BOFIT Discussion Papers
22 • 2017

Jianpo Xue and Chong K. Yip

One-child policy in China: A unified growth analysis

BOFIT
THE BANK OF FINLAND
INSTITUTE FOR ECONOMIES
IN TRANSITION

BOFIT Discussion Papers
Editor-in-Chief Zuzana Fungáčová

BOFIT Discussion Papers 22/2017
29.12.2017

Jianpo Xue and Chong K. Yip: One-child policy in China: A unified growth analysis

ISBN 978-952-323-205-1, online
ISSN 1456-5889, online

Suomen Pankki
Helsinki 2017

One-Child Policy in China: A Unified Growth Analysis

Jianpo Xue and Chong K. Yip

December 29, 2017

Abstract

This paper examines the effects of China's One Child Policy (OCP) in a stylized unified growth model where demographic change plays a central role. Introducing a population constraint into Galor and Weil (2000) model, our theoretical analysis shows that parents are willing to invest in the education of their children immediately after the OCP intervention. Raising the education level, in turn, boosts rates of technological progress and economic growth over the short run, but the low population mass resulting from the OCP hampers the natural economic evolution. This eventually reduces the education gain and technology growth, retarding economic growth in the steady state. We next calibrate our model to match the key data moments in China. A permanent OCP is found to accelerate economic growth by up to 60% over the short run (40 years, or two generations under our assumed generation length), but depress long-run growth to 6.95% (8.94% under natural evolution). For a temporary OCP lifted after two generations, the economic growth shows an immediate decline of about 27%, followed by a gradual recovery to the steady state under natural evolution. While the OCP reduces welfare, the welfare loss from a temporary OCP is less than that from a permanent OCP. This suggests that the recent decision of the Chinese government to abandon the OCP and move to a two-child policy is likely to improve economic growth and welfare over the long run.

JEL classification: J13; O43

Keywords: Unified Growth; One Child Policy (OCP); Welfare

Jianpo Xue, orcid.org/0000-0002-8567-5685. Renmin University of China. Email: jpxue@ruc.edu.cn

Chong K. Yip, orcid.org/0000-0003-2950-2461. The Chinese University of Hong Kong. Email: chong- keeyip@cuhk.edu.hk.

Acknowledgements

For helpful comments and suggestions we thank, without any implications, Zuzana Fungacova, Chao He, Laura Solanko, Junsen Zhang, Xiaobo Zhang, Kai Zhao, the audience at the Fourth Annual Conference on Chinese Economy at Fudan University, the Asian Meeting of the Econometric Society, the First Annual Conference on Public Economics at Peking University, and the seminar participants at Shanghai University of Finance and Economics, Renmin University of China, Bank of Finland. Jianpo Xue thanks Bank of Finland for hosting his visit in February 2017. The usual disclaimers apply.

1 Introduction

Since the publication of Malthus' seminal work, *An Essay on the Principle of Population*, the evolution of population and per capita income has been an important topic in the discussion of economic growth and development. In particular, economists have sought consistent frameworks that capture the historical evolution of population growth and economic growth, including the transitions from one stage of development to the next. To the best of our knowledge, Galor and Weil (2000; henceforth, GW) were the first to attempt such a unified growth model. From a macroeconomic perspective, they divide the historical evolution of population and output into three regimes, with each regime capturing the relationship between the growth rates of per capita income and population. Figure 1 depicts the growth rates of population and per capita income in Western Europe from the 7th to 20th centuries.

Before the 1700s, income per capita was roughly constant and population growth was low. This stage, which GW designate as the *Malthusian Regime*, features a positive relationship between the growth rates of output and population. The Malthusian Regime prevailed for over a millennium in the GW observation period, and likely much longer.

During 1700 to 1900, Western economies transitioned to the *Post-Malthusian Regime*. In this era, output growth allowed income per capita to continue rising instead of solely reflecting population growth. Although the Malthusian relationship between income per capita and population growth remains in place, the diluting effect of high population on income per capita is counteracted by technological progress that allows for moderate growth in both income per capita and population.

The *Modern Growth Regime* extends from 1900 to the present day. It is characterized by the demographic transition in which quality, rather than quantity, is the standard for child rearing. This regime is characterized by a decline in population growth combined with strong growth in income per capita.[1]

The GW model, a unified growth model that encompasses the endogenous transitions between the three regimes described above, provides a comprehensive theoretical framework for explaining the transition mechanism. This endogenous growth mechanism depends on the interaction of popula-

[1] The negative relationship of population growth and economic growth has been a popular topic in existing literature. Some researchers explain that the trade-off in lower fertility rates for investment in children in developed economies induces a substitution of quality for quantity (Barro and Becker, 1989; Becker et al., 1990). Others argue that the higher relative wages of women in developed economies increases the opportunity cost of raising children (e.g. Galor and Weil, 1996).

tion, education, and technology. First, increases in the *population* size boost the rate of technological progress through the rapid diffusion of new ideas and the increased likelihood of technological breakthroughs. This effect is most associated with the transition from the Malthusian Regime to the Post-Malthusian Regime. Second, parental decisions on the amount of formal *education* their children receive affect the rate of technological progress. The intuition here is that children are more likely to adopt and use advanced technology if they are more highly educated, and thus the rate of technological progress is accelerated. Finally, *technological progress* raises the rate of return to human capital, which changes the emphasis in child-rearing from quantity to quality. This shift is most associated with the transition from the Post-Malthusian Regime to the Modern Growth Regime.

The Chinese economy manifests the same three stages of GW development in the output and population growth rates over a compressed period that runs roughly from the 1500s to the present.[2] Figure 2 provides a summary based on Maddison (2003, 2007). Notably, China's transition from its Post-Malthusian stage (1914–1976) to the Modern Growth stage (1977–2003) coincides closely with the implementation of the One-Child Policy (OCP) in China around 1979. This inspires us to consider whether there is a link between the OCP and the development transition. In particular, we ask whether the transition between stages of development can be manipulated by population policies instead of natural evolution. Thus, we introduce a policy variable that affects population growth into the GW model to capture the effects of the OCP.

As the effects involve complicated endogenous interactions among the parameters, the GW model also serves as an excellent tool for examining economic dynamics in the presence of population control.[3] Unfortunately, the GW model's focus on per capita income growth may not provide a fair assessment of the OCP. As Liao (2013, p.49) points out, "focusing solely on GDP per capita as a measure of economic well-being paints an incomplete picture of the welfare consequences of population policies". To perform a welfare analysis of the OCP, we thus follow Song et al. (2015) to compute the welfare cost of the OCP relative to natural evolution. This is done by adopting the socially discounted lifetime utility of the representative household under alternative regimes.

Our first main contribution is to provide a formal theoretical analysis of the impact of population control policy on the timing of takeoff from stagnation to sustained economic growth. We seek to answer a two-part question. Could the modernization process be a manipulated outcome of

[2] For a recent overview of China growth, see Zhu (2012).

[3] The only macroeconomic analysis of OCP in China that we are aware of is Liao (2013). See also Liao (2011) for a more detailed presentation of her overlapping generations model.

government intervention? If yes, what are the costs and benefits of such intervention? As GW model is one of the few popular models that provide an instrument for understanding the interaction between the demographic transition and the takeoff from stagnation to sustained economic growth, we employ the GW model as our workhorse for the theoretical analysis and treat it as the natural evolution process, comparing it with a manipulated version in which several OCP scenarios are considered. The results of this theoretical modeling suggest that an OCP improves short-run growth performance at the expense of steady-state growth.

Our second contribution is the empirical. Based on Chinese data, our calibration shows that the long-run equilibrium growth rate of per capita GDP under natural evolution is about 8.94%. Relative to natural evolution, a permanent OCP raises economic growth for the first two generations by about 60% and 17% respectively. It then lags the rate of natural evolution and eventually is 22% lower in the steady state. A temporary OCP that lasts two generations has a positive effect on per capita GDP growth for the first two generations as in the permanent OCP case, but then becomes worse than a permanent OCP right after it is lifted. Per capita income growth is about 27% below that of natural evolution for the subsequent generation. Thereafter, per capita income growth recovers, approaching the same rate of steady-state growth. We also note the intuitively obvious fact that the welfare cost over time is always higher for a permanent OCP than a temporary OCP as the permanent OCP has more severe adverse effect on the demographics. Finally, we perform a few counterfactuals that relate to the timing and duration of OCP regimes.

Related Literature

There are many empirical studies on the relationship between population growth and economic growth. Most cross-sectional analyses find a negative relationship between the two variables, including Barlow (1994), Brander and Dowrick (1994), Coale (1986), Hazledine and Moreland (1977), Kelley and Schmidt (1994, 1995), and McNicoll (1984). The majority of empirical works, however, do not provide a *causal* effect of population changes on economic growth (Simon, 1989). A review of the debate provided by Kelley (1988) asserts that there is no definite conclusion from the body of empirical tests. Temple (1999) also supports this review.

A notable exception is Li and Zhang (2007), who present empirical evidence for a statistically significant negative causal effect of population growth on economic growth by exploiting the exogenous nature of the OCP of China. Due to limited data, however, their study only presents short-run effects. Moreover, it lacks a theoretical framework for explaining the identified dynamics.

Our paper thus seeks to move the discussion ahead by using the GW model to investigate both the qualitative and quantitative effects of the OCP on China's economic development and welfare. To this end, the most relevant study is Liao (2013), who studies the effects of OCP on income and welfare in an overlapping generations setting. She finds that OCP speeds up the accumulation of human capital and raises per capita income in the steady state. Our unified growth model yields the same conclusion on human capital accumulation, but per capita income growth only rises for a few generations and is lower along the balanced growth path. Thus, the quality improvement in labor cannot compensate its accumulated loss in quantity over time due to OCP.[4] From the welfare perspective, we corroborate Liao's finding that there is a trade-off between generations with the current generations gaining and future generations losing.

The remainder of the paper is organized as follows. Section 2 describes the basic structure of the GW model under the OCP. Following Lagerlöf (2006) and using Chinese data, we calibrate the model and provide some quantitative findings in Section 3. Section 4 states the conclusions and offers some policy considerations.

2 Basic model

Consider a two-period overlapping-generations model in which agents live for two periods.[5] In the initial childhood period, agents have no income, consume nothing and receive an education financed by their parents; whereas in the adulthood period, they earn income from their human capital input and resources owned, consume, decide on how many children they will have and how much they will invest into their children's education. For notational convenience, we follow GW and assume that members of generation t, denoted L_t, participate in the labor market in period t.

According to Galor (2005, p. 238), the unified growth model "is based upon the interaction between several building blocks: the Malthusian elements, the engines of technological progress, the origin of human capital formation, and the determinants of parental choice regarding the quantity and quality of offspring." For our purposes, the OCP obviously affects the decision of parents as to how many children they will have, the quality of their upbringing, and the human capital accumulation

[4] This is consistent with the finding of Rosenzweig and Zhang (2009) that the effect of OCP on human capital accumulation is modest.

[5] We refer to GW's original paper for details. We use identical notation to theirs as much as possible for easy reference.

process. The subsistence consumption constraint, however, remains unchanged.[6]

2.1 Human capital accumulation, technology, and income

Let h_{t+1} denote the human capital accumulated for a member of generation $t+1$ (the children of generation t). It follows that

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

where e_{t+1} is the education investment made in generation $t+1$ by generation t and g_{t+1} is technological progress, which is given by

$$g_{t+1} \equiv \frac{A_{t+1} - A_t}{A_t} = g\left(e_t, L_t\right) \tag{2}$$

where $g(0, L) > 0$, $g_i > 0$, and $g_{ii} > 0$ for $i = e, L$. Following GW, we assume that $h > 0$, $h_e > 0$, $h_g < 0$, $h_{ee} < 0$, $h_{gg} > 0$ and $h_{eg} > 0$ for $\forall\left(e_{t+1}, g_{t+1}\right) \geq 0$, such that human capital is increasing but concave in education, decreasing but convex in the rate of technological progress, and technology complements skills in the production of human capital.

Per capita production, or income, denoted by z_t, is given by the Cobb-Douglas technology:

$$z_t = h_t^{\alpha}\left(\frac{A_t X}{L_t}\right)^{1-\alpha} = h_t^{\alpha} x_t^{1-\alpha}, \tag{3}$$

where $x_t \equiv A_t X / L_t$ represents the per capita resources, A_t represents the endogenously determined technology level at time t, L_t is the efficiency labor input, X is the resource owned by the agents, and $\alpha \in (0, 1)$ measures the profit share of human capital.

2.2 Preference and population control

The utility function of an agent is given by

$$u_t = (1 - \gamma) \ln c_t + \gamma \ln\left(n_t h_{t+1}\right), \tag{4}$$

where $\gamma \in (0, 1)$, c_t and n_t are the consumption and number of (surviving) children in each period, respectively. Agents face the budget constraint

$$z_t n_t\left(\tau^q + \tau^e e_{t+1}\right) + c_t = z_t, \tag{5}$$

[6] For an alternative analysis on the relation between the China OCP and human capital accumulation, see Rosenzweig and Zhang (2009).

where τ^q and τ^e are the fractions of the individual's unit time endowment required for raising and educating a child. Similar to Liao (2013), the OCP is captured by a quantitative upper bound $\bar{n}$:

$$n_t \leq \overline{n}. \tag{6}$$

According to (6), when $n_t < \overline{n}$, we again have the original GW model. For $n_t \geq \overline{n}$, we simply have $n_t = \overline{n}$. When $n_t = \overline{n} = 1$, we have the simplest, but important, form of population control whereby population is held constant over time.[7] We take this as our benchmark case for the analysis of the OCP.

The agent has to maximize their utility subject to the following constraints: the budget constraint (5), the human capital accumulation constraint (1), the population policy restriction (6), a subsistence consumption constraint, $c_t \geq \widetilde{c}$, and the quality constraint of non-negative education, $e_{t+1} \geq 0$. Thus, the optimization problem for an agent of generation t is

$$\max_{n_t, e_{t+1}} (1-\gamma) \ln \left\{ z_t \left[1 - n_t \left(\tau^q + \tau^e e_{t+1}\right)\right] \right\} + \gamma \ln \left[n_t h\left(e_{t+1}, g_{t+1}\right)\right] \tag{7}$$

s.t.

$$z_t \left[1 - n_t \left(\tau^q + \tau^e e_{t+1}\right)\right] \geq \widetilde{c}$$

$$n_t \leq \overline{n}, \qquad e_{t+1} \geq 0.$$

The first-order conditions are given by

n_t :

$$-\frac{(1-\gamma)\left(\tau^q + \tau^e e_{t+1}\right)}{1 - n_t\left(\tau^q + \tau^e e_{t+1}\right)} + \frac{\gamma}{n_t} - \lambda_t z_t \left(\tau^q + \tau^e e_{t+1}\right) - \eta_t = 0$$

e_{t+1} :

$$\begin{aligned} -(1-\gamma)\frac{n_t \tau^e}{1 - n_t\left(\tau^q + \tau^e e_{t+1}\right)} + \gamma \frac{h_e\left(e_{t+1}, g_{t+1}\right)}{h\left(e_{t+1}, g_{t+1}\right)} - \lambda_t z_t n_t \tau^e \quad &\leq \quad 0 \text{ and } e_{t+1} \geq 0 \\ \text{and } e_{t+1}\left[-\frac{(1-\gamma)\, n_t \tau^e}{1 - n_t\left(\tau^q + \tau^e e_{t+1}\right)} + \gamma \frac{h_e\left(e_{t+1}, g_{t+1}\right)}{h\left(e_{t+1}, g_{t+1}\right)} - \lambda_t z_t n_t \tau^e\right] \quad &= \quad 0 \end{aligned}$$

λ_t :

$$z_t \left[1 - n_t\left(\tau^q + \tau^e e_{t+1}\right)\right] - \widetilde{c} \geq 0, \quad \lambda_t \geq 0 \text{ and } \lambda_t \left(z_t \left[1 - n_t\left(\tau^q + \tau^e e_{t+1}\right)\right] - \widetilde{c}\right) = 0$$

η_t :

$$\overline{n} - n_t \geq 0, \quad \eta_t \geq 0 \text{ and } \eta_t \left(\overline{n} - n_t\right) = 0.$$

From the first-order conditions, the quality-quantity decision of an agent depends on whether the constraints on subsistence consumption, population control policies, and non-negative education investment are binding.

[7] This is the only quantitative restriction on n_t such that we can have a stationary steady-state equilibrium.

2.3 Effective population control

If the policy constraint on fertility is not binding where $n < \bar{n}$ or $\eta_t = 0$, then the model is simply that of GW. As the novelty of our analysis lies in the binding fertility restriction case in which $n = \bar{n}$ or $\eta_t > 0$, we focus on this case for the derivation of the dynamical system below. In addition, as we develop the model for studying China's OCP, we must have an effective OCP in the Post-Malthusian period, when the subsistence consumption constraint no longer binds.

2.3.1 The consumption choice

When the shadow price of consumption λ_t is positive, the subsistence constraint is binding as $c_t = \widetilde{c}$. When λ_t equals zero, the consumption is above the subsistence level, i.e. $c_t > \widetilde{c}$, which is given by the budget constraint (5). Following GW in defining the level of potential income at which the subsistence constraint just binds as $\tilde{z} \equiv \widetilde{c}/\left(1-\gamma\right)$, we have

$$c_t = \begin{cases} \widetilde{c} & \text{if } z_t \le \tilde{z} \,, \\ z_t \left[1 - \overline{n}\left(\tau^q + \tau^e e_{t+1}\right)\right] & \text{if } z_t \ge \tilde{z} \,. \end{cases} \tag{8}$$

2.3.2 The fertility choice

The number of the children is determined by the policy parameter $n_t = \overline{n}$ in the Post-Malthusian period, where $\lambda_t = 0$. Thus, η_t can be solved as

$$\eta_t = \frac{\gamma}{\overline{n}} - \left[\frac{1-\gamma}{1-\overline{n}\left(\tau^q + \tau^e e_{t+1}\right)}\right]\left(\tau^q + \tau^e e_{t+1}\right). \tag{9}$$

Then, we have

$$\eta_t = \frac{\gamma - \overline{n}\left(\tau^q + \tau^e e_{t+1}\right)}{\overline{n}\left[1-\overline{n}\left(\tau^q + \tau^e e_{t+1}\right)\right]} \equiv \eta\left(e_{t+1}, \overline{n}\right). \tag{10}$$

From (3), we have

$$z_t = h_t^{\alpha} x_t^{1-\alpha} \equiv z\left(e_t, g_t, x_t\right). \tag{11}$$

It is straightforward to show that the partial derivatives are given by

$$z_e\left(e_t, g_t, x_t\right) > 0, z_g\left(e_t, g_t, x_t\right) < 0, z_x\left(e_t, g_t, x_t\right) > 0.$$

Finally, the efficient level of resources per capita is determined by

$$\frac{x_{t+1}}{x_t} = \frac{1+g_{t+1}}{\overline{n}}\,.$$

2.3.3 The education choice

From the first-order condition for e_{t+1}, we define an implicit function of e_{t+t} and g_{t+1} as follows:

$$\bar{G}(e_{t+1}, g_{t+1}, \bar{n}) \equiv (\tau^q + \tau^e e_{t+1}) h_e - [1 - \Phi(\bar{n}, e_{t+1})] \tau^e h \begin{cases} = 0 & \text{if } e_{t+1} > 0 \\ \leq 0 & \text{if } e_{t+1} = 0 \end{cases} \tag{12}$$

where

$$\Phi(\bar{n}, e_{t+1}) = \frac{\gamma - \overline{n}(\tau^q + \tau^e e_{t+1})}{\gamma [1 - \overline{n}(\tau^q + \tau^e e_{t+1})]} \tag{13}$$

by using (10). From (13), we obtain

$$\Phi_e(\bar{n}, e_{t+1}) = \frac{\partial \Phi(\bar{n}, e_{t+1})}{\partial e_{t+1}} = -\frac{(1-\gamma)\overline{n}\tau^e}{\gamma [1 - \overline{n}(\tau^q + \tau^e e_{t+1})]^2} < 0 ,$$

$$\Phi_n(\bar{n}, e_{t+1}) = \frac{\partial \Phi(\bar{n}, e_{t+1})}{\partial \bar{n}} = -\frac{(1-\gamma)(\tau^q + \tau^e e_{t+1})}{\gamma [1 - \overline{n}(\tau^q + \tau^e e_{t+1})]^2} < 0.$$

Hence, we have

$$\bar{G}_n = \tau^e h \Phi_n < 0 ,$$

$$\bar{G}_g = (\tau^q + \tau^e e_{t+1}) h_{eg} - (1 - \Phi) \tau^e h_g > 0 ,$$

$$\bar{G}_e = (\tau^q + \tau^e e_{t+1}) h_{ee} + \Phi \tau^e h_e + \tau^e h \Phi_e < 0 ,$$

where

$$\Phi \tau^e h_e + \tau^e h \Phi_e = -\frac{\tau^e h_e}{1 - \overline{n}(\tau^q + \tau^e e_{t+1})} \left[1 - \frac{\gamma - \overline{n}(\tau^q + \tau^e e_{t+1})}{\gamma} \right] < 0.$$

To ensure that there exists a positive g_{t+1} such that the chosen level of education is zero, we assume further that

Assumption A1 $\bar{G}(0, 0, \overline{n}) < 0$.

The solution of e_{t+1} is given by

$$\bar{G}(e_{t+1}, g_{t+1}, \bar{n}) = 0.$$

In addition, following GW, we assume e_{t+1} to be concave in g_{t+1}:

Assumption A2 $\partial^2 e(g_{t+1}; \bar{n}) / \partial g_{t+1}^2 < 0$ for $g_{t+1} > \bar{g}$.

We next obtain the following lemma to determine the education level e_{t+1}:

Lemma 1 *Under Assumptions A1 and A2, the level of education e_{t+1} is a non-decreasing concave function of* g_{t+1} :

$$e_{t+1} = e\left(g_{t+1}; \bar{n}\right) \begin{cases} = 0 & \text{if } g_{t+1} \leq \bar{g} \\ > 0 & \text{if } g_{t+1} > \bar{g} \end{cases} \tag{14}$$

where $\bar{g} > 0$ such that $\bar{G}\left(0, \bar{g}, \bar{n}\right) = 0$, and

$$\frac{\partial e\left(g_{t+1}; \bar{n}\right)}{\partial g_{t+1}} > 0, \frac{\partial e\left(g_{t+1}; \bar{n}\right)}{\partial \bar{n}} < 0,$$

for $\forall g_{t+1} > \bar{g}$.

Next, recall (2) and the fact that $n = \bar{n}$; we have

$$g_{t+1} = g\left(e_t, L_t\right) = g\left(e_t, L_0 \bar{n}^t\right). \tag{15}$$

This defines another relationship between technological progress and education that shifts over time.[8] However, when the population control policy parameter is set such that the population size is constant (i.e., $\bar{n} = 1$), then (15) becomes stable over time.

2.4 The dynamical system

Recalling the definition of x_t, (14) in Lemma 1 and (15), we obtain the full dynamical system as follows:

$$x_{t+1} = \left(\frac{1 + g_{t+1}}{\overline{n}}\right) x_t \tag{16}$$

$$e_{t+1} = e\left(g_{t+1}; \overline{n}\right) = e\left(g\left(e_t, L_t\right); \overline{n}\right) \begin{cases} = 0 & \text{if } g_{t+1} \leq \bar{g} \\ > 0 & \text{if } g_{t+1} > \bar{g} \end{cases} \tag{17}$$

$$g_{t+1} = g\left(e_t, L_t\right) \tag{18}$$

$$L_{t+1} = \overline{n} L_t. \tag{19}$$

where the last dynamic equation comes from the definition of the population growth rate. This system then governs the evolution of income per worker, education/human capital, technological progress, and the population size of the economy.

[8] We note that the relevant restriction is $\bar{n} \geq 1$. For the analysis of $\bar{n} > 1$, it is qualitatively identical to the case of natural evolution in GW. However, in the analysis of $\bar{n} < 1$, $g\left(e_t, L_t\right)$ can shift downward over time.

2.4.1 The evolution of (e_t, g_t)

To analyze the evolution of education (e_t) and technological progress (g_t), we follow GW and focus on (17) and (18) for a given population size L. We define the ee locus to be the (e_{t+1}, g_{t+1}) combinations that satisfy (17), whereas the tg locus is defined by (18). We depict the case of multiple steady states for a moderate population size in Figure 3.

There are two stable steady states. One is a Malthusian trap $\left(0, g^{\ell}\right)$, while another represents a Modern Growth steady state $\left(e^{h}, g^{h}\right)$. The unstable steady state (e^u, g^u) is the threshold for dividing the two stable equilibria. Depending on L and $\overline{n}$, we can provide the qualitative characterization of (e_t, g_t) under three different configurations. It is straightforward to show that[9]

$$\frac{d\bar{g}}{d\overline{n}} > 0.$$

This, together with Lemma 1, implies that a reduction in $\bar{n}$ (hence, a lower $\bar{g}$), shifts the ee locus downward in Figure 3. However, the tg locus depends on the current population size, so a reduction in $\bar{n}$ does not affect it instantaneously. With $g_L(e_t, L_t) > 0$, the reduction in $\bar{n}$ begins to affect the tg locus in the subsequent period. More important, depending on the resulting magnitude of $\bar{n}$, the dynamics of the population size will continue to affect the location of the tg locus over time. Specifically, for $\bar{n} > (<) 1$, the tg locus shifts up (down) over time in the (e_t, g_t) space.

2.4.2 Comparative statics

Consider the benchmark case in which $\overline{n} = 1$ initially. We have a constant population size over time (i.e. $L_t = \bar{L}\ \forall t$). Depending on the initial population size, we can obtain only one of the three possible configurations depicted in GW without the endogenous transition over time. Beginning with this benchmark case, a rise (reduction) in $\overline{n}$ first shifts the ee locus up (down). The instantaneous effect of the rise (reduction) in $\overline{n}$ moves us toward the low (high) steady state $\left(0, g^{\ell}\right)$ $[\left(e^{h}, g^{h}\right)]$. However, when $\overline{n}$ is increased (reduced), the tg locus begins to shift up (down) over time in the (e_t, g_t) space.

[9] Under an effective population control policy, we can obtain the threshold technology growth rate $\bar{g}$ by setting $\bar{G}(0, \bar{g}, \bar{n}) = 0$ (Lemma 1). After some substitution and rearrangement, we have

$$\bar{G}(0, \bar{g}, \bar{n}) = \tau^{q} h_e(0, \bar{g}) - \varepsilon \tau^{e} h(0, \bar{g}) = 0$$

where

$$\varepsilon = \frac{1-\gamma}{\gamma} \frac{\overline{n}\tau^{q}}{1 - \overline{n}\tau^{q}}.$$

Applying the implicit function theorem yields the comparative statics result.

We eventually converge on the stable high (low) steady state $\left(e^h, g^h\right)$ $\left[\left(0, g^\ell\right)\right]$. Although the two loci change in opposite directions, the shift of the tg locus over time eventually dominates in the benchmark case. This provides an illustration of the trade-off effects of population control policies between the short and long run.

Now consider an alternative case in which population policy is reduced from $\bar{n} > 1$ to $\bar{n} = 1$ so as to preserve a stable population size. The reduction of $\bar{n}$ shifts the ee locus down, whereas the tg locus remains stable at the current population size over time (see Figure 4). This is an example of implementing a policy to replace the mechanism of natural evolution (the shift of the tg locus due growth in the population over time) to achieve the same qualitative equilibrium outcome.

The higher the current population growth rate under population control ($\bar{n}$), the larger the magnitude of the downward shift in the ee locus. Thus, effective population control is more likely to help a country escape the development trap and move to a stable high steady state $\left(e^h, g^h\right)$.

Finally, suppose that we are at the Post-Malthusian stage in which population reaches a medium size such that multiple steady states emerge. Given the introduction of the population control policy represented by a reduction in $\bar{n}$, the first outcome is a downward shift in the ee locus. There are three possible ultimate steady-state outcomes depending on the severity of the population control policy. If the new population policy target is at $\bar{n} = 1$, we are very likely to achieve a stable new higher steady state $\left(e^h, g^h\right)$. This positive outcome is guaranteed when we have the possibility of $\bar{n} > 1$. This is because the tg locus begins to shift up over time, and thus, the high steady state is a certain equilibrium outcome. However, if the population control policy is sufficiently stringent that $\bar{n} < 1$, then the final outcome is completely different. Although a large reduction in $\bar{n}$ can shift the ee locus down significantly to where we are initially able to achieve the Modern Growth Regime, the subsequent developments differ. When $\bar{n} < 1$, the tg locus also begins to shift down over time. With this restricted level of $\bar{n}$, the final outcome must be the case in which the population size declines to such a low level that we fall into the Malthusian trap.

2.5 Global dynamics

We now consider how population control policy governs the demographic transition and hence the *evolution* of the economy from the Post-Malthusian Regime to the Modern Growth Regime. Following GW, the global analysis is based on a sequence of phase diagrams that describe the evolution of the system within each regime and the transition between the regimes on the (e_t, x_t) dimension. The phase diagrams contain two elements: the XX locus, which denotes the set of all pairs (e_t, x_t) for which effective resources per worker are constant $(x_{t+1} = x_t, \forall t)$, and the EE locus, which denotes the set of all pairs (e_t, x_t) for which the level of education per worker is constant $(e_{t+1} = e_t, \forall t)$.

We first derive the XX locus, which is given by

$$x_{t+1} = x_t \iff 1 + g(\hat{e}, L_t) = \overline{n} .$$

It is a vertical curve in the (e_t, x_t) space located at $e_t = \hat{e}$. Without delving excessively into analytical detail, we simply make the following assumption for $\hat{e}$:

Assumption A3 $\bar{g} < g(\hat{e}, L) < g^h\left(e^h, L\right)$.

We then conclude

$$\begin{aligned} x_{t+1} &> x_t \quad \text{if} \;\; e_t > \hat{e} \\ x_{t+1} &= x_t \quad \text{if} \;\; e_t = \hat{e} \\ x_{t+1} &< x_t \quad \text{if} \;\; e_t < \hat{e} \; . \end{aligned}$$

Furthermore, for a reduction (rise) in $\bar{n}$, the XX locus shifts to the left (right).

Next, for the EE locus, we have

$$\begin{aligned} EE &\equiv \{(e_t, x_t) : e_{t+1} = e_t\} \\ or \qquad e_{t+1} &= e\left(g\left(e_t, L_t\right); \overline{n}\right) \; . \end{aligned}$$

For a given population size, the steady-state values of e_t are independent of x_t. Thus, the EE locus is again a vertical line in the (e_t, x_t) space, the location of which depends on the size of the population L (which in turn determines the relative positions of the ee locus and the tg locus). The effects of a change in $\overline{n}$ on its location operate through the interactions of the ee locus and the tg locus. Overall, we have three possible cases of steady-state equilibria for any given level of population size and $\bar{n}$.

2.6 Conditional steady-state equilibria

We apply our global dynamic analysis to the benchmark case in which $\overline{n} > 1$ such that the size of the population evolves naturally over time. Suppose that a tightening of $\overline{n}$ to unity is effective when the population size is at its intermediate level, at which multiple equilibria are present (see Figure 5).

The instantaneous effect is that the ee locus in Figure 4 shifts down, meaning that the high steady state (e^h, g^h) moves to the right, whereas the low steady state (e^u, g^u) moves to the left. As a result, the EE locus $(e_{t+1} = e_t, \forall t)$ located at e^u (e^h) shifts left (right), whereas the XX locus $(x_{t+1} = x_t, \forall t)$ shifts left. Thus, the region where the law of motion indicates a convergence toward e_h expands. The limiting case is the situation where the EE locus located at e^u coincides with the vertical axis so that $e_t = e_h$.

The above analysis of global dynamics can be completely different if the population control policy is stringent enough to achieve $\overline{n} < 1$, leading to a decline in the population size over time. The instantaneous effect again is that the ee locus in Figure 4 shifts down, but the reduction in L also shifts down the tg locus over time. The location of the steady states begins to reverse: the high steady state (e^h, g^h) moves to the left, whereas the low steady state (e^u, g^u) moves to the right. In the phase diagram, this is also reflected in the reversed movements of both the EE and XX loci: the EE locus located at e^u (e^h) shifts right (left), whereas the XX locus shifts right. As a result, the region where $e_{t+1} > e_t$ shrinks over time and eventually vanishes so that education can only decline over time. Other things being equal, we are ultimately converging to the Malthusian steady-state equilibrium of $e_t = 0$. Thus, a permanent population control policy that ultimately yields $(\overline{n} < 1)$ must be harmful.

Our analysis reveals that there is an instantaneous or short-run gain from restricting population growth that allows the economy to move toward the high-growth steady state. Qualitatively, a compromise to improve the overall situation seems to involve tightening the restriction on population growth for a certain period of time (i.e. temporarily) and then relaxing the restriction to prevent a decline in the population size over time.

3 Quantitative analysis of China's OCP

China introduced its OCP in 1979 with the aim of increasing resources per capita and facilitating China's economic reforms. Under the policy, each family was limited to a single child, with penalties imposed for subsequent births. The OCP successfully reduced the average annual population growth rate from the 1.87% (observed from 1960 to 1979) to the 1.28% (observed from 1980 to 1999). Before the formal announcement of the OCP, premier Zhou Enlai initiated a nationwide campaign in the 1970s that called upon cadres at all administrative levels to promote population control. Later marriage, longer intervals between births, and fewer children were advocated. The officially stated means of policy implementation were education, propaganda, and mild persuasion. While this approach to population control policy resulted in a decline in the population growth rate in the early 1970s, more aggressive measures seen necessary. In 1979, the Chinese government officially announced the OCP.[10]

In this section, we introduce a numerical version of the model to study the quantitative effects of the OCP. To proceed, we specify the functional forms for the technology and preferences of the basic model *à la* Lagerlöf (2003, 2006). Then we choose the parameterization following common practice in the literature. We also propose a welfare analysis for assessing the OCP. Finally, we graphically present our findings of the effects of the OCP on growth and welfare.

3.1 Functional forms

Following Lagerlöf (2003, 2006), we set $\tau^q = \tau$ and $\tau^e = 1$. The human capital accumulation function is specified as

$$h_{t+1} = h\left(e_{t+1}, g_{t+1}\right) = \frac{e_{t+1} + \rho\tau}{e_{t+1} + \rho\tau + g_{t+1}} \ ,$$

where $\rho \in (0, 1)$ denotes the relative time cost of having a child, and hence, $e_{t+1} + \rho\tau$ can be regarded as the effective level of education. Furthermore, technological progress g_{t+1} takes the form

$$g_{t+1} = g\left(e_t, L_t\right) = \left(e_t + \rho\tau\right) a\left(L_t\right)$$

where $a\left(L_t\right)$ is the scale effect determined by

$$a\left(L_t\right) = \min\left\{\theta L_t, a^*\right\}$$

where θ and a^* are both positive scale parameters. Therefore, the education dynamics e_{t+1} are a function of e_t and L_t.

Definition 1 *The recursive system is defined by three dynamic equations on g_{t+1}, A_{t+1} and L_{t+1} and two specific equations for e_{t+1} and n_t under the population control policy in the Post-Malthusian Regime:*

$$g_{t+1} = \left(e_t + \rho\tau\right) a_t \ ,$$

$$A_{t+1} = \left(1 + g_{t+1}\right) A_t \ ,$$

$$L_{t+1} = n_t L_t \ ,$$

[10] See Yang and Chen (2004) and Liao (2013) for a detailed review of the OCP in China.

where

$$a_t = \min\{\theta L_t, a^*\} \ .$$

When population control policy is not in effect (i.e. natural evolution is allowed), education and fertility choices are determined by

$$e_{t+1} = \max\left\{0, \sqrt{(1-\rho)\,\tau g_{t+1}} - \rho\tau\right\}$$

$$n_t = \begin{cases} \frac{\gamma}{\tau+e_{t+1}} & if\ z_t \geq \frac{\widetilde{c}}{1-\gamma} \\ \frac{1-\widetilde{c}/z_t}{\tau+e_{t+1}} & if\ z_t < \frac{\widetilde{c}}{1-\gamma} \end{cases}$$

where

$$z_t = \left(\frac{e_t+\rho\tau}{e_t+\rho\tau+g_t}\right)^{\alpha}\left(\frac{A_t X}{L_t}\right)^{1-\alpha} .$$

When the OCP is in effect, education and fertility choices are determined by

$$e_{t+1} = \max\left\{0, \sqrt{\left(\varepsilon^{-1}+\frac{\gamma\rho}{1-\gamma}\right)\tau g_{t+1} + \left[\frac{]}{g_{t+1}}\left[2\,(1-\gamma)^2} - \left[\rho\tau + \frac{g_{t+1}}{2\,(1-\gamma)}\right]\right]\right\}$$

$$n_t = \overline{n}$$

both for given initial values of L_0, e_0, and n_0, together with the parameters a^*, α, τ, ρ, γ, θ, X, $\widetilde{c}$.

3.2 Parameterization

Following the suggestion of Boldrin and Jones (2002), we define the length of a generation to be 20 years. The labor share of output α is set to be 0.443, which is estimated using employee compensation as a fraction Chinese GDP.[11] The time devoted to education in the Modern Growth Regime e^* equals 7.5%, the world average, whereas the fertility rate in the Modern Growth Regime n^* is normalized to 1, and the initial population L_0 to be 0.364 (Lagerlöf, 2006). We also set the fixed time cost τ at 0.15, which is the same as the US value.[12]

In the unified growth framework, we concentrate on the interaction between the demographic transition and the take-off from the Post-Malthusian Regime to the Modern Growth Regime. To

[11] This is based on the Income Approach Components of the Gross Regional Product Table from the National Bureau of Statistics of China. Another reference for a detailed analysis of the factor income distribution in China is Bai and Qian (2009).

[12] See the detailed discussion on choosing e^*, n^* and τ (Lagerlöf, 2006). Here we implicitly assume that the education time e^*, fertility rate n^*, and the education time τ in the Modern Growth Regime are identical for all countries. In other words, all countries converge to the same steady-state over the long run.

highlight the effect of population control policy, we assume that the OCP is the only effective policy factor that influences China economic growth in this period.[13] We calibrate the target value of the technology growth rate in the Modern Growth Regime g^* and the timing of imposing the OCP to match two certain key data moments of the Chinese experience. These key moments are *the timing* of implementing OCP in China, i.e. the final generation of the Post-Malthusian period (say, 35th generation); and the *per-adult income growth rate*, which is 6% after 40 years (two generations) of OCP. From this, we back out the steady-state growth rate of technology g^* and the per capita GDP under natural evolution. These values are 17.5541 and 8.94%, respectively.

Having obtained values for g^* and e^*, we can solve a^* and ρ from the equations for the Modern Growth Regime

$$g^* = a^{*2}\tau\left(1-\rho\right) \ ,$$

$$e^* = a^*\tau\left(1-\rho\right) - \rho\tau \ .$$

The parameter γ is set such that population is constant in the Modern Growth Regime, i.e. $n^* = \gamma/\left(\tau + e^*\right)$.

We assume that the population control parameter $\overline{n} = 1$ is such that the population size does not decline when the OCP is in effect. Following Lagerlöf (2006), the remaining parameters such as θ, X, and $\widetilde{c}$ are all normalized to one.

For the initial values, we also follow the method used in Lagerlöf (2006). We assume that the education level e_0 is zero and, hence, that the initial technology is $g_0 = \rho\tau\theta L_0$. The income equals the subsistence level such that $z_0 = \widetilde{c}/\left(1-\tau\right)$. From the production function, we can solve for A_0 for a given z_0, L_0, X, θ, and α. The remaining parameters (θ, X, and $\widetilde{c}$) are all normalized to 1. We provide a summary of the parameterization in Table 1.

3.3 Welfare

In addition to Lagerlöf's quantitative analysis of demographics and growth, we provide a welfare assessment of the OCP along the lines of Song et al. (2015). We assess the welfare effects of the permanent and the temporary OCP. To compute the welfare cost of the OCP relative to natural

[13] China implemented many reforms in the late 1970s, including the Opening Up Policy, the restoration of national college entrance examination, and the abolition of the people's communes, etc. All these reforms had great impact on the factor productivity and contributed to China's economic growth. Here, we concentrate on the growth effect of the *demographic* transition, i.e. the sphere in which the OCP had its most profound effect.

evolution, we follow the standard criterion of adopting the (socially) discounted lifetime utility of the representative household under regime j (either OCP or natural evolution):

$$V_0^j = \sum_{t=0}^{\infty} \phi^t L_t^j u_t^j \left(c_t^j, n_t^j, h_{t+1}^j \right)$$

where $\phi \in (0,1)$ is the social discount factor across generations and $u_t^j \left(c_t^j, n_t^j, h_{t+1}^j \right) = (1-\gamma) \ln c_t^j + \gamma \ln \left(n_t^j h_{t+1}^j \right)$ is given by (4). Thus, the equivalent variation is obtained from ω in the following specification:

$$\sum_{t=0}^{\infty} \phi^t L_t^{NE} u_t^{NE} \left((1+\omega) c_t^{NE}, n_t^{NE}, h_{t+1}^{NE} \right) = \sum_{t=0}^{\infty} \phi^t L_t^{OCP} u_t^{OCP} \left(c_t^{OCP}, n_t^{OCP}, h_{t+1}^{OCP} \right)$$

where $\omega < 0$ measures the welfare loss due to the implementation of the OCP. The choice of the social discount factor ϕ is crucial for the analysis. Following Song et al. (2015), we employ $\phi = 0.975$ for our hypothetical planner.

3.4 Findings

3.4.1 The permanent OCP case

From the calibration, once the OCP is implemented ($n_t = \bar{n} = 1$), the instantaneous effect is a corresponding jump in GDP per capita. Population control promotes strong growth in GDP per capita in the short run. This finding is consistent with our theoretical prediction and the empirical results of Li and Zhang (2007). In the benchmark case, as shown in Figure 6, the timing of the imposition of the OCP is chosen to be the 35th generation, i.e. the final generation of the Post-Malthusian era. When the OCP is implemented, a critical mass of population cannot be accumulated due to zero population growth. This reduces growth performance in the steady state. However, Figure 6 also shows that education begins to increase once the OCP is implemented. This implies that the OCP causes agents to experience the quantity-quality trade-off earlier than under natural evolution. This is because the reduction in $\bar{n}$ reduces the threshold level of technological growth ($\bar{g}$) such that it pays to acquire education. However, once the quantity-quality trade-off begins under natural evolution, the relative gain in per capita income growth under OCP vanishes.

From the analysis, we can see that the OCP in China yields higher economic growth than does natural evolution for more than two generations (40+ years), owing to both the instantaneous effect of a smaller population base and a higher education level resulting from an earlier quantity-quality trade-off. Specifically, the per capita income growth rates are 5.82% and 6% for the 36th and

37th generations under permanent OCP, whereas they are 3.64% and 5.12%, respectively, under natural evolution. The policy's long-run cost is much higher, however, with a 22% decline in per capita GDP growth in the steady state (6.95% under permanent OCP versus 8.94% under natural evolution), due to the lower population mass and education in the steady state. In fact, growth under natural evolution is higher than growth under OCP starting from the third generation after the implementation of the policy.

Moreover, the earlier the government imposes the OCP, the lower the resulting GDP per capita growth rate. This is consistent with our unified growth theory of OCP. The earlier the OCP is implemented, the less likely we are to achieve critical mass in the labor force, thereby magnifying the negative quantity effect on growth relative to the positive quantity-quality trade-off effect.

To see this, we perform two OCP experiments. We first impose the OCP one generation earlier (34th generation). Figure 7 shows that the trade-off between the short-run gain and long-run cost rises significantly. However, if we postpone the OCP for one generation such that it is imposed during the Modern Growth Period (36th generation), then the trade-off between the short-run gain and long-run cost diminishes. This confirms our intuition that delaying the implementation of the OCP reduces the negative quantity effect and increases the positive quantity-quality trade-off effect.

Summary 1 *The OCP promotes growth in the short run, but retards it in the steady state. The earlier the OCP is imposed, the higher its long-run cost in terms of lower growth.*

3.4.2 The temporary OCP case

The Chinese central government recently abandoned the OCP by allowing each family to have two children. For analytical convenience, we can regard this as the situation in which the population constraint is non-binding. Thus, we can study the suspension of the OCP by treating the original OCP as a temporary policy that lasted for two generations (approximately 40 years, 1979–2016). We illustrate the effects of China's temporary OCP in Figure 8.

Figure 8 shows that the economy enjoys higher income growth relative to natural evolution for two generations, then falls behind and ultimately returns to the same steady-state level. Notably, when population growth rebounds, per capita income growth declines. The duration of the transition is essentially identical to that under natural evolution. As shown in Figure 8, population growth with a temporary OCP is higher than that under natural evolution for a few generations in transition. This intuitively makes sense; a critical population mass has to be achieved under the temporary

OCP to obtain the same steady-state level of income growth. The temporary OCP exhibits more fluctuations in income growth than does the permanent OCP. This is due to the fluctuations in population growth because the economy has to make up for the loss in population due to the OCP after it has been abandoned. In addition, as in the permanent OCP case, the quantity-quality trade-off begins to be effective once the OCP is in effect. However, once the OCP is lifted, the quantity-quality trade-off is reversed. Thus, the quantity-quality trade-off fluctuates under the temporary OCP, whereas it is monotone under natural evolution.

The temporary OCP extends for the duration of the Post-Malthusian period and delays the emergence of the Modern Growth period. This is intuitive because the temporary OCP delays the accumulation of the critical mass of population in the unified growth model.

Our calibration shows that the OCP is reversible since the natural evolution of the economy is restored after the policy is removed. However, it also highlights the fact that the two-generation gain in income growth under the temporary OCP comes at the expense of approximately eight generations of lower growth. Nevertheless, our quantitative exercise shows that any temporary policy on population in the GW model does not have a permanent effect on long-run growth.

Before concluding our analysis on the temporary OCP, we study the effect of the duration of the temporary OCP. Figure 9 shows that the longer the duration of the temporary OCP, the larger its deviation from the benchmark of natural evolution. For instance, if we delay the removal of the OCP for one more generation (i.e. temporary policy lasts three generations), the relative decline in per capita income growth from the natural-evolution level is much more substantial during the transition.

Summary 2 *Once the OCP is removed, the economy reverts to the steady state under natural evolution. Population growth, per capital income growth, and education all fluctuate during the transition, and the emergence of the Modern Growth era is delayed. The longer the duration of the temporary OCP, the lower per capita income growth in transition.*

3.4.3 Welfare

We now assess the welfare consequences by solving for the equivalent consumption variation of the OCP relative to natural evolution. Both temporary and permanent OCPs give rise to an initial welfare gain for less than two generations in return for a subsequent permanent welfare loss (see Figure 10).

Welfare is reduced even when per capita income growth is above its level under natural evolution in the short run. The reason is that the population level at the time when the OCP is implemented is too low ($L_t^{NE} > L_t^{OCP}$). Although the OCP promotes short-run growth, it reduces welfare. The demographic factor plays a crucial role in determining overall welfare. Furthermore, as shown in Figure 10, if the OCP is temporary, its adverse effect on the population mass is less, so the welfare loss is smaller. This makes sense; population growth, education level, and per capita income growth are lower in the steady state in the permanent OCP case than in the temporary OCP case. The latter approaches the same steady state as in the case of natural evolution.

Now suppose we postpone the OCP by one generation. We know that the cost in terms of growth is smaller because the initial population mass is larger, and thus, the deviation from natural evolution is smaller. In terms of welfare cost, the intuition carries over to the case of a permanent OCP, except that we have no short-run gain due to the restriction of the population mass by the OCP. When we postpone the OCP, the welfare loss in the short run is higher for four generations but the subsequent loss is smaller. This is consistent with our findings on the effects of the OCP on economic growth.

Figure 11 presents an interesting observation on postponing the temporary OCP for a generation. Again, we observe welfare loss for the entire time path due to the delay of OCP implementation. However, the welfare loss is exacerbated over time when the OCP is temporary. To understand this result, we note that population growth rebounds in the benchmark temporary OCP case after the policy is abandoned. As a result, the steady-state population mass achieves nearly the same level as under natural evolution. However, when the OCP is imposed during the Modern Growth era (36th generation), the initial population mass is higher and the initial population growth rate is lower than in the benchmark case. After two generations, when the OCP is eliminated, the rate at which population growth rebounds is reduced such that the population mass in the steady state is lower than the initial level (see Figure 11). This is the source of the welfare loss over the entire horizon considered relative to the benchmark case. This intuition concerning the adjustment of the population mass can be applied to understand the welfare cost of the duration of the temporary OCP. The longer the temporary OCP lasts, the smaller the population mass. Therefore, as shown in Figure 12, the welfare loss increases with the duration of the temporary OCP.

Summary 3 *The OCP reduces welfare. The welfare loss from the temporary OCP is smaller than that from the permanent OCP. Delaying the implementation of the permanent OCP always results in a trade-off between a higher short-run loss and a lower long-run cost. In the case of the temporary*

OCP (depending on the timing of the implementation relative to the Modern Growth era), there can be no welfare gain for delaying the OCP. The welfare cost increases with the policy's duration.

4 Concluding remarks

This paper extended the GW (2000) model by introducing a population constraint to understand the role of the OCP on China's economic growth and demographic transition. Qualitatively, the OCP promotes growth in the short run, but reduces it in the steady state. The earlier the imposition of the OCP, the lower the economic growth. From the calibration, we found that without the OCP, the steady-state growth rate of per capita GDP under natural evolution is approximately 8.94%. Other things being equal, a permanent OCP in China delivers higher economic growth for approximately two generations, but its long-run cost is much higher. Ultimately, it results in a 22% reduction in per capita GDP growth in the steady state.

We also considered the Chinese government's recent decision to move to a two-child policy. By allowing each family to have two children, the original OCP becomes a temporary policy that lasted for two 20-year generations. After rising for two consecutive generations, per capita GDP growth declines and slowly returns to the level that would be observed under natural evolution. Relative to its absence, the OCP creates a trade-off in growth between a gain for the first two generations and a loss afterwards. In addition, following the methodology of Song et al. (2015), we assess the welfare cost of the OCP. We find that the welfare cost over time is always higher for the permanent OCP than the temporary OCP.

We also provided a few counterfactual exercises. On one hand, hastening implementation of a permanent OCP increases the adverse effect on growth. On the other hand, delaying the time when the temporary OCP is lifted leads to weaker economic growth over time. Both of these counterfactuals imply a larger reduction in the population mass such that the adverse effect on growth is larger. In terms of welfare, the findings are robust in that both exercises yield a higher welfare loss over time. An interesting and important finding from our counterfactuals is that the welfare cost of the temporary OCP is very sensitive to its timing relative to the Modern Growth era. We find that if we impose the temporary OCP when the economy enters the Modern Growth Regime, we can be worse off both in the short run and in the steady state. Again, the intuition is based on the adjustment of the population mass in response to the OCP. In light of these demographic and macroeconomic implications, policymakers should be quite cautious in pursuing population restrictions.

This paper focused on the demographic change of the macroeconomy caused by the OCP, and was based on a belief that the first-order effect of OCP must fall on the population. For the sake of tractability, we abstract from many factors of China growth noted in the literature, including savings, investment, openness, capital flows, as well as external and internal trade. We believe that some of the effects from these factors can be captured in the total factor productivity (TFP) term of production technology. As discussed in Lagerlöf (2006), most quantitative findings of the GW model do not change qualitatively when TFP changes. However tantalizing, investigation into how these factors interact with the OCP must remain a matter for future research.

References

[1] Bai, C., Qian, Z., 2009. Factor income share in China: The story behind the statistics (in Chinese). Econ. Res. J. 3, 27-41.

[2] Barlow, R., 1994. Birth rate and economic growth: Some more correlations. Popul. Dev. Rev. 20, 153-165.

[3] Barro, R.J., Becker, G.S., 1989. Fertility choice in a model of economic growth. Econometrica 57, 481-501.

[4] Becker, G.S., Murphy, K.M., Tamura, R.F., 1990. Human capital, fertility, and economic growth. J. Political Econ. 98, S12-S37.

[5] Boldrin, M., Jones, L.E., 2002. Mortality, fertility, and saving in a Malthusian economy. Rev. Econ. Dyn. 5, 775-814.

[6] Brander, J.A., Dowrick, S., 1994. The role of fertility and population in economic growth: New results from aggregate cross-national data. J. Popul. Econ. 7, 1-25.

[7] Coale, A., 1986. Population trends and economic development, in: Menken, J. (ed.), *World Population and US Policy: The Choice Ahead*. W. W. Norton, New York, pp. 96-104.

[8] Galor, O., 2005. From stagnation to growth: Unified growth theory, in: Aghion, P., Durlauf, S. (eds.), *Handbook of Economic Growth*. North-Holland, Amsterdam, pp. 171-293.

[9] Galor, O., Weil, D.N., 1996. The gender gap, fertility, and growth. Am. Econ. Rev. 86, 374-387.

[10] Galor, O., Weil, D.N., 2000. Population, technology, and growth: From Malthusian stagnation to the demographic transition and beyond. Am. Econ. Rev. 110, 806-828.

[11] Hazledine, T., Moreland, R.S., 1977. Population and economic growth: A world cross-section study. Rev. Econ. Stat. 59, 253-263.

[12] Kelley, A.C., 1988. Economic consequences of population change in the Third World. J. Econ. Lit. 26, 1685-1728.

[13] Kelley, A.C., Schmidt, R.M., 1994. Population and income change: Recent evidence. World Bank Discussion Paper 249.

[14] Kelley, A.C., Schmidt, R.M., 1995. Aggregate population and economic growth correlations: The role of the components of demographic change. Demography 32, 543-555.

[15] Lagerlöf, N.P., 2003. From Malthus to modern growth: Can epidemics explain the three regimes? Int. Econ. Rev. 44, 755-777.

[16] Lagerlöf, N.P., 2006. The Galor-Weil model revisited: A quantitative exercise. Rev. Econ. Dyn. 9, 116-142.

[17] Li, H., Zhang, J., 2007. Do high birth rates hamper economic growth? Rev. Econ. Stat. 89, 110-117.

[18] Liao, P-J., 2011. Does demographic change matter for growth? Eur. Econ. Rev. 55, 659-677.

[19] Liao, P-J., 2013. The one-child policy: A macroeconomic analysis. J. Dev. Econ. 101, 49-62.

[20] Maddison, A., 2003. The World Economy: Historical Statistics. Organisation for Economic Co-operation and Development, Paris.

[21] Maddison, A., 2007. *Chinese Economic Performance in the Long Run: 960-2030 AD*. Organisation for Economic Co-operation and Development, Paris.

[22] Malthus, T.R., 1826. *An Essay on the Principle of Population*, sixth ed. Cambridge University Press, Cambridge, UK.

[23] McNicoll, G., 1984. Consequences of rapid population growth: An overview and assessment. Popul. Dev. Rev. 10, 537-544.

[24] Rosenzweig, M.R., Zhang, J., 2009. Do population control policies induce more human capital investment? Twins, birthweight, and China's one child policy. Rev. Econ. Stud. 76 (3), 1149-1174.

[25] Simon, J.L. 1989. On aggregate empirical studies relating population variables to economic development. Popul. Dev. Rev. 15, 323-332.

[26] Song, M. Z., Storesletten, K., Wang, Y., Zilibotti, F., 2015. Sharing high growth across generations: pensions and demographic transition in China. Am. Econ. J. Macroecon. 7 (2), 1-39.

[27] Temple, J., 1999. The new growth evidence. J. Econ. Lit. 37, 112-156.

[28] Yang, D.T., Chen, D., 2004. Transformations in China's population policies and demographic structure. Pac. Econ. Rev. 9 (3), 269-290.

[29] Zhu, X., 2012. Understanding China's growth: Past, present, and future. J. Econ. Perspect. 26 (4), 103-124.

Table 1: Parameter values

	Interpretation	Value
Parameters		
α	Labor share	0.443
τ	Fixed time cost of raising children	0.15
ρ	Educational part of τ	0.9813
a^*	Scale effect parameter	79
γ	Weight on fertility in utility function	0.225
θ	Scale effect parameter	1
X	Land	1
$\widetilde{c}$	Subsistence consumption	1
Endogenous variables		
e^*	Education, modern growth	0.075
g^*	Technological growth, modern growth	17.554
n^*	Fertility, modern growth	1
$\widehat{L}$	Threshold population	52.337
Initial conditions		
n_0	Initial fertility	1
L_0	Initial population	0.364
A_0	Initial technology	0.6236
e_0	Initial education	0
g_0	Initial technological growth	0.0536
z_0	Initial per-worker income	1.176
Potential GDP growth rate		8.94

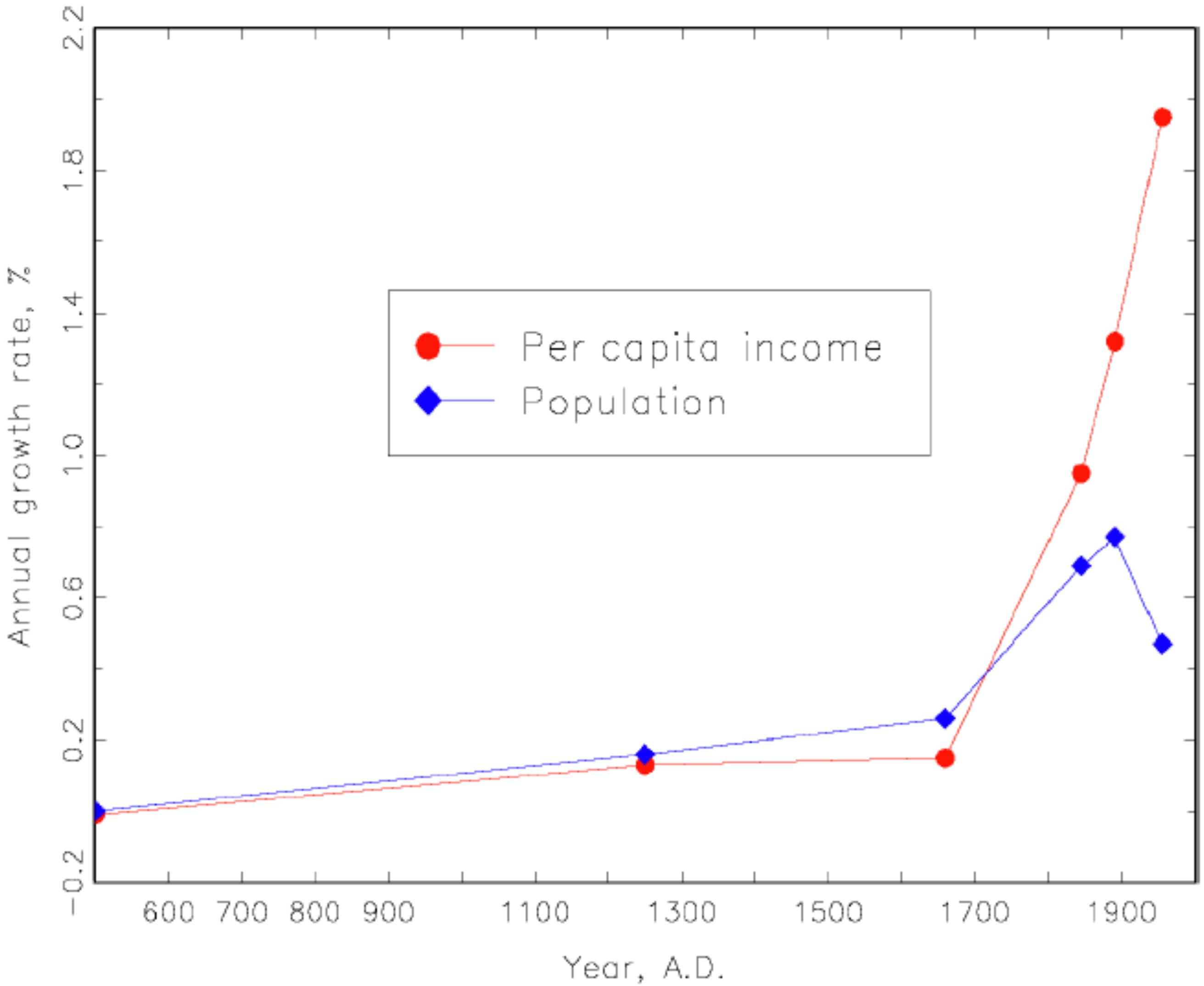
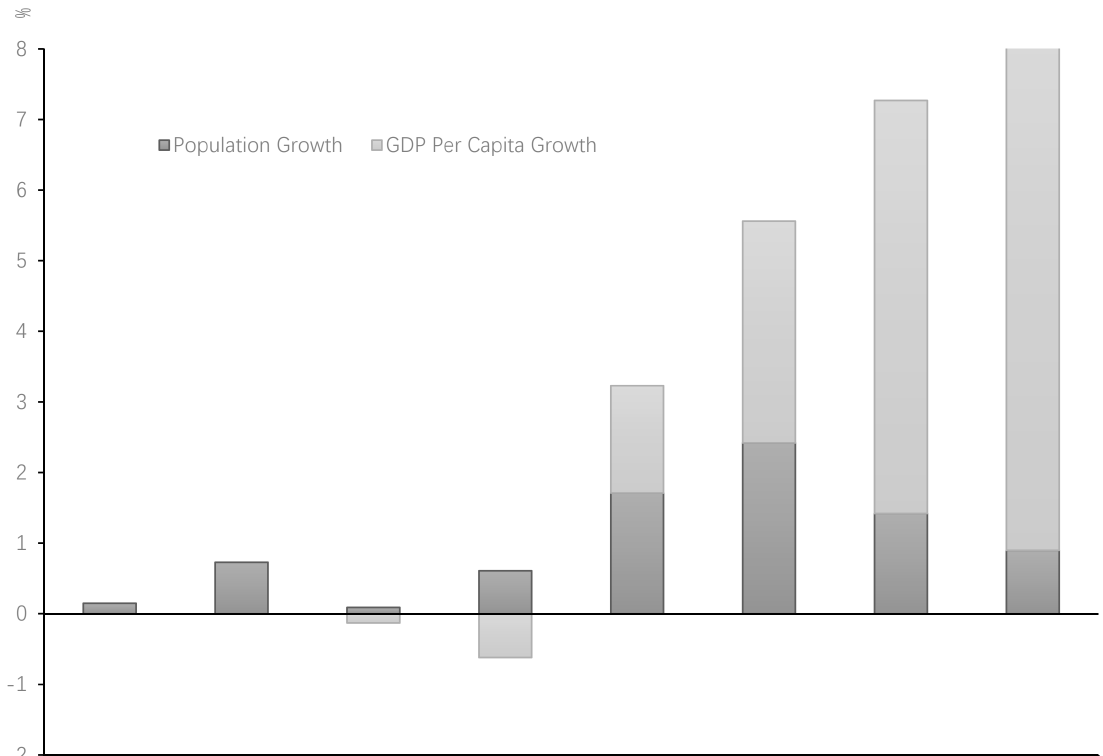


Figure 1 Growth rates in Western Europe (Lagerlof, 2006)

Figure 2 Growth rates in China estimated by Maddison



	1500-1700	1701-1850	1851-1913	1914-1950	1951-1961	1962-1976	1977-1992	1993-2003
GDP Per Capita Growth	0	0	-0.13	-0.62	1.52	3.14	5.85	7.75
Population Growth	0.15	0.73	0.09	0.61	1.71	2.42	1.42	0.9

Source: Maddison (2003), Maddison (2007).

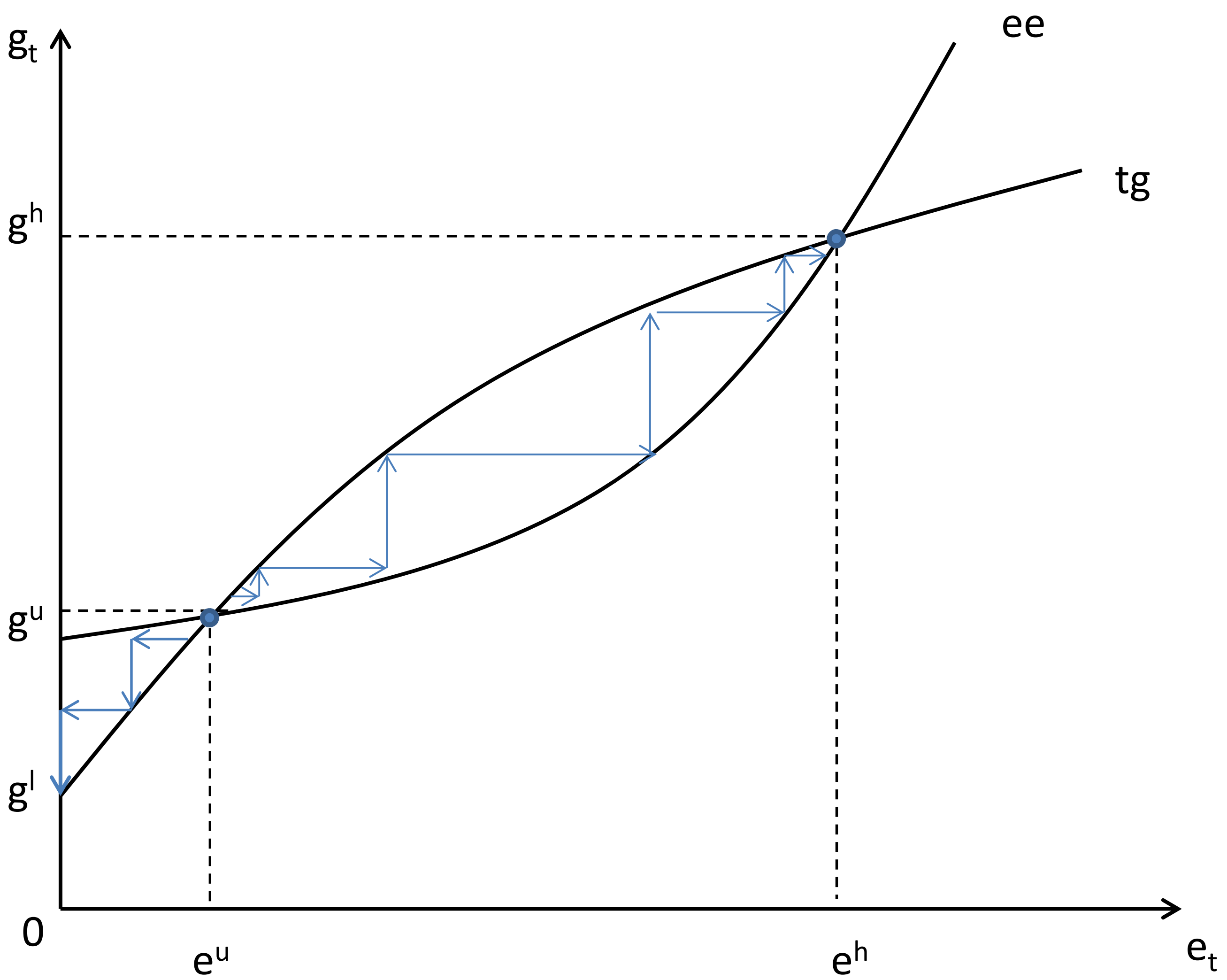


Figure 3. The evolution of technology and education for a moderate population size

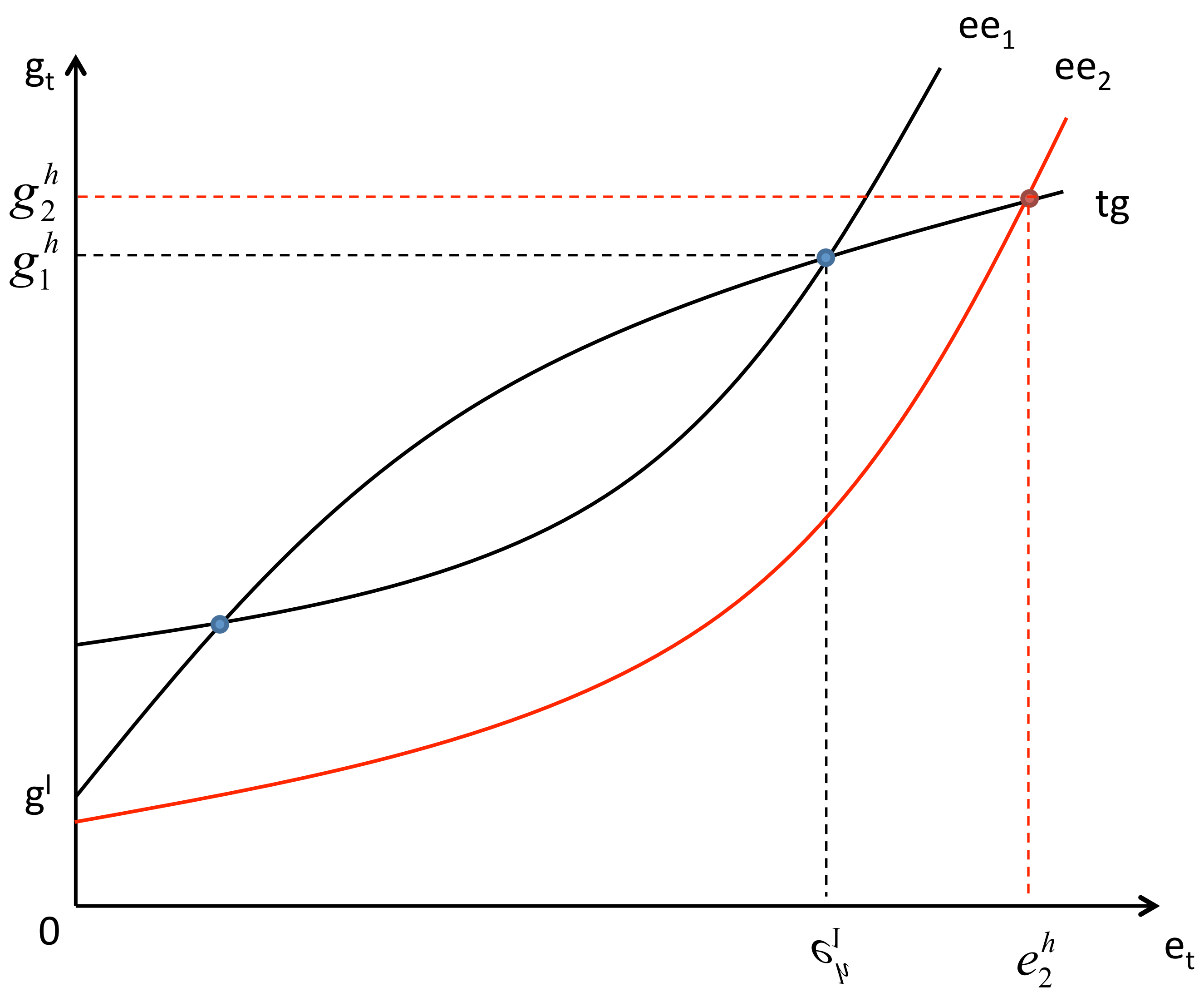


Figure 4 The effect of OCP where $\overline{n}$ is reduced to 1

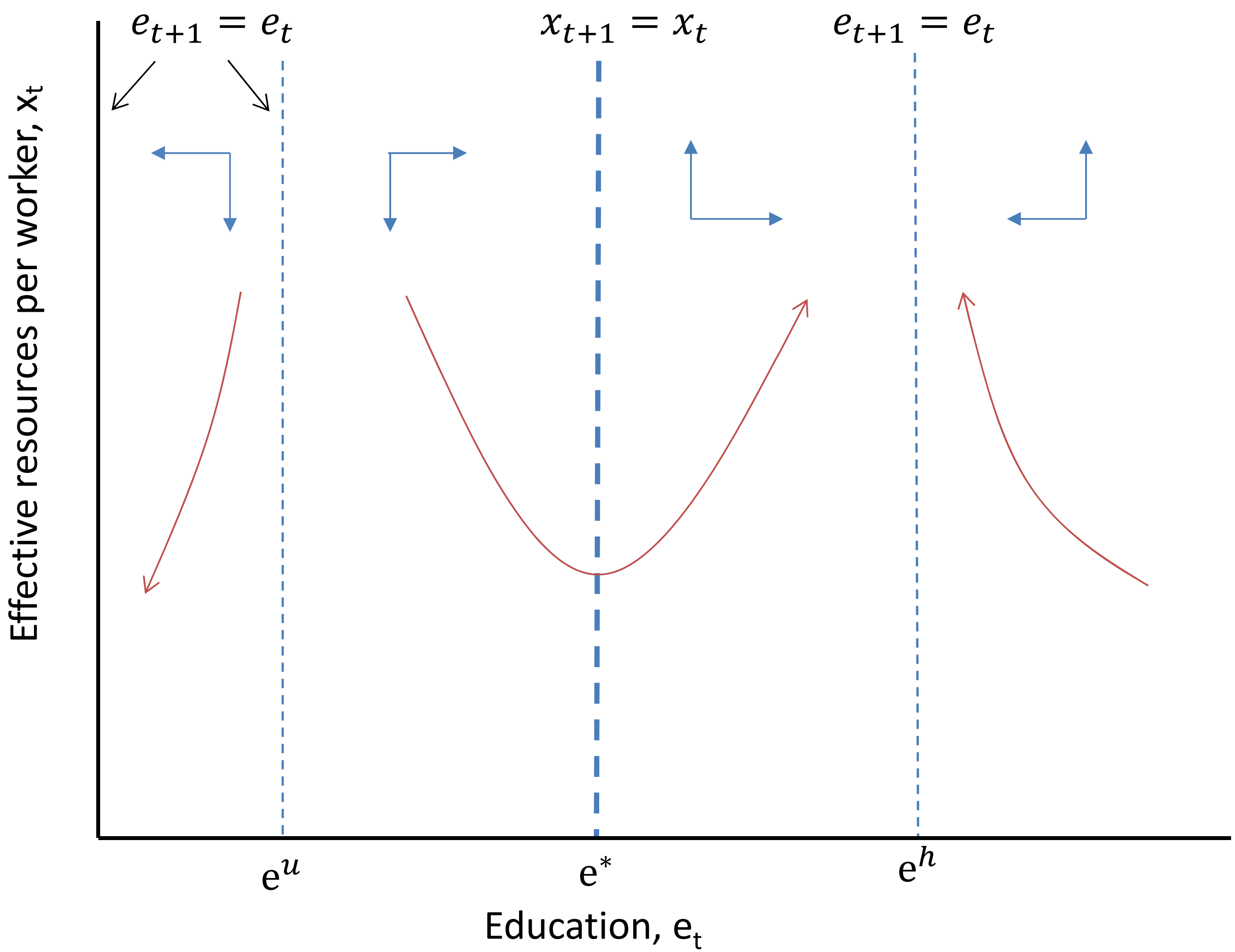


Figure 5. The conditional dynamical system for a moderate population size

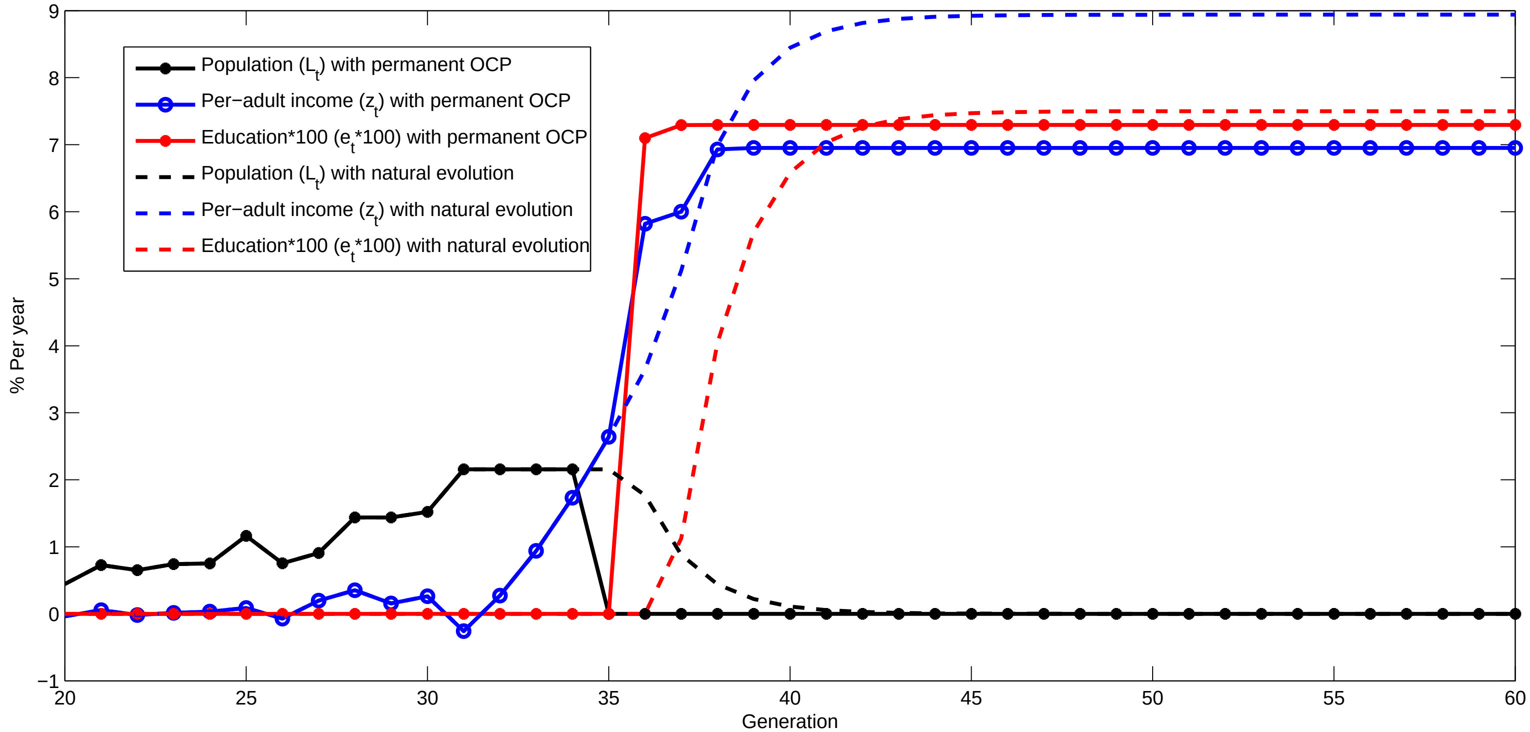


Figure 6. Implementation of permanent OCP at 35th generation

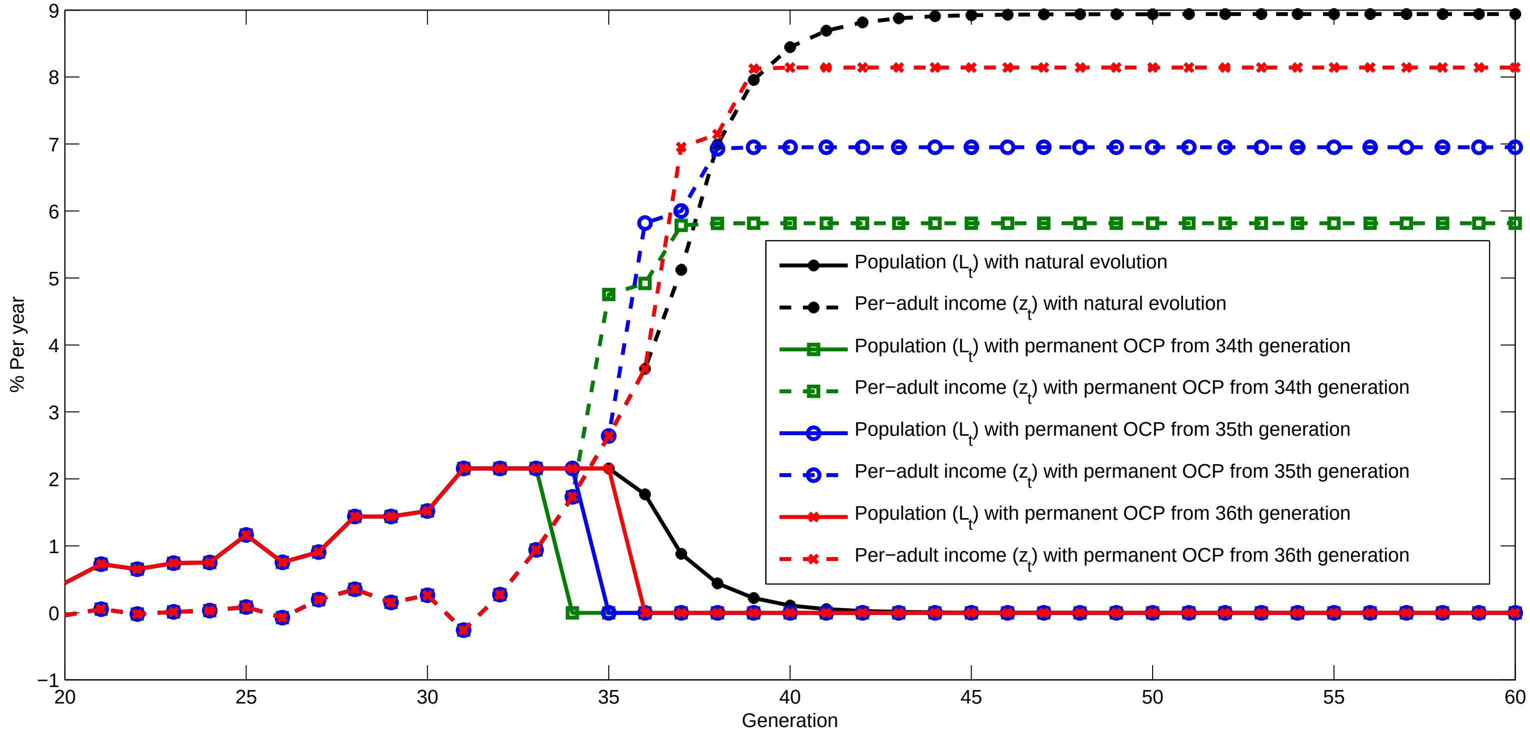


Figure 7. Implementations of permanent OCP at 34th, 35th, and 36th generations

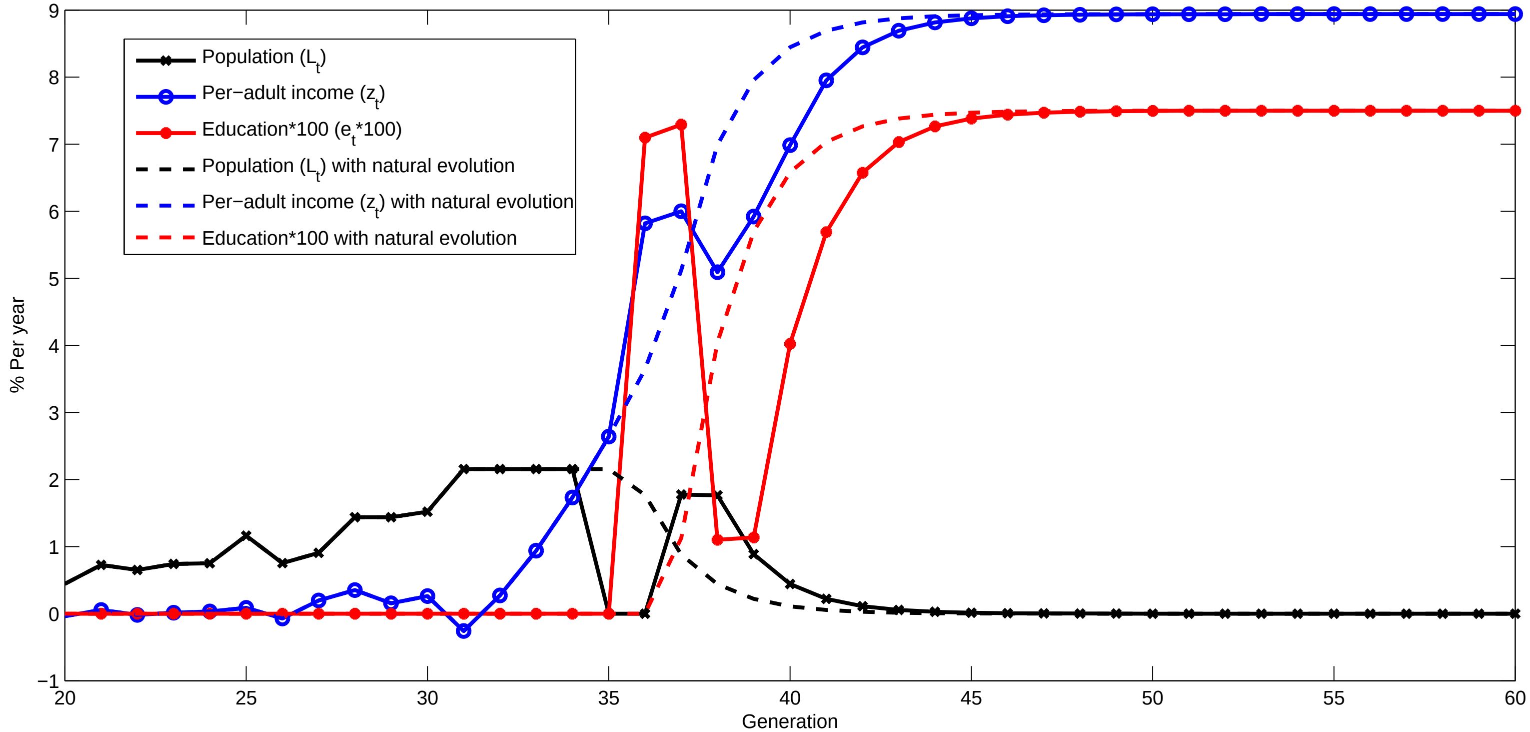


Figure 8. Implementation of temporary OCP at 35th and 36th generations

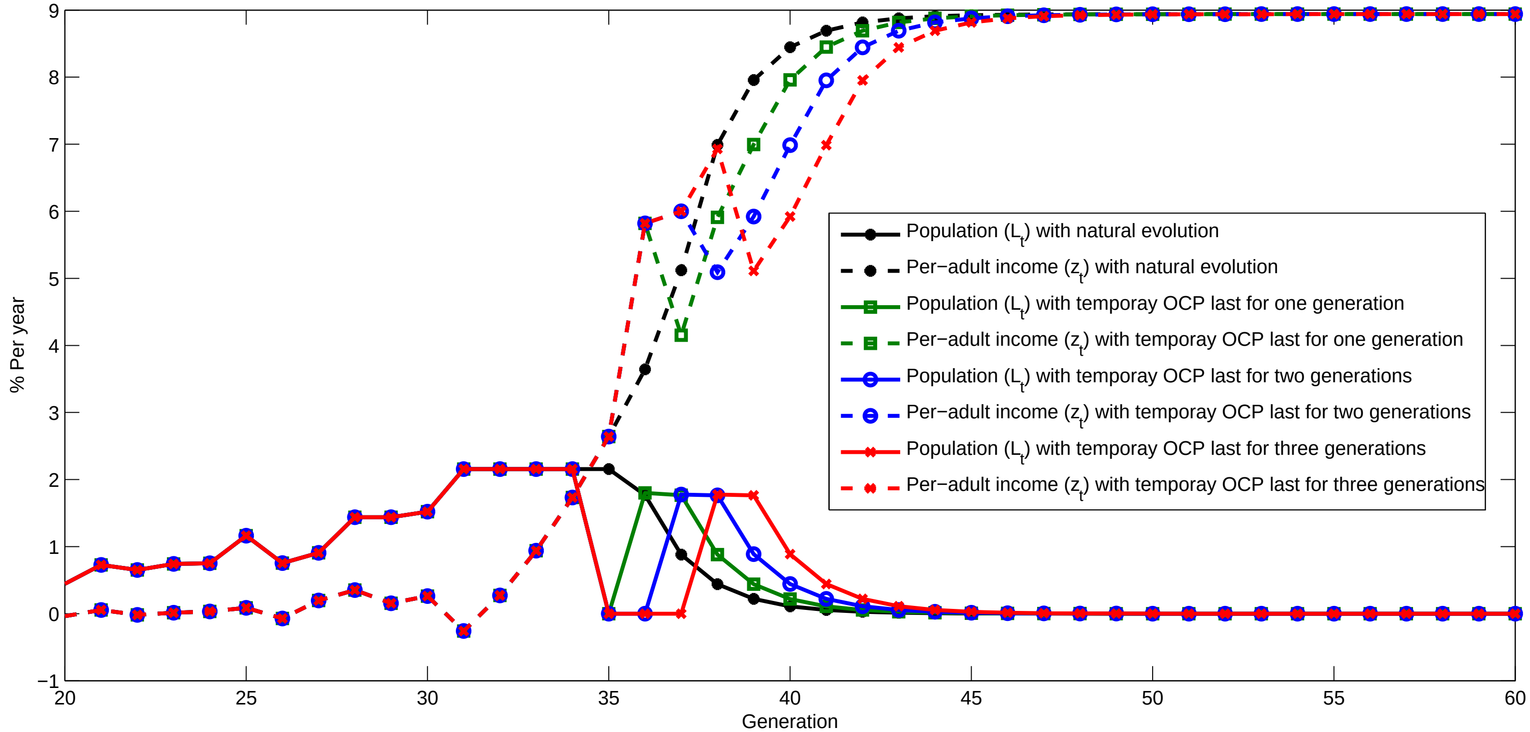


Figure 9. Implementation at 35th generation of temporary OCPs of different durations

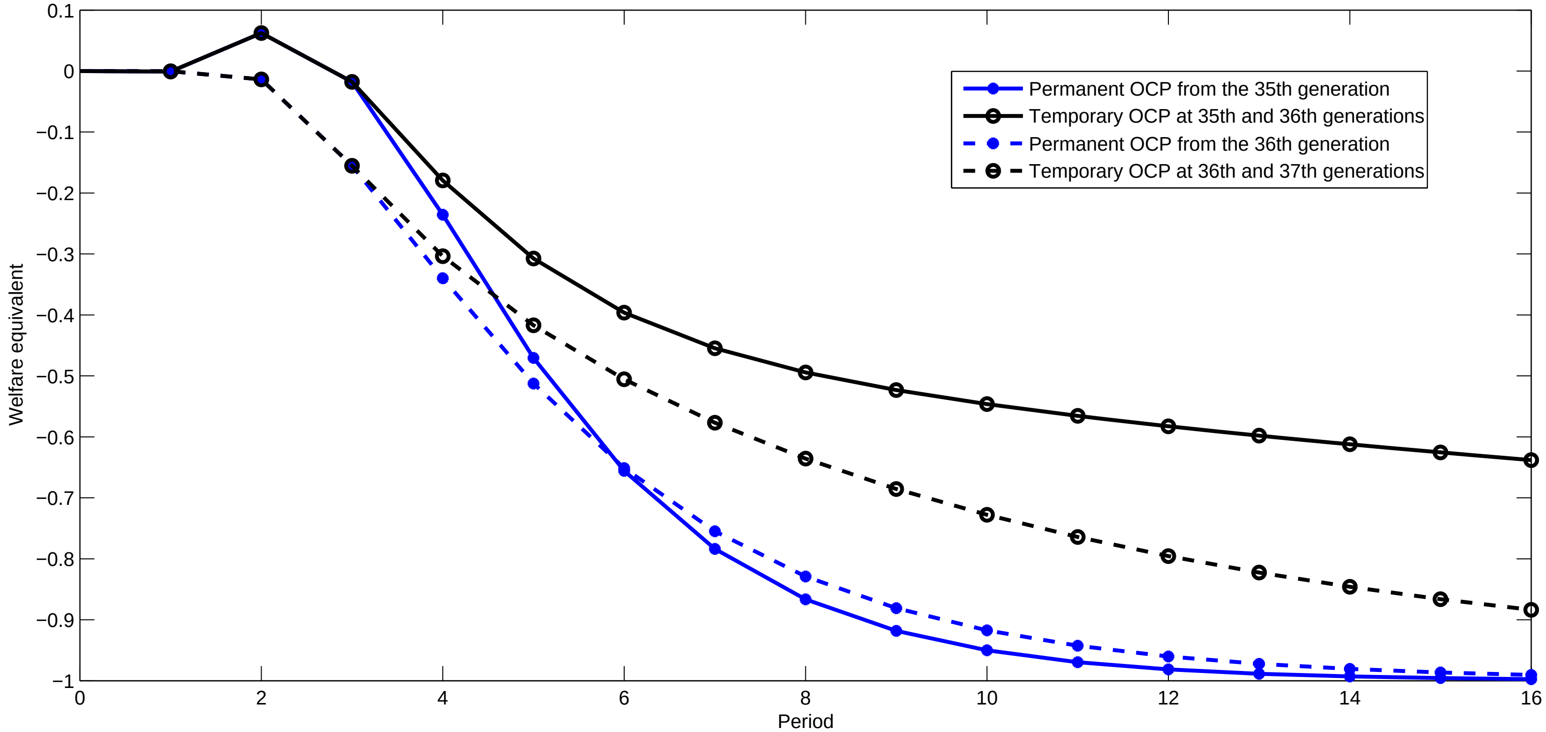


Figure 10. Welfare equivalent under permanent and temporary OCP from the 35th and 36th generations

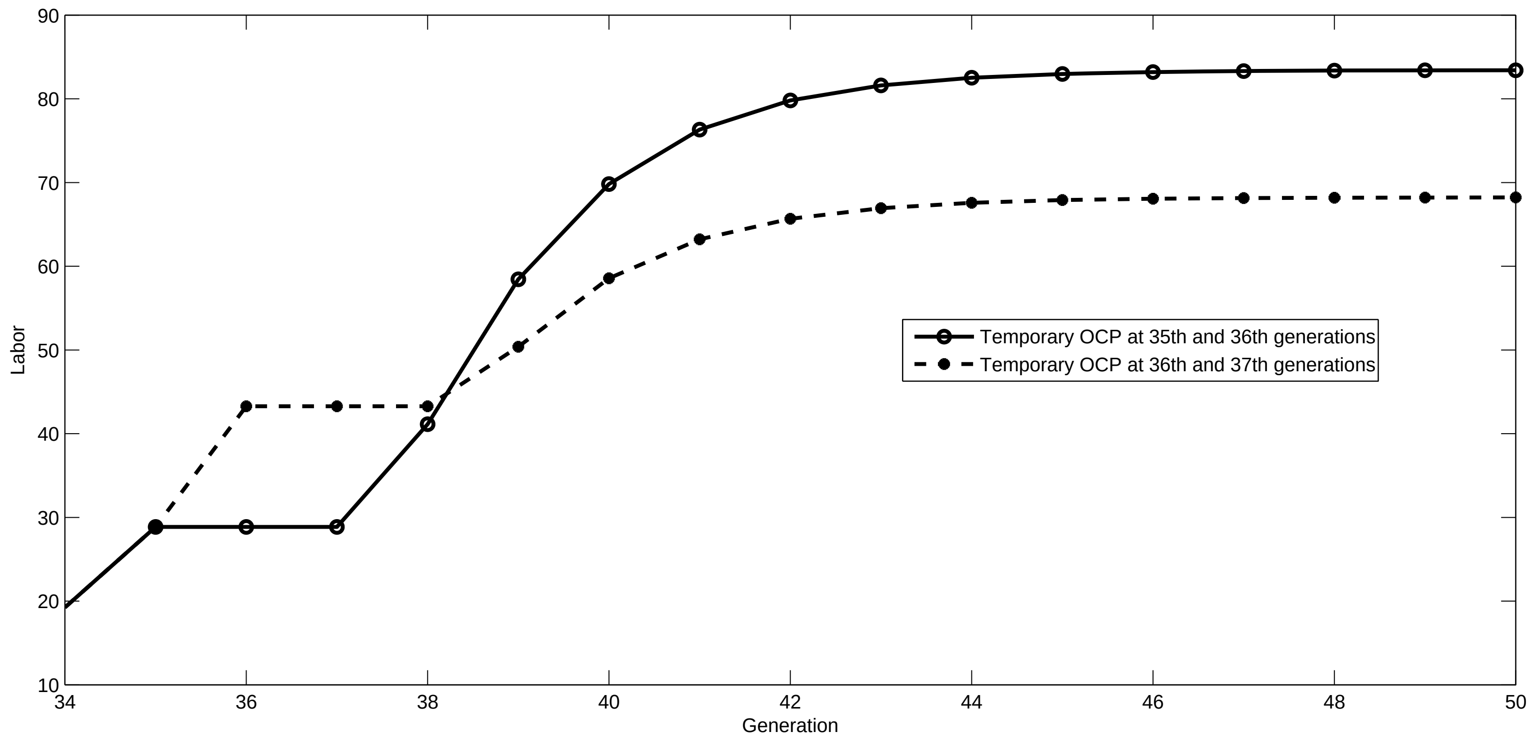


Figure 11. Population mass under temporary OCP implementing from the 35th or 36th generations

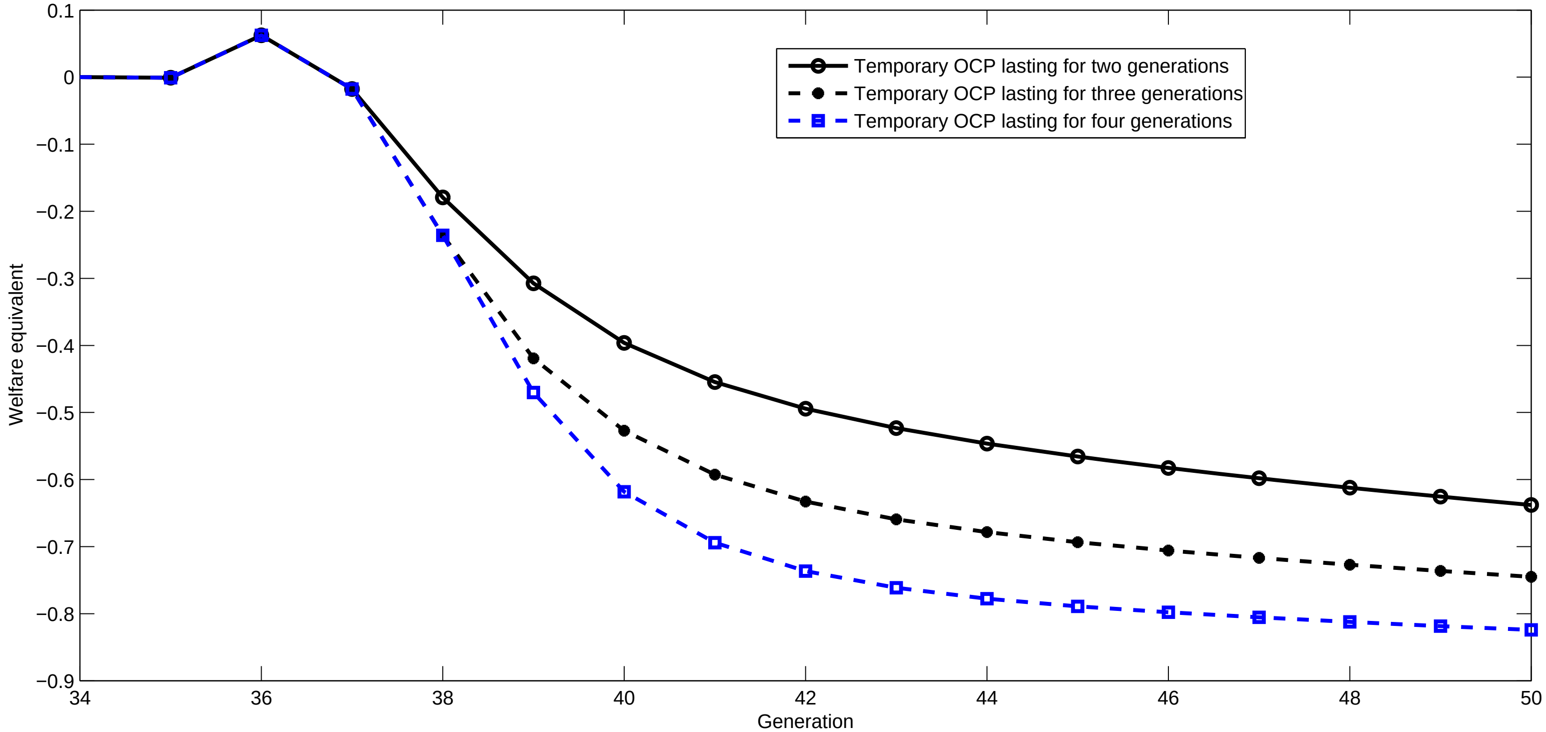


Figure 12. Welfare equivalent under temporary OCPs lasting for 2, 3 and 4 generations

BOFIT Discussion Papers

A series devoted to academic studies by BOFIT economists and guest researchers. The focus is on works relevant for economic policy and economic developments in transition / emerging economies.

2016
No 1 Guonan Ma and Wang Yao: Can the Chinese bond market facilitate a globalizing renminbi?
No 2 Iikka Korhonen and Riikka Nuutilainen: A monetary policy rule for Russia, or is it rules?
No 3 Hüseyin Şen and Ayşe Kaya: Are the twin or triple deficits hypotheses applicable to post-communist countries?
No 4 Alexey Ponomarenko: A note on money creation in emerging market economies
No 5 Bing Xu, Honglin Wang and Adrian van Rixtel: Do banks extract informational rents through collateral?
No 6 Zuzana Fungáčová, Anastasiya Shamshur and Laurent Weill: Does bank competition reduce cost of credit? Cross-country evidence from Europe
No 7 Zuzana Fungáčová, Iftekhar Hasan and Laurent Weill: Trust in banks
No 8 Diana Ayala, Milan Nedeljkovic and Christian Saborowski: What slice of the pie? The corporate bond market boom in emerging economies
No 9 Timothy Frye and Ekaterina Borisova: Elections, protest and trust in government: A natural experiment from Russia
No 10 Sanna Kurronen: Natural resources and capital structure
No 11 Hongyi Chen, Michael Funke and Andrew Tsang: The diffusion and dynamics of producer prices, deflationary pressure across Asian countries, and the role of China
No 12 Ivan Lyubimov: Corrupt bureaucrats, bad managers, and the slow race between education and technology
No 13 Tri Vi Dang and Qing He: Bureaucrats as successor CEOs
No 14 Oleksandr Faryna: Exchange rate pass-through and cross-country spillovers: Some evidence from Ukraine and Russia
No 15 Paul D. McNelis: Optimal policy rules at home, crisis and quantitative easing abroad
No 16 Mariarosaria Comunale and Heli Simola: The pass-through to consumer prices in CIS economies: The role of exchange rates, commodities and other common factors
No 17 Paul Castañeda Dower and William Pyle: Land rights, rental markets and the post-socialist cityscape
No 18 Zuzana Fungáčová, Ilari Määttä and Laurent Weill: What shapes social attitudes toward corruption in China? Micro-level evidence
No 19 Qing He, Jiyuan Huang, Dongxu Li and Liping Lu: Banks as corporate monitors: Evidence from CEO turnovers in China
No 20 Vladimir Sokolov and Laura Solanko: Political influence, firm performance and survival

2017
No 1 Koen Schoors, Maria Semenova and Andrey Zubanov: Depositor discipline in Russian regions: Flight to familiarity or trust in local authorities?
No 2 Edward J. Balistreri, Zoryana Olekseyuk and David G. Tarr: Privatization and the unusual case of Belarusian accession to the WTO
No 3 Hongyi Chen, Michael Funke, Ivan Lozev and Andrew Tsang: To guide or not to guide? Quantitative monetary policy tools and macroeconomic dynamics in China
No 4 Soyoung Kim and Aaron Mehrotra: Effects of monetary and macroprudential policies – evidence from inflation targeting economies in the Asia-Pacific region and potential implications for China
No 5 Denis Davydov, Zuzana Fungáčová and Laurent Weill: Cyclicality of bank liquidity creation
No 6 Ravi Kanbur, Yue Wang and Xiaobo Zhang: The great Chinese inequality turnaround
No 7 Yin-Wong Cheung, Cho-Hoi Hui and Andrew Tsang: The Renminbi central parity: An empirical investigation
No 8 Chunyang Wang: Crony banking and local growth in China
No 9 Zuzana Fungáčová and Laurent Weill: Trusting banks in China
No 10 Daniela Marconi: Currency co-movements in Asia-Pacific: The regional role of the Renminbi
No 11 Felix Noth and Matias Ossandon Busch: Banking globalization, local lending, and labor market effects: Micro-level evidence from Brazil
No 12 Roman Horvath, Eva Horvatova and Maria Siranova: Financial development, rule of law and wealth inequality: Bayesian model averaging evidence
No 13 Meng Miao, Guanjie Niu and Thomas Noe: Lending without creditor rights, collateral, or reputation – The “trusted-assistant” loan in 19th century China
No 14 Qing He, Iikka Korhonen and Zongxin Qian: Monetary policy transmission with two exchange rates and a single currency: The Chinese experience
No 15 Michael Funke, Julius Loermann and Andrew Tsang: The information content in the offshore Renminbi foreign-exchange option market: Analytics and implied USD/CNH densities
No 16 Mikko Mäkinen and Laura Solanko: Determinants of bank closures: Do changes of CAMEL variables matter?
No 17 Koen Schoors and Laurent Weill: Russia's 1999-2000 election cycle and the politics-banking interface
No 18 Ilya B. Voskoboynikov: Structural change, expanding informality and labour productivity growth in Russia
No 19 Heiner Mikosch and Laura Solanko: Should one follow movements in the oil price or in money supply? Forecasting quarterly GDP growth in Russia with higher-frequency indicators
No 20 Mika Nieminen, Kari Heimonen and Timo Tohmo: Current accounts and coordination of wage bargaining
No 21 Michael Funke, Danilo Leiva-Leon and Andrew Tsang: Mapping China’s time-varying house price landscape
No 22 Jianpo Xue and Chong K. Yip: One-child policy in China: A unified growth analysis

BOFIT Discussion Papers
http://www.bofit.fi/en • email: bofit@bof.fi
ISSN 1456-4564 (print) // ISSN 1456-5889 (online)