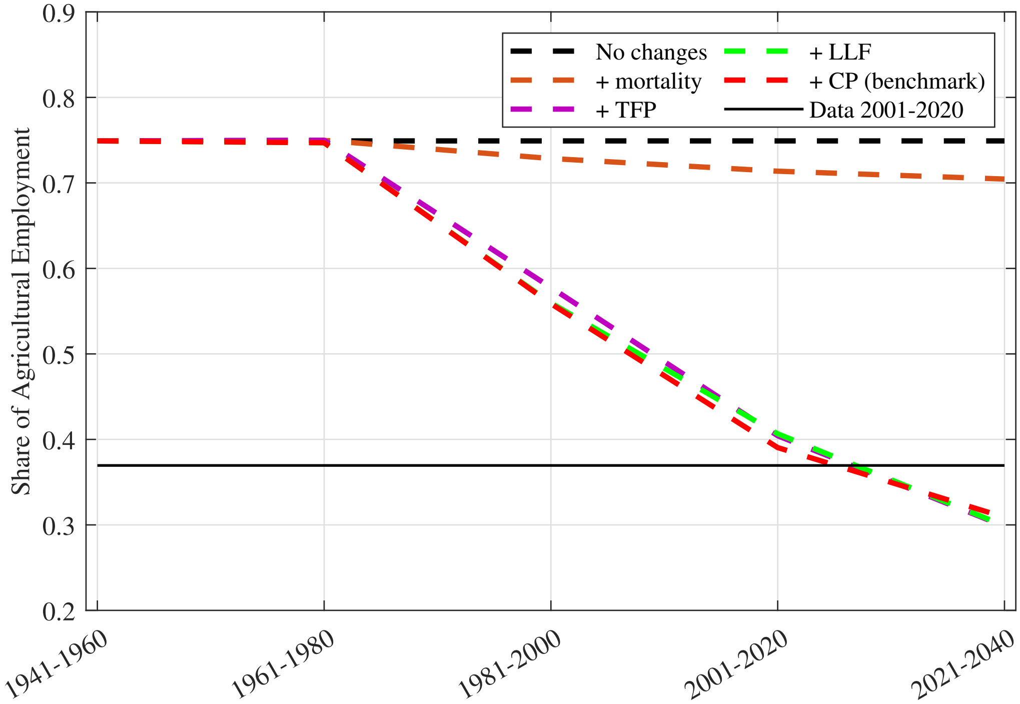



**Fig. 9** Share of Agricultural Employment in the Model

By contrast, the effects of mortality decline and the population policies on structural transformation are much smaller. If there is only mortality decline, the share of agricultural employment would be 71.4% in 2001-2020, only 3.5 percentage points lower than that in 1940-1960. The LLF Campaign reduces the share of agricultural employment by 1.8 percentage points in 1981-2000, and the OCP reduces it by 1.6 percentage points in 2001-2020.

# 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, it was further used to control migration. There were two types of *hukou*: rural/agricultural and urban/non-agricultural. People with rural *hukou* were supposed to work at agriculture, while urban people 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, 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 to the 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 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 $\upsilon_t$ 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 $\theta_{a,t}$ in rural areas and $\theta_{m,t}$ in urban areas. Notice that the taxes paid by agricultural workers are fully refunded to them. However, there are net transfers among non-agricultural 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 $\chi log(w_{m,t+1} - T_{m,t+1} + D_{m,t+1})$, where $T_{m,t+1}$ is the lump-sum tax and $D_{m,t+1}$ is the lump-sum subsidy. For rural parents, the utility from children's quality is still $\chi log(w_{a,t+1})$ if the children are unskilled. However, if the children are skilled, the utility becomes $\nu_{t+1}\chi log(w_{m,t+1} - T_{m,t+1} + D_{m,t+1}) + (1 - \nu_{t+1})\chi log(w_{m,t+1} - T_{m,t+1})$, 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 endowing 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 disincentive 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, $\upsilon_t$, and the subsidy rates, $\theta_{a,t}$ and $\theta_{m,t}$. Due to the complexity of the *hukou* system and lack of data, an accurate estimation of $\upsilon_t$ is difficult to conduct. As a compromise, I make a rough but feasible estimate based on the population size with rural and urban *hukou*, for which the details are shown in Appendix E. I set $\upsilon$ 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 $\theta_{a,t}$ is set to 0, because it has no effect on household decisions due to the lump-sum nature of the taxes and subsidies. For the subsidy rate in urban areas $\theta_{m,t}$, I compute the government expenditure on education, health care, pension and other social assistance programs as a fraction of non-agricultural output, following Ngai et al. (2019). The details for the data and computation are provided in Appendix F. 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-, ... | |
| $\upsilon_t$ | *Hukou* conversion quota | {1, 0.02, 0.27, 0.50, 0.50, ...} | Appendix E |
| $\theta_{m,t}$ | Urban subsidy rate | {0.024, 0.024, 0.028, 0.061, 0.061, ...} | Appendix F |

**Table 5** Estimated Parameters with *Hukou*

| | Description | Value |
|---|---|---|
| $\psi$ | Weight of utility from non-agricultural goods | 0.3430 |
| $\chi$ | Weight of utility from children | 0.1113 |
| $m_0$ | Non-homothetic part of non-agricultural consumption | 0.0259 |
| $q_0$ | Effect of the LLF Campaign | 0.6102 |

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, the TFP growth, the population policies and the *hukou* policy.

The results regarding TFR are shown in Fig. 10. 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 1.79 to 1.64 in 1981-2000 and from 1.53 to 1.34 in 2001-2020.

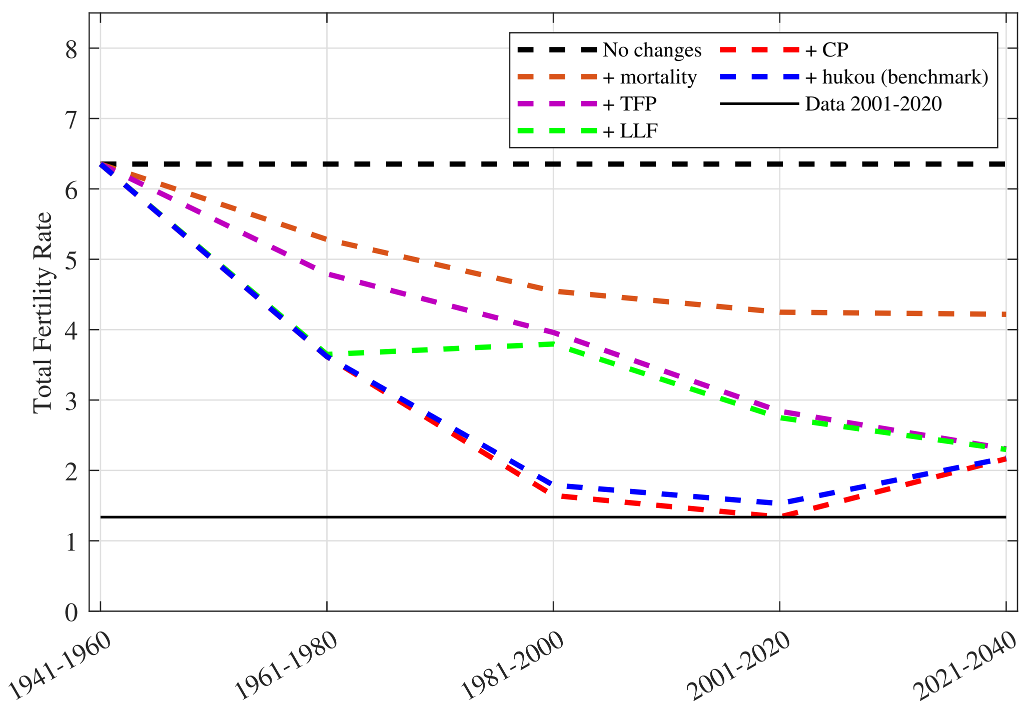



**Fig. 10** TFR in the Model (with *Hukou*)

The results regarding structural transformation are shown in Fig. 11. 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, although mortality decline and the population policies also have some effects. Second, the effects of the *hukou* system on structural transformation are negligible. The share of agricultural employment is increased by only 0.4 percentage points in 1981-2000 and 0.1 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 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.

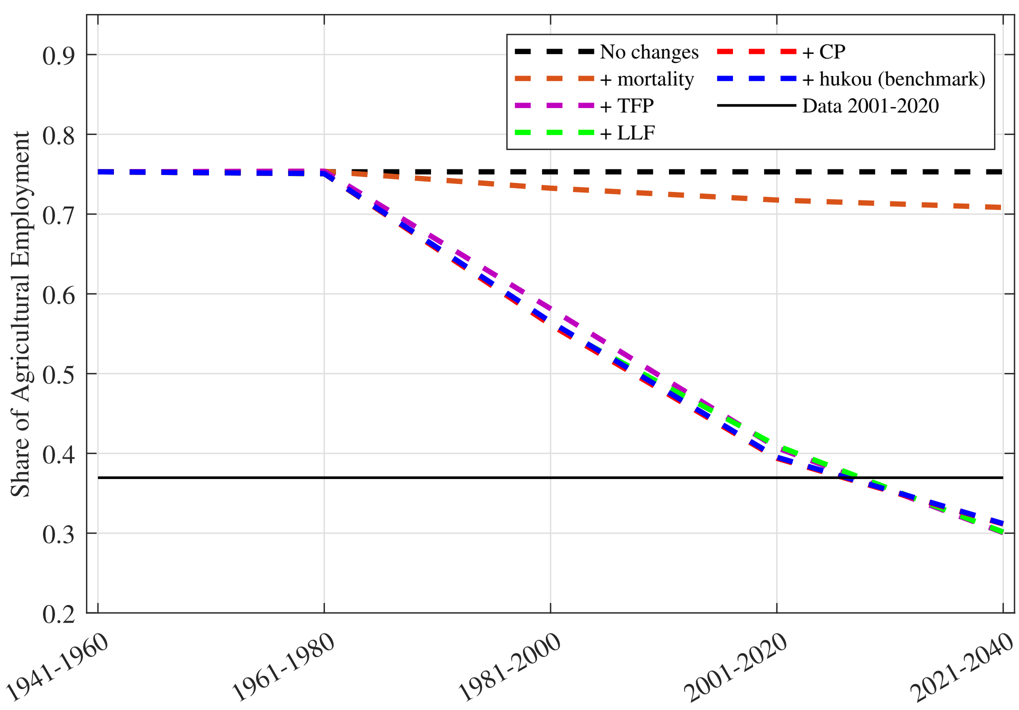



**Fig. 11** Share of Agricultural Employment in the Model (with *Hukou*)

# 7 Conclusions

What has driven China's fast fertility decline is controversial. This study considers three most important factors, mortality decline which increases the expected cost of each newborn, productivity growth which leads 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 movement of workers from agriculture to non-agriculture and endogenous fertility and education choices.

Counterfactual experiments are conducted by adding the exogenous changes one by one. The results on 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 6.40 in 1941-1960 to 1.34 in 2001-2020. With only mortality decline, the TFR would be 4.27 in 2001-2020. If we further add the TFP growth, the TFR would drop to 2.85. Hence, these two factors alone can account for 70% of the total decline in the number of children.

However, the population policies are critical 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 4.83 to 3.77. The impact of the OCP is much stronger. Adding the OCP reduces the TFR from 3.81 to 1.65 in 1981-2000 and from 2.77 to 1.34 in 2001-2020, accounting 30.0% of the total decline. Due to the large effect of the OCP, the TFR is predicted to rebound to 2.17 after it is replaced with the 3CP in 2021-2040.

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 74.9% in 1941-1960 to 39.0% in 2001-2020, and 86.3% of the decline can be accounted for by productivity growth. Although mortality decline and the population policies also play some roles in the structural transformation, their effects are much smaller. Mortality decline reduces the share of agricultural employment by 3.5 percentage points. The LLF Campaign leads to a drop by 1.8 percentage points in 1981-2000 and the OCP leads to another decline of 1.6 percentage points in 2001-2020.

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 1.79 to 1.64 in 1981-2000 and from 1.53 to 1.34 in 2001-2020. However, it has very limited effects on structural transformation.

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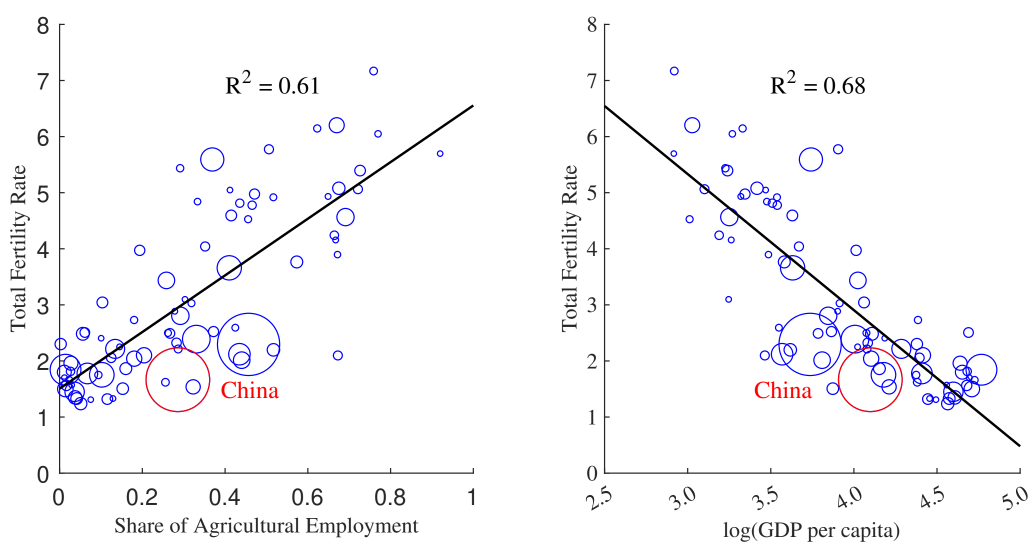
# Appendices

## Appendix A. Some Facts in the Global Context

Fig. 2 in the main text show 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 the cross-country evidence. In Appendix Fig. 1, I plot the TFR against the share of agricultural employment and against 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.

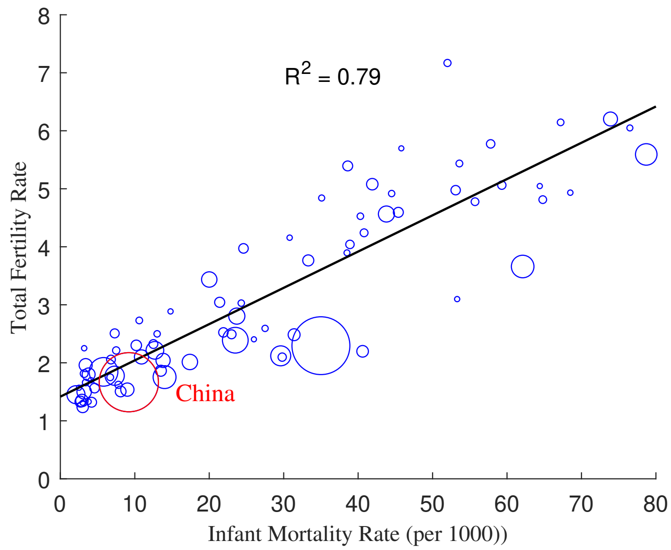



Note: Data used are cross-country data in 2015 with population > 10 million from the World Bank. The size of the circle is proportional to the population.

**Appendix Fig. 1** Economic Development and TFR in the Global Context

The TFR and IMR are strongly correlated in China in the period 1950-2020 (Fig. 3 in the main text). This relationship is not unique to China but holds in the global context.

In Appendix Fig. 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 population > 10 million from the World Bank. The size of the circle is proportional to the population.

**Appendix Fig. 2** Infant Mortality and Fertility in the Global Context

# Appendix B. Unit Elasticity of Substitution between Agricultural and Non-agricultural Goods

In the baseline model, the elasticity of substitution between agricultural and non-agricultural goods is set to 0.197, following Yao and Zhu (2021). With this specification, TFP growth can affect structural transformation in two ways. First, TFP growth increases income, and richer people spend relatively more non-agricultural goods (income effect). Second, imbalanced TFP growth reduces the price in the sector with faster TFP growth, inducing workers to move away from this sector (price effect).

Following Kongsamut et al. (2001), a unit elasticity of substitution is also widely used in the literature, which only allows for the income effect. In this appendix, the baseline analysis is repeated with a unit elasticity. The estimated parameters are reported in Appendix Table 1. The model fit is shown in Appendix Fig. 3. The results of the counterfactual experiments are shown in Appendix Fig. 4 and 5.

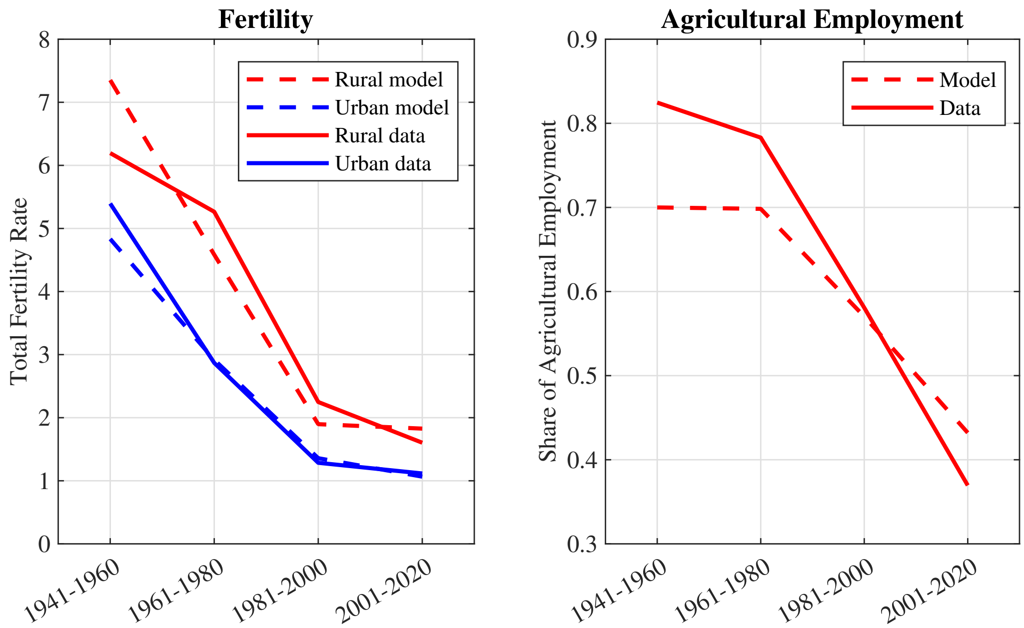
The main difference in the estimated parameters is that $\psi$ and $m_0$ are much larger. Since the price effect is shut down, a larger income effect (i.e., a larger $m_0$) is required in the model to match the drop in agricultural employment in the data. However, a larger $m_0$ will increase the share of agricultural employment all the time in the model. To match the data, the importance of non-agriculture goods (i.e., $\psi$) in the utility function should be increased.

**Appendix Table 1** Estimated Parameters

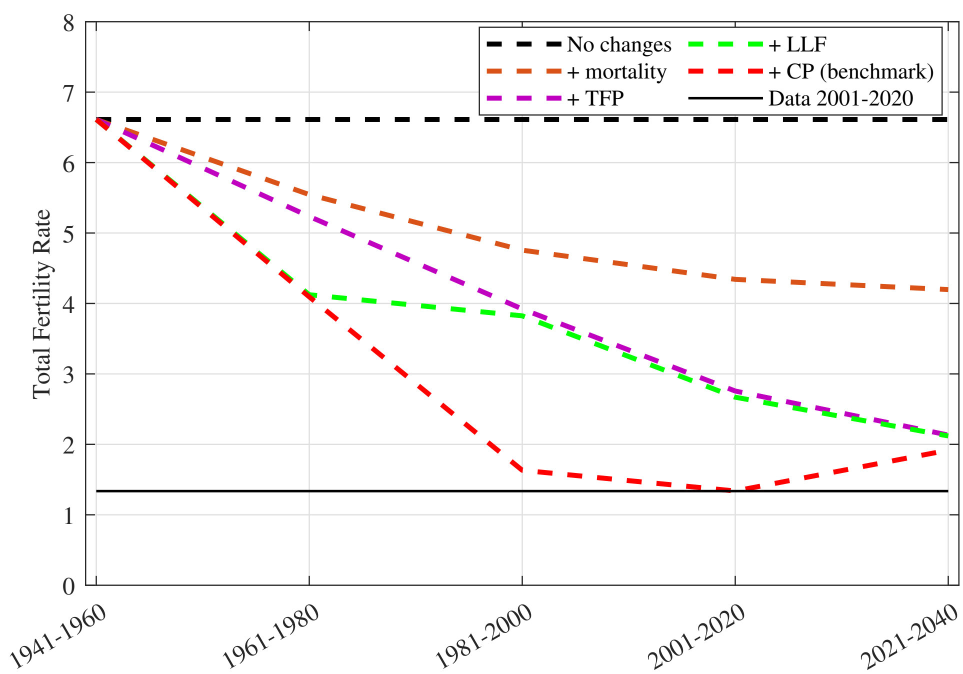
| | Description | $\epsilon = 0.197$ | $\epsilon = 1$ |
|---|---|---|---|
| $\psi$ | Weight of utility from non-agricultural goods | 0.3551 | 0.7574 |
| $\chi$ | Weight of utility from children | 0.1117 | 0.0826 |
| $m_0$ | Non-homothetic part of non-agricultural consumption | 0.0260 | 0.0467 |
| $q_0$ | Effect of the LLF Campaign | 0.5659 | 0.5280 |

Since TFP growth can only affect structural transformation through the income effect now, the model performs worse in fitting the data. In particular, the model predicts fewer workers moving from agriculture to non-agriculture.

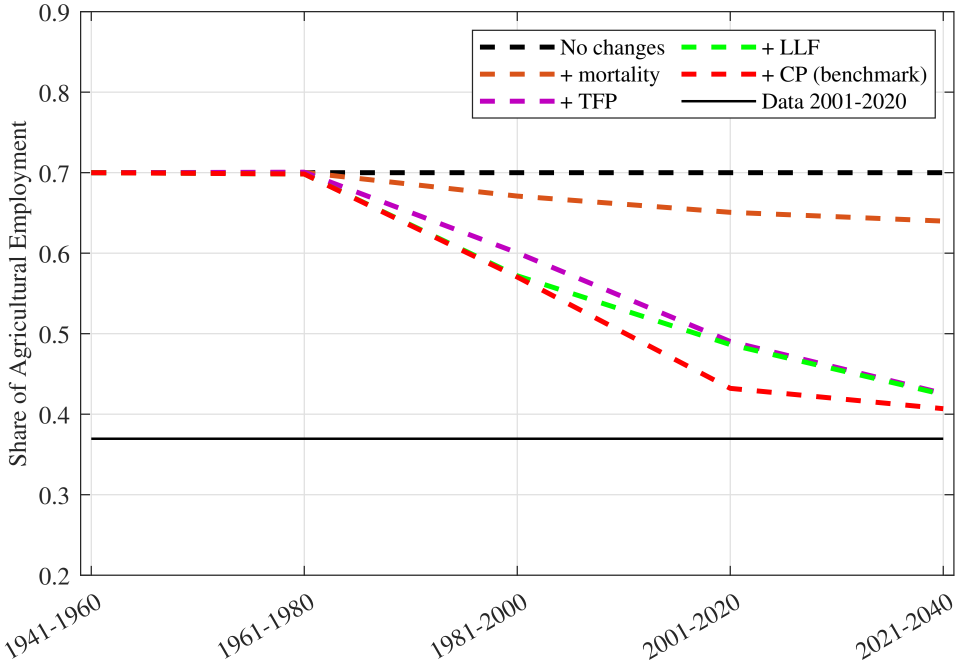
Despite the difference in model fit, the findings on the relative importance of different factors for China's demographic and economic transition are largely unchanged. That is, the population policies are critical for reducing the TFR to far below the replacement level around 1990 and 2010, and TFP growth is the main driving force behind China's structural transformation.




**Appendix Fig. 3** Model and Data (Unit Elasticity)



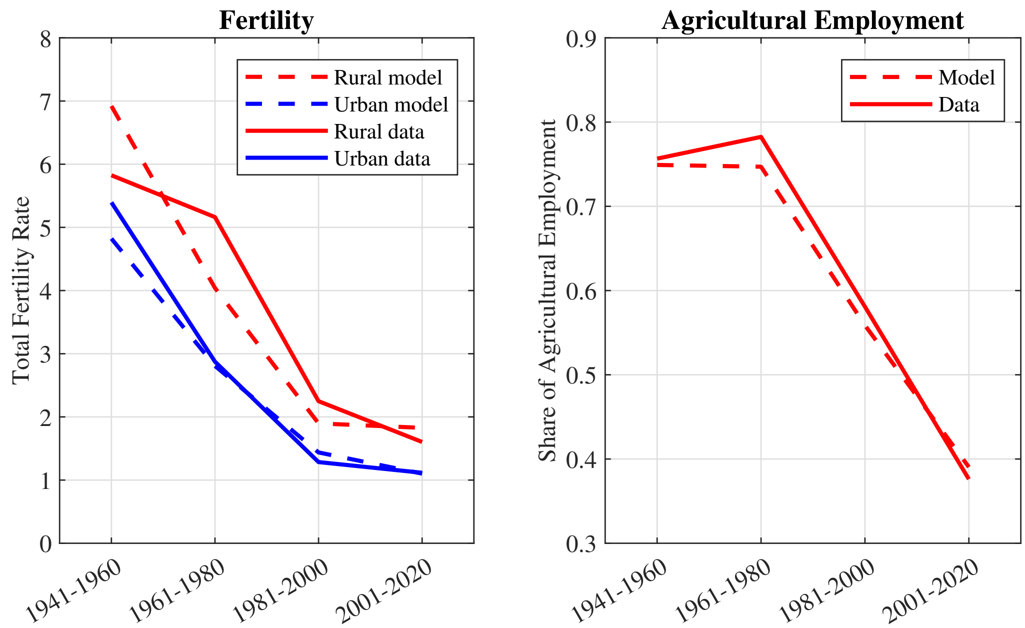

**Appendix Fig. 4** TFR in the Model (Unit Elasticity)




**Appendix Fig. 5** Share of Agricultural Employment in the Model (Unit Elasticity)

## Appendix C. Model Fit without Dropping Abnormal Values in the Data

The share of agricultural employment was very low in the Great Leaping 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. Appendix Fig. 6 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 obviously lower in 1941-1960. The share of agricultural employment is also lower in 1941-1960.

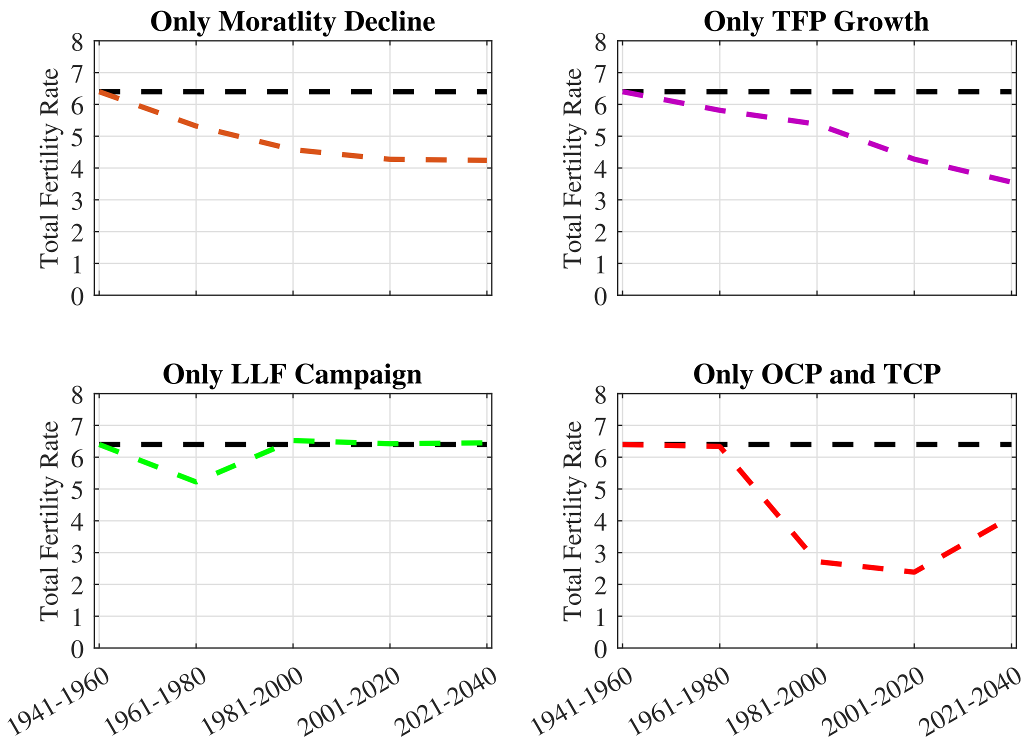



**Appendix Fig. 6** Model and Data (without Dropping Abnormal Values)

## Appendix D. Alternative counterfactual Experiments

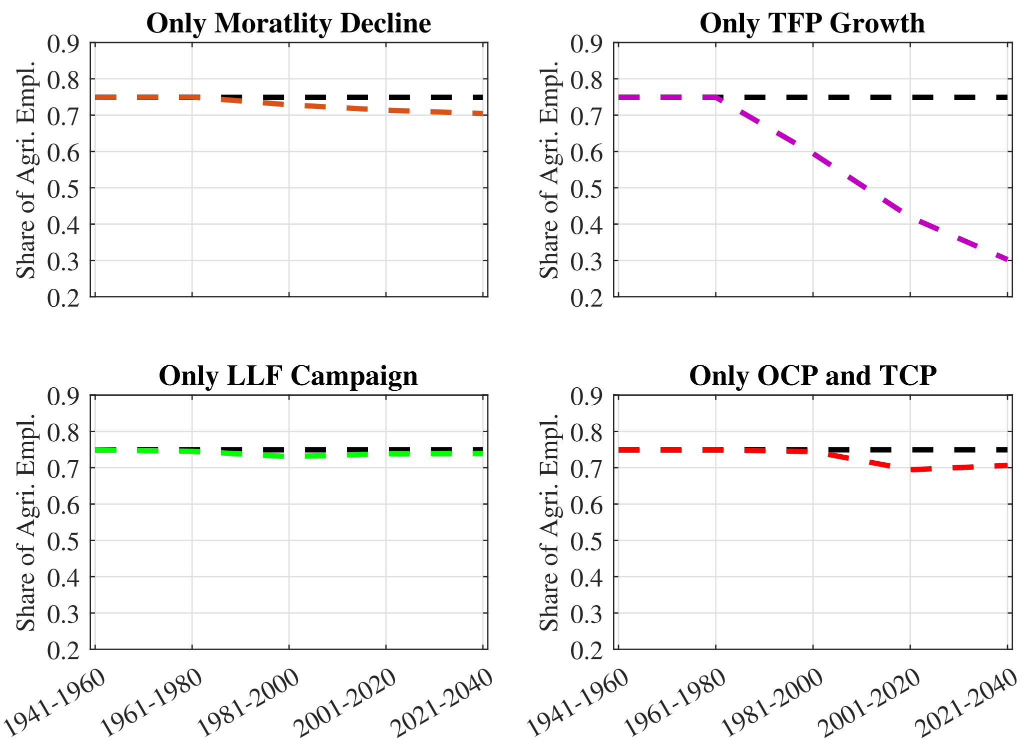
In the main analysis, the exogenous changes are added one after another: first, mortality decline; next, TFP growth; and finally, the population policies. The rationale for this order is that mortality decline proceeded TFP growth in the data and the population policies were imposed additionally by the government. An alternative analysis is to consider only one change each time and examine their effects separately. The results are shown in Appendix Fig. 7 and 8.

Appendix Fig. 7 shows that mortality decline and TFP growth have large effects on the TFR. Mortality decline can reduce the TFR from 6.40 in 1941-1960 to 4.27 in 2001-2020 (the same as in Fig. 8), and TFP growth can reduce the TFR to 4.28. The LLF Campaign can reduce the TFR in 1961-1980 by 1.18. The magnitudes of the effects of these factors are in line with the findings in Fig. 8. One different finding is that the effects of the OCP are even larger. If there is only the OCP, the TFR can drop to 2.72 in 1981-2000 and 2.39 in 2001-2020. However, this is not surprising considering the harsh punishment in case of violation.




**Appendix Fig. 7** TFR in the Model

Appendix Fig. 8 shows that TFP growth has largest effects on structural transformation. It can reduce the share of agricultural employment substantially from 74.9% in 1941-1960 to 41.9% in 2001-2020. By contrast, the effects of mortality decline and the OCP are quite small. Mortality decline can reduce the share of agricultural employment to 71.4% (the same as in Fig. 9), while the OCP can reduce it to 69.4%. Finally, the LLF Campaign causes a small decline from 74.9% to 73.1% in 1981-2000. Overall, the findings verify that TFP growth is the main driving force behind China's structural transformation.




**Appendix Fig. 8** Share of Agricultural Employment in the Model

## Appendix E. 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 urban population equals 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, $\upsilon$ 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 $\upsilon$ 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, 1995-2020) 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 Labour Statistical Yearbook* 2020 (NBSC, 2020).

## Appendix F. 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, health cares, 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 of 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 provide 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 of 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 in government health spending, following Ngai et al. (2019). Afterwards, 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 years and use the same number for each model period.

The data of 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.