Does Higher Education Expansion Enhance Productivity?

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July 14, 2018

Abstract

This paper studies the impact of the higher education expansion in China on average labor productivity. I argue that in an economy such as China's, where allocation distortions widely exist, educational policy affects labor productivity not only through its effect on human capital stock, but also through its effect on human capital allocation across sectors. Thus, its impact could be limited if misallocation becomes more severe following the policy. I build a two-sector general equilibrium model with policy distortions, where overlapping generations of households make educational and occupational choices. Quantitative results show that, given policy distortions, China's higher education expansion had a small but negative effect on its average labor productivity (-2.5 percent). The crowding out of productive capital caused by magnified resource misallocation plays a key role in driving down productivity. However, the productivity effect of the educational policy would turn positive if distortions were further reduced or removed.

1 Introduction

Human capital has long been considered the engine of economic growth (Schultz, 1961; Lucas, 1988; Barro, 1991; Galor and Moav, 2004; Manuelli and Seshadri, 2014),[1] and government policies that promote the society-wide level of education have thus been well regarded. In fact, many countries have experienced a government-led education expansion program at some stage of their development.[2] However, a salient feature of developing countries is the widely existing factor misallocation, which has caused substantial productivity losses (Restuccia and Rogerson, 2008; Hsieh and Klenow, 2009; Brandt, Tombe and Zhu, 2013).[3] Since the working of an educational policy is expected to channel through a production factor – human capital, its effects may be limited if factor misallocation becomes more severe following the policy. In this paper, I examine how an educational policy may affect the average labor productivity through its effect on the allocation as well as the stock of human capital using China's higher education expansion, and how an economic reform may influence the effectiveness of the educational policy by triggering more efficient allocation.

While empirical studies find positive returns to education in China at the individual level,[4] a strand of the literature argues that the contribution of education to aggregate productivity depends critically on how talent and skills are allocated across different sectors or activities (Baumol, 1990; Murphy, Shleifer, and Vishny, 1991). Pritchett (2006) claims that, in many developing countries, the social returns to education can be far below the private returns because an overwhelmingly large share of college graduates were employed by the less-efficient public sector. While China's higher education expansion in the late 1990s increased the supply of skilled workers significantly, no previous study has examined its impact on aggregate productivity,

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[1]For more studies on the role of human capital in economic growth, see Uzawa (1965), Rosen (1976), Romer (1990), Mankiw, Romer, and Weil (1992), Benhabib and Spiegel (1994), Barro and Sala-i-Martin (1995), Bils and Klenow (2000), Caselli (2005), Hsieh and Klenow (2010), Goodfriend and McDermott (1995), Hanushek and Kimko (2000), Hanushek and Woessmann (2008), Erosa, Koreshakova, and Restuccia (2010), Cubas, Ravikumar, and Ventura (2016), and Hanushek and Woessmann (2012).

[2]For example, Korea and Thailand expanded their tertiary education in the 1980s. The expansion raised the tertiary enrollment rate from about 10 percent in 1980 for both countries to nearly 100 percent for Korea and over 50 percent for Thailand in recent years. In Taiwan, human capital improvement was given the first policy priority since the 1950s, which led to tremendous growth in its higher-educated labor force for the following three decades (Tallman and Wang, 1994). Many other countries, such as China, Japan, Malaysia, Singapore, etc., had similar experiences of education expansion. The reader is also referred to Boldrin et al. (2004) for a review of human capital policies of the four Asian Tigers.

[3]See more studies on the impact of misallocation on TFP in Alfaro et al. (2008), Bartelsman et al. (2013), Banerjee and Duflo (2005), and Schmitz (2001).

[4]See, for example, Li (2003), Li and Luo (2004), Zhang et al. (2005), and Fleisher et al. (2011).

taking into account the widespread allocation distortions in China. Moreover, this higher education expansion was accompanied by a large-scale economic reform of the state sector and other market-oriented policies; thus, its effect may be masked by the concurrent institutional changes that were enforced to improve productivity. It is therefore of critical importance to understand the isolated effect of the educational policy on productivity as well as its interactive effects with other policies.

To address these questions, I construct a two-sector general equilibrium model with policy distortions, where overlapping generations of households make educational and occupational choices depending on ability as well as government educational and economic policies. The key features of the model are as follows. (i) There two sectors, and despite their lower productivity (TFP), state sector firms receive subsidies from the government for the use of production factors. (ii) Households who are heterogeneous in ability make an educational choice of whether to acquire college education, and then an occupational choice between the private and the state sector upon graduation. Both choices depend on ability. Higher ability not only lowers the disutility of college education, but also the layoff probability of a skilled worker in the private sector (while a skilled worker in the state sector may secure her job perfectly). (iv) The higher education policy enters the model via an exogenous component of the disutility cost of college education; that is, higher education expansion lowers this disutility.

The model thereby characterizes two main tradeoffs regarding the two lifetime choices. For the educational choice, college education enhances one's future labor income, but incurs a disutility cost. For the occupational choice, the private sector may pay a higher wage to the skilled workers due to its higher productivity, but its jobs are less secure than that of the state sector. In equilibrium with reasonable parameterization, the model presents a sorting mechanism under which households are self-selected into three categories based on ability: the ablest acquire college education and then become skilled workers of the private sector, the least able do not go to college and become unskilled workers, and the mediocre enter college and then become skilled workers of the state sector.

The educational policy then affects average labor productivity through two main channels. One is the *growth* effect. By lowering the disutility cost of college education, the higher education expansion encourages more people to enter college and hence increases the society's human capital stock. Since skilled labor complements the more productive technology, average labor productivity can be improved. The other is the *reallocation* effect. As more individuals with lower ability enter college

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and then become skilled workers under this policy, relatively more of them prefer the state sector to the private sector, since they would have a higher chance of being unemployed if choosing the latter. Thus, the policy plays a role in reallocating relatively more skilled workers to the state sector, intensifying human capital misallocation. The sectoral reallocation of human capital then directs physical capital toward the state sector due to factor complementarity, magnifying physical capital misallocation as well. Furthermore, worsened misallocation raises subsidies demanded by the (expanding) state sector firms, which tightens the loanable funds market and crowds out capital from production, further dampening labor productivity.

I calibrate the model to fit the data of the pre- and post-regimes in China,[5] and then apply the numerical model to quantitative analysis including various policy experiments. I also construct a productivity-based measure of human capital for the purpose of policy evaluation. I find that, while the higher education expansion increased China's human capital by 11 percent, it reallocated relatively more human capital toward the state sector: the private sector share of human capital would have increased by 29 percent had there been no college expansion. Overall, the policy had a small but *negative* effect on the average labor productivity in China. Had there been no college expansion, China's average labor productivity would have increased by 2.5 percent. While magnified factor misallocation per se plays a relatively minor role in driving down labor productivity, it raises subsidies to the state sector and tightens the loanable funds market, crowding out productive capital. This crowding out effect turns out to have a subtantively negative impact on labor productivity.

While the negative effect of the educational policy seems striking, it is not to say that higher education expansion in China was wrong. Instead, my analysis suggests that in order to reach the maximal social welfare goals or labor productivity, higher education should be further expanded. However, this must be accompanied with deepened economic reform that further reduces or completely eliminates allocation distortion. In fact, the productivity effect of the higher education expansion would turn positive when distortions are sufficiently small.

To compare my estimates with those in the literature, I examine total productivity gains from eliminating allocation distortions. These turn out to be 73 percent for the pre-regime and 17 percent for the post-regime, respectively. While these estimates are comparable to those in Brandt, Tombe, and Zhu (2013), they are smaller than those in Hsieh and Klenow (2009), which are 115 and 87 percent for the two regimes,

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[5]The pre-regime refers to the stage when neither higher education expansion nor state sector reform has been implemented, and the post-regime regime refers to the stage when both policies have been enforced.

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respectively. I argue that there are two main reasons for this result. First, my model does not account for the within-sector distortion as in Hsieh and Klenow (2009), whereas this distortion could be large due to firm-level heterogeneity across regions, industries, and sizes within the state or the private sector; thus, my paper may have underestimated policy distortions. Second, Hsieh and Klenow (2009) may have overestimated the productivity gains from eliminating distortions because they do not take into account the human capital effect of distortion by simply assuming a fixed supply of human capital. Nonetheless, using a model with endogenous educational choices, my result shows that policy distortions indeed have a positive effect on human capital stock (10 and 7 percent for the two regimes, respectively) through their effect on factor prices.

Regarding the literature on the educational policy, there is no existing work that assesses the impact of China's higher education expansion on aggregate productivity to compare with;[6] but in a relevant study, Vollrath (2014) investigates the efficiency of human capital allocation in 14 developing countries (not including China) and finds that eliminating wage distortions between sectors only has a small effect (< 5 percent) on aggregate productivity. This estimate is smaller than those generated from my model, which are 47 and 16 percent in the pre- and post-regimes, respectively. I argue that this difference can be largely attributed to the assumption of Vollrath's model that physical capital stock and allocation are both constant, while using a more-general equilibrium model, my analysis suggests that although human capital misllocation per se has a minor effect on labor productivity, it generates physical capital misallocation and more importantly, the crowding out of productive capital, which turns out to have a substantially negative effect on labor productivity. In fact, Vollrath also points out in his paper that incorporating the dynamic response of physical capital accumulation and allocation to human capital allocation could generate a much larger productivity effect of eliminating wage distortion.

The contribution of this paper is summarized as follows. This is the first theoretical work that studies the impact of the higher education expansion in China on its aggregate productivity. By developing a general equilibrium model with policy distortions, I document a reallocation effect of the educational policy that may generate a sizeable negative effect on labor productivity, which, however, has been largely ignored by the human capital literature. Importantly, my analysis incorporates dynamic feedback between the labor market and the capital market in a

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[6]The prior literature on China's higher education expansion mainly focuses on its impact on inequality, rather than productivity (e.g., Meng et al., 2013; Yeung, 2013).

two-sector economy; thus, it produces more reasonable estimates than studies focusing on one market while assuming the other fixed. Furthermore, different from that in the recent misallocation literature, my theory makes both human capital stock and allocation endogenous and affected by policy distortions through altered factor prices; thus, it identifies an additional channel through which distortion may affect productivity. Finally, my results underscore that, to enhance the effectiveness of an education expansion policy, it is crucial for policy makers to enforce complementary economic policies to improve allocation efficiency. While this study focuses on China, this policy implication can be generally applied to many other developing countries with severe prevailing distortions.

The rest of the paper proceeds as follows. Following a brief introduction of the background, Section 2 provides the details of the model economy, followed by a characterization of the equilibrium in Section 3. Section 4 presents calibration and Section 5 quantitative analysis. Section 6 concludes.

Background

China's nationwide college enrollment expansion, launched in 1999, was a critical means by the central government to stimulate domestic demand, promote economic growth, and release employment pressure. The policy made college education much more accessible to ordinary people by expanding college admissions substantially. In 1999 alone, the college enrollment number reached nearly 1.6 million, a 48 percent increase from the previous year. The expansion continued throughout the following years and significantly increased China's skilled labor force. On average, the annual growth rate of China's college enrollment reached over 16 percent during the 1998–2010 period, a sharp increase from an average of 6.8 percent during the 1977–1998 period.[7] The college enrollment rate (defined as the ratio of the college enrollment number to the number of people taking the college entrance examination) was on average less than a quarter during the 1977–1998 period, but was about 60 percent from 1999 to 2010. The college entry number as a share of China's working-age population was well below 0.15 percent before 1999, but increased to 0.66 percent in 2010 following a dramatic upward shift in 1999 (Figure 1). The share of the whole population with a college degree also increased from 1.42 percent in 1990 to 8.93 percent in 2010 (China Statistical Yearbook).

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[7]1977 was the first year that China resumed its college admission since the Cultural Revolution.
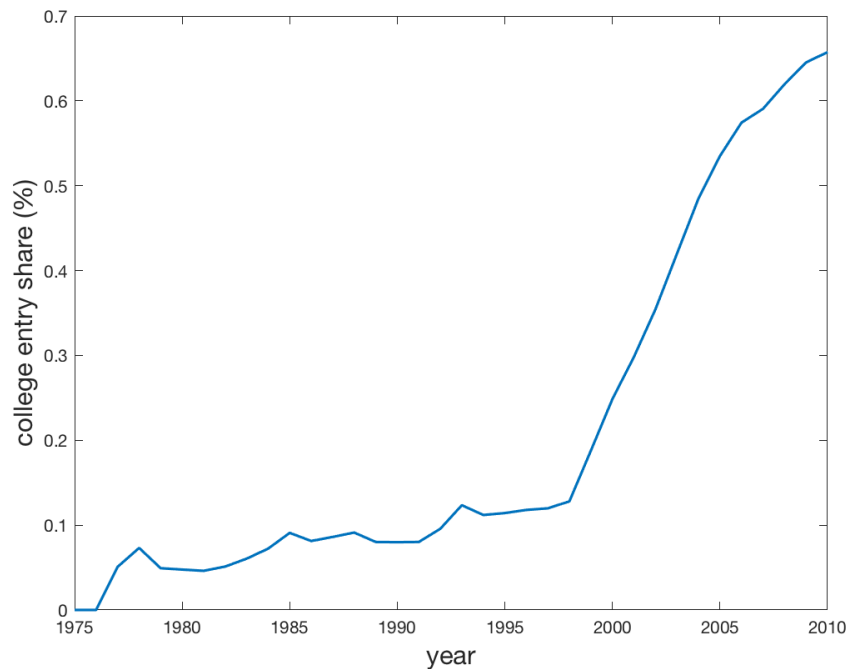
Figure 1. College entry number as a share of the working-age population

Notes: This figure shows the college enrollment number as a share of the working-age population (aged between 15 and 64) in China during the 1977–2010 period.
Data source: China Statistical Yearbook

The college enrollment expansion was accompanied by a large-scale economic reform of the state sector. Begun in the mid-1990s, the reform became substantial after 1998. The state-owned enterprises ("SOEs" hereafter), while given priority for access to various resources, were highly inefficient and employed a large number of excessive workers; thus, they became a barrier to China's economic growth (Brandt, Hsieh and Zhu, 2008). This situation was particularly severe before the 1990s reform.[8] Then by cutting off subsidies to most SOEs, laying off millions of excessive workers ("Xiagang"), shutting down or privatizing the least productive SOEs and establishing new ones, the state sector reform enhanced aggregate productivity as well as that of the surviving SOEs substantially (see Hsieh and Song (2015) for a comprehensive analysis of the state sector reform). However, studies find that, even after the reform, China's state-dominated financial system still favored financing the SOEs despite their lower returns to capital (Dollar and Wei, 2007; Dobson and Kashyap, 2006; Allen, Qian, and Qian, 2005; Boyrean-Debray and Wei, 2005; the reader is also

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[8]Bai et al. (2000) argue that during transition SOEs were given low profit incentives by the government due to their obligations to maintain employment to support social stability.

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refered to Song, Storesletten, and Zilibotti, 2011, for an important study on China's economic growth with financial frictions and resource misallocation).

Following the higher education expansion and the state sector reform, China's labor market experienced a structural change. Figure 2 shows the labor allocation of four skill-intensive industries (Panel (a)) and four labor-intensive ones (Panel (b)) for the state and the private sectors, respectively.[9] [10] It can be seen that for the skill-intensive industries, the private sector employment has grown very rapidly since 2002, which is the year when the first group of college students since college expansion entered the labor market, whereas the state sector employment has been relatively stable. Differing from that, the labor-intensive industries saw a large drop of state sector employment around 1998 following the reform, whereas there was a stable growth of the private sector throughout the years. These observations illustrate that (i) China's skill-intensive industries have grown relatively faster than the labor-intensive ones, indicating a relative increase of the skilled labor force; and (ii) although in both skill- and labor-intensive industries, the private-sector share of employment has increased over time, in skill-intensive industries this increase accelerated after 2002, suggesting a reallocation of the new skilled workers between sectors. However, since the college expansion and economic reform took place almost in the same period and the latter was designated to improve allocation efficiency, it is hard to tell from the data which policy drove the labor reallocation and, by doing so, how each of them contributes to labor productivity. By building a structural model which is then applied to quantitative analysis, this paper will answer these questions.

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[9]The skill-intensive industries are defined as industries in which the employment share with a college degree was above 30 percent in 2002, and labor-intensive industries are those in which this share was less than 10 percent in 2002.

[10]Data on the share of skilled employment at the industry-sector level is lacking, but it is noted that the share of employment with a college degree has increased steadily over the years for most industries (for the two sectors combined). For the four labor-intensive industries, it remained below 10 percent for manufacturing and construction in 2010, while it increased to slightly above 10 percent for wholesale and mining; for the four skill-intensive industries, it increased to over 60 percent for three of them in 2010 except real estate.
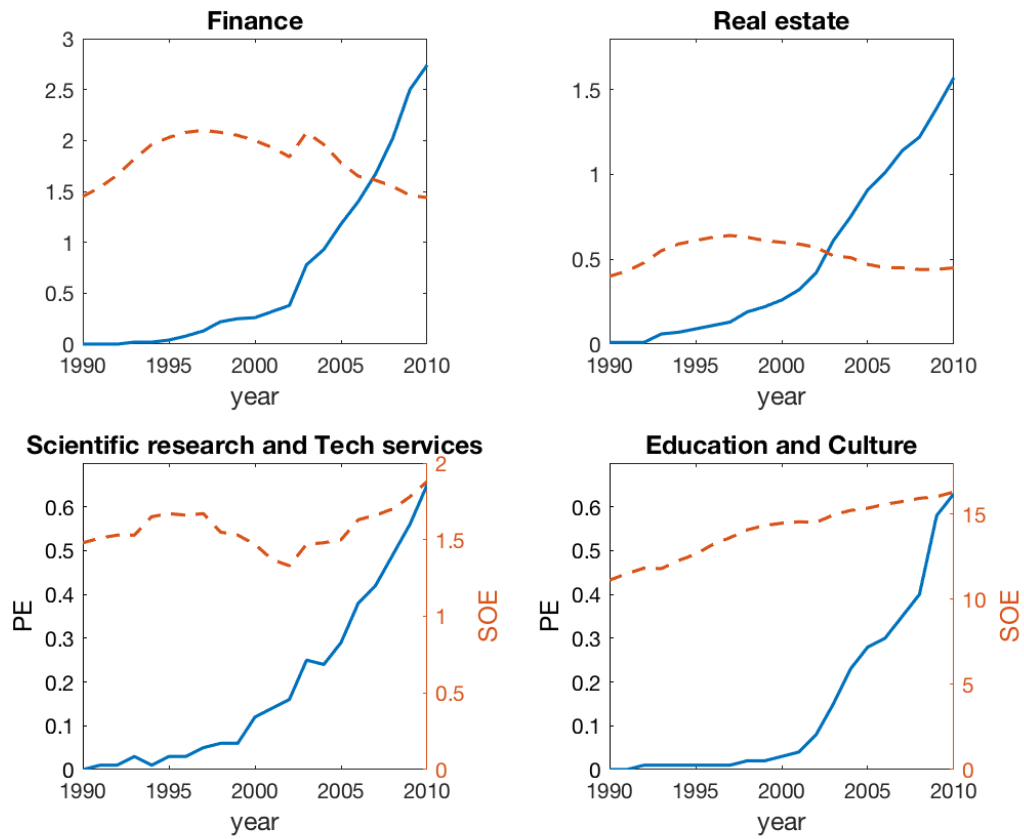
(a). Employment of skill-intensive industries (in millions)
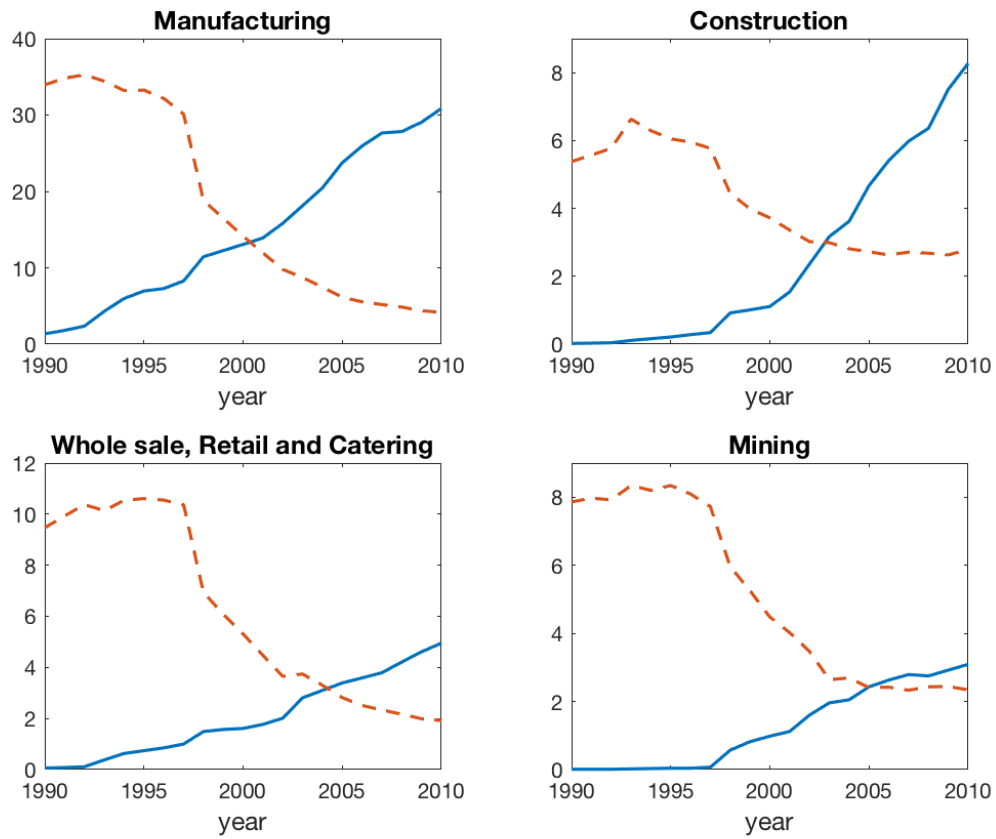
(b). Employment of labor-intensive industries (in millions)

Figure 2. Industry labor allocation

Notes: This set of figures shows the employment (in millions) of the state sector and the private sector for four skill-intensive industries (Panel (a)) and four labor-intensive industries (Panel (b)) during the 1990–2010 period. The solid line represents the private sector, and the dashed line represents the state sector.

Data source: China Labor Statistical Yearbook.

2 The Model

To properly capture the key features of the Chinese economy for studying the policy of interest, I develop a two-sector general equilibrium model with overlapping generations (OLG) of households. Firms in the state sector are less productive than their private sector counterparts, but they receive subsidies for factors of production. Households are heterogeneous in ability, and make an educational choice and an occupational choice over their life course. Both choices depend crucially on their ability and are also influenced by government policies.

2.1 Production and distortions

Time is discrete. Production takes place in two sectors, a private sector and a state sector. For simplicity, I assume firms within each sector are identical; let us call firms in the private sector private enterprises (PE) and those in the state sector state-owned enterprises (SOE). All firms produce homogeneous goods (which are treated as the numeraire) using unskilled labor, skilled labor, and physical capital with a constant-return-to-scale (CRS) technology given by

$$PE: \quad Y^P(K^P, H^P, L^P) \quad = vL^P + A^P(K^P)^{\alpha^P}(\Psi(\overline{a}^P)H^P)^{1-\alpha^P} \tag{1}$$

$$SOE: \quad Y^S(K^S, H^S, L^S) \quad = vL^S + A^S(K^S)^{\alpha^S}(\Psi(\overline{a}^S)H^S)^{1-\alpha^S} \tag{2}$$

where L^i (H^i) and K^i are the amount of unskilled (skilled) labor and physical capital employed by i firms, $\overline{a}^i$ is the average ability of workers in type i firms, and the superscript i denotes the type or sector of the firm, i.e., P for PE and S for SOE. I assume firms in each sector may choose from two types of technology, one using unskilled labor only and the other both skilled labor and physical capital. For simplicity, I assume that outputs from the two types of production, namely, unskilled and skilled production, are perfect substitutes. The former is linear in unskilled labor and is identical for PE and SOE, and the latter takes the standard Cobb-Douglas form, where workers' labor input is augmented by their ability measured by $\Psi(\overline{a}^i)$; thus, $\Psi'(\overline{a}^i) > 0$. That both technologies are CRS implies that the number of firms does not matter. These two types of technologies mimic the real-world technologies available to firms; that is, a low-tech one which is less productive but only requires labor input, and hence is widely adopted in labor-intensive industries, and a high-tech one that is skill- and capital-augmenting and is more productive, and hence is more popular in skill-intensive industries.

To be consistent with the literature, I assume that $A^P > A^S$; that is, PEs have

higher TFP than SOEs for their skilled production. I abstract from heterogeneity in the unskilled production across sectors, since the higher TFP of PEs is largely driven by their greater profit incentive, which matters to a lesser degree for the labor-intensive production than the skill-intensive one. Moreover, the capital shares of output in the two sectors, α^P and α^S, are allowed to differ, since PEs and SOEs may specialize in industries with different capital intensity. I also assume that a firm cannot observe an individual worker's ability but only the average ability of its skilled workers; hence, it pays the same wage to all of its skilled workers. All markets are competitive except for factor price distortions to be explained below.

Following Restuccia and Rogerson (2008) and Hsieh and Klenow (2009), I model policy distortions as a tax or subsidy rate on factor prices. Instead of assuming a tax or subsidy on output or physical capital as in their models, I assume that SOEs receive subsidies for both renting capital and hiring skilled workers in order to assess the effect of physical capital and human capital distortions separately, while PEs do not receive any subsidy at all and thus pay market prices for all factor inputs. Denote the market rental rate of capital by R and wage received by a skilled SOE worker by w_H^S, then what SOE actually pays out of its own pocket is $(1-\tau_K)R$ and $(1-\tau_w)w_H^S$, respectively, where τ_K and τ_w measure the degree of policy distortions on physical and human capital allocations, respectively (i.e., $\tau_K \geqslant 0$, $\tau_w \geqslant 0$). PEs receive no subsidy and hence pay R for capital and w_H^P to the skilled workers. Note that w_H^P may differ from w_H^S in equilibrium. In addition, both firms pay the same wage $w_L = \nu$ to their unskilled workers due to the simple linear form of the unskilled production. Finally, the average labor productivity is given by

$$APL = \frac{Y^P + Y^S}{L + H^P + H^S} \tag{3}$$

2.2   The household

The economy is populated with overlapping generations of households who live for three periods. Each household consists of one individual who makes an educational choice – whether to acquire college education when young, and then, upon graduating from college, an occupational choice – whether to work for a PE or SOE in the middle age period. Following Fender and Wang (2003), I assume that individuals are initially identical in all aspects except their ability, which is exogenously determined at one's birth and remains unchanged throughout her life. Ability is crucial in one's life, as

it not only affects one's disutility cost of acquiring college education and thus one's educational choice, but also one's job security if she works for PE as a skilled worker, and thus her occupational choice. Ability, denoted by a, follows an $i.i.d.$ distribution with cdf $F(a)$. I assume this distribution as cohort-invariant and normalize the measure of each cohort to one. In addition, individuals have no initial wealth at birth.

All individuals derive utility from the third-period consumption. Apart from this, only the disutility cost of acquiring higher education affects utility. This disutility cost can be viewed as a nonpecuniary cost, e.g., how painful one feels about preparing for the college entrance exam. There is neither endogenous leisure nor altruism. The utility function of an individual born at t with ability a can thereby be written as follows:

$$u_t(a) = c_t^{t+2}(a) - \Omega\frac{\eta}{a}, \tag{4}$$

where the first term c_t^{t+2} is one's consumption at the third period of life, which depends on her income and thus, ability.[11] The second term measures the disutility cost of college education, where Ω is an indicator function that equals one if the individual goes to college when young, and zero if she does not. The disutility, measured by $\frac{\eta}{a}$, consists of two components: η is the exogenous disutility cost of education, which will be used to measure the educational policy that rations higher education enrollments, i.e., larger η means more restrictive college admission; moreover, an individual's ability a affects the disutility cost negatively, since people with higher ability find it easier to prepare for the college entrance exam and will also enjoy college life more. Note that in the quantitative analysis, I will assume the exogenous disutility component as a relative measure; that is, I use $\eta_0 \equiv \frac{\eta}{\overline{w}_H}$ to measure the educational policy, where $\overline{w}_H$ is the average skilled wage.[12]

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[11]The linear functional form of utility greatly simplifies my analysis of household choices without losing any key features needed for modeling.

[12]An alternative way of modeling educational policy is to let policy assign a quota of college enrollments. As will be shown below, this way of modeling turns out to be equivalent to that in the present paper. Under the alternative model, the quota assigned by an educational policy gives each individual attempting to enter college a probability to be admitted. This probability depends both on the quota and one's ability and will be determined in equilibrium. Denote this probability by $p(a; Q)$ for an individual with ability a under an educational policy measured by a college enrollment quota Q. Thus, $p'_a(a; Q) > 0$ and $p'_Q(a; Q) > 0$. Then the expected utility of an individual who attempts to enter college is $Eu(a) = p(a; Q)Eu(c_{college}) + (1 - p(a; Q))Eu(c_{noncollege}) = Eu(c_{noncollege}) + p(a; Q)[Eu(c_{college}) - Eu(c_{noncollege})]$. In the present paper, the expected utility for one going to college can be written as $Eu(a) = Ev(c_{college}) - \frac{\eta}{a} = Ev(c_{noncollege}) + [Ev(c_{college}) - Ev(c_{noncollege})] - \frac{\eta}{a}$, where $v(\cdot)$ is utility derived from consumption. Since the term $Ev(c_{college}) - Ev(c_{noncollege})$ is linear in skilled wage due to the linearity of $v(\cdot)$, and η can be written as $\eta = \eta_0\overline{w}_H$, the whole term $[Ev(c_{college}) - Ev(c_{noncollege})] - \frac{\eta}{a}$ is linear in skilled wage or college premium, which is identical to

The timeline of one's life is as follows.

In the first period, an individual decides whether to acquire higher education (i.e., going to college). If she does, she cannot work in this period, and also needs to pay an education fee θ which has to be borrowed from the market since she has no initial wealth. However, she may anticipate being employed as a skilled worker from the next period on.[13] If the individual does not go to college, she can start working immediately but only as an unskilled worker, receiving an unskilled wage for her entire life. Note that although the education fee θ is exogenous in the model, in reality, it may increase following the college expansion as more resources may be needed for higher education, such as new land, new buildings, more teachers, and more government subsidies to universities and colleges, which is indeed the case in China. Thus, in calibration I allow θ to change after the college expansion.

In the second period, those who went to college when young become skilled workers. They need to make an occupational choice between PE and SOE, and will receive skilled wage w_H^P or w_H^S accordingly. They also need to repay their education loan at a market interest rate, r (by definition, $r = R - \delta$, where δ is the depreciate rate of physical capital), while those who did not go to college remain to be unskilled workers. In addition, I assume that all middle-aged households pay a lump-sum tax τ, regardless of her educational level or employer.[14]

In the third period, I assume that frictions of sectoral mobility make workers unable to switch the sector, while skilled workers of SOEs enjoy better job security than their PE counterparts. For a skilled PE worker, with a probability $\Phi(a)$ she will be laid off and become unemployed for the whole period, where $\Phi'(a) < 0$ reflects the fact that higher ability lowers one's likelihood of losing a job. In contrast, all skilled workers in SOEs secure their jobs perfectly in this period. This assumption mirrors the reality that many SOEs are inclined to offer "iron bowls" to the highly educated workers, even if they are not productive enough, while private firms have greater profit incentives and thus are more likely to fire the incapable workers, even if they had high educational attainment. Moreover, due to the lack of protection from the government, private firms are themselves more likely to shut down and in

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the second term of the alternative model when assuming linear utility; this term also increases with ability and decreases with the restrictiveness of educational policy, the same as in the alternative model.

[13]Instead of assuming education loans, one may also model the education fee to be paid by parents (i.e., the middle-aged). This is equivalent to the present model regarding the steady state solution but would be more complicated, as it requires intergenerational decisions and altruism.

[14]The lump-sum tax assumption is made to avoid introducing new distortions to households' choices. The amount of tax will be determined in equilibrium to balance the government budget.

that case, they will have to dismiss their workers anyway; these workers may face difficulties in finding a new job if their ability is low.[15] For an unskilled worker, though, I assume that the layoff probability is a constant, ϕ_L, in the last period, which is identical for all irrespective of their ability or sector. Given the same wage and layoff probability in the two sectors, an unskilled worker is indifferent between PE and SOE, and thus has no directed occupational choice.[16]

Finally, since only consumption of the last period of life enters the utility, households save all their income in earlier periods of life and receive interest payments. Their consumption in the last period conditional on their choices is thereby:

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\begin{aligned}
c_{t,L}^{t+2} &= [w_{L,t}(1 + r_{t+1}) + w_{L,t+1} - \tau_{t+1}](1 + r_{t+2}) + (1 - \phi_L)w_{L,t+2} \\
c_{t,H,S}^{t+2} &= [w_{H,t+1}^S - (1 + r_{t+1})\theta - \tau_{t+1}](1 + r_{t+2}) + w_{H,t+2}^S \\
c_{t,H,P}^{t+2}(a) &= [w_{H,t+1}^P - (1 + r_{t+1})\theta - \tau_{t+1}](1 + r_{t+2}) + [1 - \Phi(a)]w_{H,t+2}^P
\end{aligned}
\tag{5}
$$

where $c_{t,L}^{t+2}$, $c_{t,H,S}^{t+2}$, and $c_{t,H,P}^{t+2}(a)$ are the last period consumption of one born at t choosing to be an unskilled worker, a skilled SOE worker, and a skilled PE worker, respectively.

3   Optimization and Equilibrium

This section characterizes optimization conditions and the equilibrium. For a better understanding of the working of the educational policy, I also explain the effects of the higher education expansion in more detail in Section 3.5.

3.1   The household

With perfect foresight about lifetime income, a household's educational and occupational choices can be solved backwardly.

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[15]The layoff function can be viewed as a reduced form of a model in which employers receive a noisy signal of individual workers' ability after one period of employment. The higher one's true ability is, the more likely that her employer will receive a good signal, and hence the less likely she will be fired. Alternatively, one may consider a model without the assumption of unemployment, by allowing individuals' ability to be perfectly observed by their employers. Under this assumption, each individual skilled worker is paid by her marginal productivity (which depends on her ability), while the unskilled wage is again independent of ability. This alternative model has a very similar mechanism as the present model of sorting individuals into different education and occupation categories (see Section 3.1 for more discussion).

[16]Hence, the sectoral allocation of unskilled workers is undetermined in this model.

Occupational choice

At the second period of one's life (date $t+1$), a skilled individual (born at t) faces an occupational choice (denoted by o) between the private and the state sectors, i.e., $o \in \{P, S\}$. The individual makes the decision by comparing the expected consumption in the next period that will accrue from working for the two sectors; hence, she chooses to work for PE if and only if $c_{t,H,P}^{t+2} \geqslant c_{t,H,S}^{t+2}$, since the cost of college education has been a sunk cost. Straightforward manipulation of equation (4) shows that this condition is equivalent to $(w_{H,t+1}^P - w_{H,t+1}^S)(1 + r_{t+2}) + w_{H,t+2}^P - w_{H,t+2}^S \geqslant \Phi(a)w_{H,t+2}^P$. Intuitively, an individual prefers PE if the wage gain from working for PE versus SOE outweighs the expected loss of being fired in the last period of life. Note that higher ability lowers the probability of losing a job in PE (because $\Phi'(a) < 0$) and thus makes PE more attractive.

Under certain conditions, specifically, when the relative TFP of PE to SOE is sufficiently high and policy distortions (i.e., τ_K, τ_w) are not too large so that $w_H^P > w_H^S$, there exists a threshold ability $\hat{a}$ such that college graduates with ability above $\hat{a}$ choose to work for PE, while those with ability below $\hat{a}$ go to SOE, where $\hat{a}$ of generation t can be determined by:

$$\Phi(\hat{a}_t) = \left[(w_{H,t+1}^P - w_{H,t+1}^S)(1 + r_{t+2}) + w_{H,t+2}^P - w_{H,t+2}^S\right]/w_{H,t+2}^P. \tag{6}$$

In the steady state, this equation can be simplified as

$$\Phi(\hat{a}) = (2 + r)\left(1 - \frac{w_H^S}{w_H^P}\right) \tag{7}$$

Equation (7) illustrates the main tradeoff concerning the occupational choice, which lies between the relative wage and the unemployment risk. Since PE has higher productivity, it may offer a higher wage to skilled workers than SOE, as long as policy distortions are not too large. However, this gain may be offset by unemployment risk if the worker's ability is not high enough. Consequently, only skilled workers with sufficiently high ability choose to work for PE, whereas those with lower ability would rather secure the "iron bowl" offered by SOE. Moreover, a higher interest rate increases the relative PE skilled employment by lowering $\hat{a}$, as it raises the opportunity cost of working for SOE through a wealth effect.

Educational choice

At the first period, an individual (again, born at t), having perfectly forecasted what

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she would choose in the next period conditional on her decision at this period, makes an educational choice (denoted by e) of whether to go to college, i.e., $e \in \{H, L\}$. The person makes the decision by comparing the potential income gain from a college degree versus the disutility cost of acquiring college education; thus, she chooses to go to college if and only if $max\{E[c_{t,H,P}^{t+2}(a)], E[c_{t,H,S}^{t+2}]\} - E[c_{t,L}^{t+2}] \geqslant \frac{\eta}{a}$. Note that one's college premium (the left-hand side of this inequality) increases in a, while her disutility cost of college education (the right-hand side of the inequality) decreases in a; thus, individuals with higher ability are more likely to go to college and become skilled workers. In particular, when certain conditions are satisfied, such as the cost of college education is sufficiently high (i.e., high η and θ) and the unskilled unemployment rate (ϕ_L) is not too large, and assuming the condition for the existence of $\hat{a}$ holds, then there exists another threshold ability $\tilde{a}$ such that individuals with ability above $\tilde{a}$ choose to go to college, while those with ability below $\tilde{a}$ become unskilled, where $\tilde{a}$ of generation t can be determined by

$$\left[w_{H,t+1}^S - (1 + r_{t+1})\theta\right](1 + r_{t+2}) + w_{H,t+2}^S - \frac{\eta}{\tilde{a}_t}$$
$$= \left[w_{L,t}(1 + r_{t+1}) + w_{L,t+1}\right](1 + r_{t+2}) + (1 - \phi_L)w_{L,t+2} \quad (8)$$

The steady state form of this equation is then given by

$$\frac{\eta}{\tilde{a}} = w_H^S(2 + r) - (1 + r)\theta^2 - w_L\left[(2 + r)(1 + r) + 1 - \phi_L\right] \quad (9)$$

where the left-hand side of the equation represents the disutility cost of college education of an individual at the margin (i.e., with ability $\tilde{a}$), and the right-hand side is the college premium (for skilled workers in SOE). Moreover, similar to the occupational choice, a higher interest rate increases the opportunity cost of being unskilled through the wealth effect when w_H^S is sufficiently higher than w_L, and thus lowers $\tilde{a}$ and increases the skilled share of population.

Lifetime choices

To this end, we note that the model presents a sorting mechanism under which households self-select into different categories of education and occupation based on ability, which is illustrated in Figure 3. This figure shows the utility of a household (vertical axis) with different ability (horizontal axis) conditional on her choices between being unskilled, a skilled SOE worker, and a skilled PE worker. As can be seen, the utility of an unskilled worker (u_L) is constant regardless of her ability,

since there is neither disutility from education nor layoff risk that are affected by ability, while the utility of a skilled worker increases with ability. Moreover, the utility function of skilled PE workers is steeper than that of skilled SOE workers because for the former, higher ability not only lowers disutility from education as for the latter, but also reduces the layoff risk. Moreover, for one with ability at the lower bound (i.e., $\underline{a}$), being unskilled would make her better off than being a skilled SOE worker, whereas the latter would make her better off than being a skilled PE worker. These properties then pin down the two threshold abilities as well as the sorting mechanism; that is, individuals with low abilities (between $\underline{a}$ and $\tilde{a}$) do not go to college and become unskilled workers, those with mediocre abilities (between $\tilde{a}$ and $\hat{a}$) acquire college education and then work for SOEs, and only those with high abilities (above $\hat{a}$) become skilled PE workers.
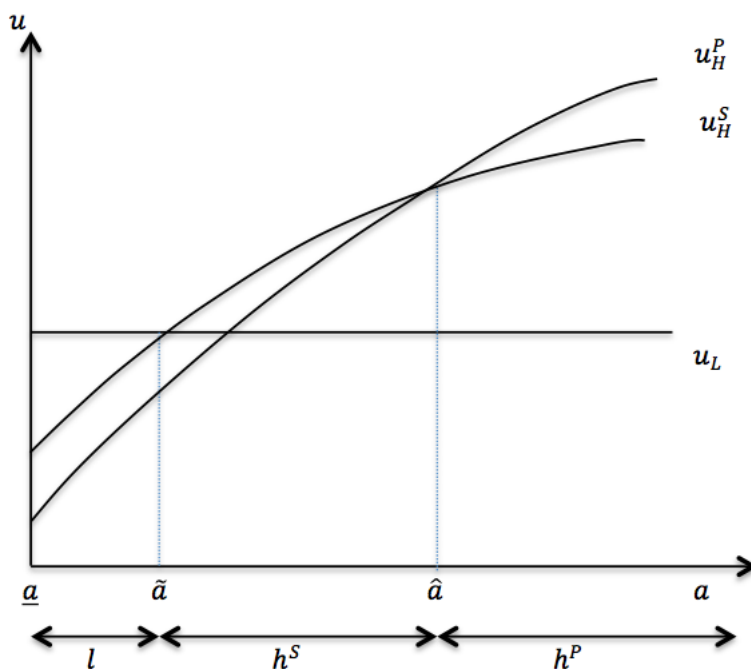

Figure 3. Lifetime choices by ability

3.2 The firm

Firms maximize profit by choosing the amount of physical capital to rent and the number of unskilled and skilled workers to hire in each period, taking policy distortions as given. As firms do not save for the future, their problem is static. Hence, the optimal conditions of firms' problem is simply equating the marginal product of

each production factor to its marginal cost. The demand for capital and for the two types of labor in the two sectors are thus given by (where subscript t is skipped)

Capital:

$$PE: \qquad R \qquad = \alpha^P A^P \Psi(\overline{a}^P)^{1-\alpha^P}(k^P)^{\alpha^P-1} \tag{10}$$

$$SOE: \quad (1-\tau_K)R \ = \alpha^S A^S \Psi(\overline{a}^S)^{1-\alpha^S}(k^S)^{\alpha^S-1} \tag{11}$$

Skilled labor:

$$PE: \qquad w_H^P \qquad = (1-\alpha^P)A^P \Psi(\overline{a}^P)^{1-\alpha^P}(k^P)^{\alpha^P} \tag{12}$$

$$SOE: \quad (1-\tau_w)w_H^S \ = (1-\alpha^S)A^S \Psi(\overline{a}^S)^{1-\alpha^S}(k^S)^{\alpha^S} \tag{13}$$

where $k^i \equiv \frac{K^i}{H^i}$, $i \in \{P,S\}$, is physical capital per skilled worker in type i firm. By assumption the unskilled wages are the same for PE and SOE:

$$w_L = \nu \tag{14}$$

3.3 Market clearing conditions

There are three markets in this economy – unskilled labor, skilled labor, and loanable funds markets. Below I show the market clearing condition for each market.

First, the unskilled labor market clearing condition at period t is given by

$$L_t^P + L_t^S = F(\tilde{a}_t) + F(\tilde{a}_{t-1}) + F(\tilde{a}_{t-2})(1 - \phi_{L,t}) \tag{15}$$

where $\tilde{a}_t$ denotes the threshold ability of going to college of the generation born at t. Equation (15) says that the total demand for the unskilled by the private and the state sectors at period t (the left-hand side) equals the sum of unskilled workers supplied from three generations coexisting in the same period (the right-hand side).

Second, for the skilled labor market, the clearing condition at period t is

$$H_t^P \ = \ 1 - F(\hat{a}_{t-1}) + \int_{\hat{a}_{t-2}}^{\infty} [1 - \Phi_t(a)]dF(a) \tag{16}$$

$$H_t^S \ = \ [F(\hat{a}_{t-1}) - F(\tilde{a}_{t-1})] + [F(\hat{a}_{t-2}) - F(\tilde{a}_{t-2})] \tag{17}$$

Similarly, $\hat{a}_t$ represents the threshold ability of being a skilled PE worker for the generation born at t. Different from the unskilled market, the skilled market features sectoral segregation, where the demand and supply of skilled workers in each of the

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private and the state sectors are equalized.

Third, the loanable funds market clearing condition at t is

$$K_t^P + K_t^S + \theta_t(h_t^P + h_t^S) + (h_{t-1}^P + h_{t-1}^S)(1 + r_t)\theta_{t-1} + \tau_t$$
$$= (l_t^P + l_t^S)w_{L,t} + (l_{t-1}^P + l_{t-1}^S)\left[(1 + r_t)w_{L,t-1} + w_{L,t}\right] + h_{t-1}^P w_{H,t}^P + h_{t-1}^S w_{H,t}^S \quad (18)$$

where l_t^i (h_t^i) is the amount of unskilled (skilled) workers of the generation born at t working in sector i. In particular, equation (18) shows that the demand side of the loanable funds market consists of four parts: productive capital of firms, education loan of young college students, loan repayment of middle-aged skilled workers, and total subsidies to SOE (which equals tax revenue τ); the supply side of this market includes wages earned by young and middle-aged unskilled workers plus savings of the latter, and wages earned by middle-aged skilled workers in both PE and SOE.

Finally, the average ability of each type of firm at period t is given by

$$\bar{a}_t^P = \left[\int_{\hat{a}_{t-1}}^{\infty} a\, dF(a) + \int_{\hat{a}_{t-2}}^{\infty} a(1 - \Phi_t(a))dF(a)\right] / H_t^P \quad (19)$$

$$\bar{a}_t^S = \left[\int_{\tilde{a}_{t-1}}^{\hat{a}_{t-1}} a\, dF(a) + \int_{\tilde{a}_{t-2}}^{\hat{a}_{t-2}} a\, dF(a)\right] / H_t^S \quad (20)$$

and government budget balance is satisfied:

$$\tau_t = \tau_{K,t} R_t K_t^S + \tau_{w,t} w_{H,t}^S H_t^S \quad (21)$$

that is, tax revenue equals the total subsidies to SOE for renting capital and hiring skilled workers.

3.4   Dynamic general equilibrium

Definition: A *competitive equilibrium* is a set of allocations $\{L^P, L^S, H^P, H^S,$ $K^P, K^S, c(a)\}_t$ and a set of prices $\{R, w_H^P, w_H^S, w_L\}_t$, such that given prices, policy distortions $\{\tau_K, \tau_W\}$, and distribution of ability $F(a)$,

(i) each household chooses $e \in \{H, L\}$, $o \in \{P, S\}$ and consumption to maximize her utility, and the sorting threshold abilities are given by (6) and (8);

(ii) each firm chooses capital and labor $\{K^i, H^i, L^i\}_t$ ($i \in \{P, S\}$) to maximize profit satisfying (10)–(14);

(iii) labor and loanable funds markets clear at each period, that is, (15)–(18) hold for each t; and

(iv) government's budget balance is satisfied, that is, (20) holds for each t.

3.5 The effects of higher education expansion

To better understand the working of the higher education expansion, this section characterizes the main channels through which this policy affects average labor productivity in a general equilibrium setting. As mentioned in the model section, higher education expansion can be measured as a reduction in the exogenous disutility cost of college education, that is, a decrease in the value of parameter η (or, more practically and as is shown in the next section, a decrease in a relative measure $\eta_0 \equiv \eta/\bar{w}_H$). Due to the existence of allocation distortion, this educational policy may not only affect the stock but also the allocation of human capital across sectors, which may then affect the allocation of other resources as well. Below I explain the two main channels of the policy effect (see Figure 4 for further illustration).

First, the *growth* effect. As higher education expansion lowers one's disutility cost of acquiring college education given her ability, it encourages more individuals to go to college and then become skilled workers, thereby increasing the society's stock of human capital. Since skilled labor complements the more-productive technology, the average labor productivity can be improved. Consistent with the conventional view on the role of human capital, this channel has a positive effect on labor productivity.

Second, the *reallocation* effect. Under the sorting mechanism, only individuals with higher ability (above $\tilde{a}$) go to college. By inducing more individuals to enter college (i.e., lowering $\tilde{a}$), the higher education expansion brings more less-able workers to the skilled labor market (thus, it lowers the average ability of skilled workers and their average productivity). As a result, a larger fraction of these individuals would prefer SOE to PE, since their risk of being fired in PE would be higher than the pre-expansion skilled workers on average. Therefore, the policy causes relatively more human capital to be allocated to the less-productive SOE. The reallocation of *human* capital alone, however, is unlikely to cause an overall negative impact of college expansion on labor productivity because even if all the increased skilled workers go to SOE, they are still more productive than their unskilled counterparts. Importantly, the negative productivity effect of college expansion is magnified when the reallocation of *physical* capital is taken into account. To illustrate this point, first, the reallocation of human capital across sectors directs physical capital to move toward the state sector, due to complementarity of production factors. Second, the reallocation of both production factors then tightens the loanable funds market and raises the interest rate as it increases subsidies demanded by SOE; this essentially

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crowds out productive physical capital. Consequently, not only does the capital per worker become lower for PE relative to SOE, but the average capital per worker in the economy is lowered. These effects may have a substantive detrimental effect on average labor productivity, but are largely ignored by the literature.

As higher education expansion has two offsetting effects on average labor productivity, its overall impact remains a quantitative question. To evaluate that, we must first calibrate the model to fit the data to which we now turn.
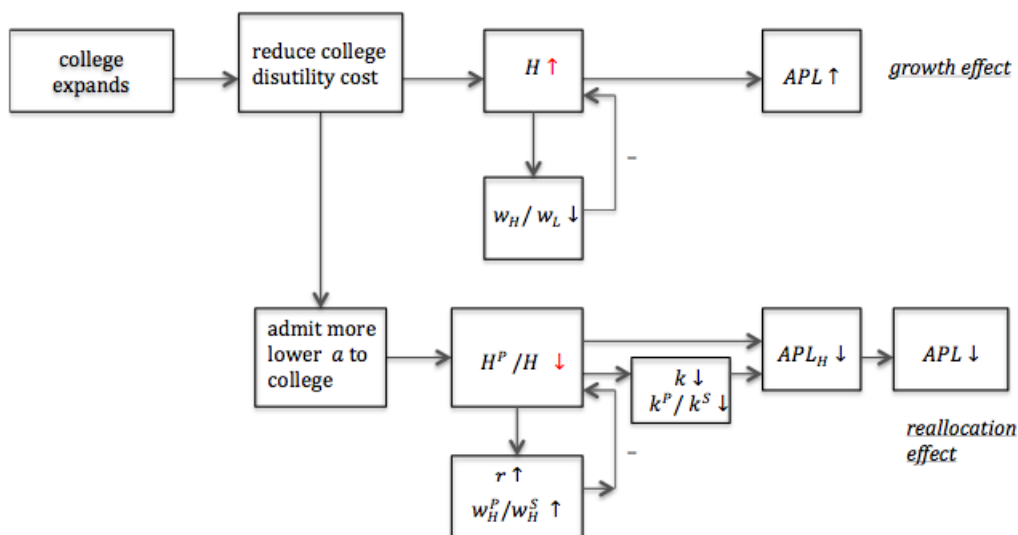
Figure 4. The effect of higher education expansion

4   Calibration and Numerical Solution

I am now prepared to calibrate the model to fit the data; once this task is done, I can use the numerical model for quantitative analysis including various policy experiments in the next section.

4.1   Calibration

The main strategy for calibration is that I assume some parameters to be constant over the two regimes while allowing others to vary to reflect institutional changes in the economy. I use data on China's labor market from 1990 to 2008. Since the state sector reform in China became substantial in 1998, roughly the same period as the higher education expansion, I view these two policies as concurrent and divide the sample period 1990–2008 into two subperiods, where 1990–1998 is considered

as the pre-regime when neither policy was implemented and 2002–2008 as the post-regime when both policies were implemented.[17] In particular, I calibrate two sets of parameters for the two regimes, respectively, to fit the average data of each subperiod, assuming the model economy has reached the steady state for that subperiod. For convenience, the pre-regime is also referred to as the old (first) steady state and the post-regime as the new (second) steady state for the rest of the paper (which will be briefed as "ss1" and "ss2", respectively).[18] Specifically, parameters that reflect policy changes, including η_0 (recall that $\eta_0 \equiv \frac{\eta}{\bar{w}_H}$), τ_K, and τ_W, are allowed to differ across the two steady states. In addition, sectoral TFPs, A^P and A^S, and the unemployment parameters or function, ϕ_L and $\Phi(a)$, are also allowed to change, as the former reflects a consequence of the economic reform and the latter captures structural changes of the labor market.

To fit the three-period OLG setting, I assume that three cohorts coexist at each period which lasts for 20 years, and normalize the population of each cohort to one. Moreover, since the college decision is made around age 15, I assume only a quarter of the young cohort population is active and thereby exclude the remaining three quarters from analysis; thus, although the total population at a period is 3, the "active" population is 2.25.

For household ability, I assume that it follows a Pareto distribution which is regarded by the literature to capture income distribution well; that is, $F(a) = 1 - (\frac{a}{a_m})^{-t_a}$, where the location parameter a_m represents the lower bound ability and the shape parameter t_a is a tail index. The ability function in production is assumed to be $\Psi(\bar{a}^i) = \frac{\bar{a}^i}{a_m}$ ($i \in (P, S\})$; that is, the relative average ability of skilled workers raises productivity. Moreover, I assume that the layoff probability of skilled PE workers in the third period of life takes the form $\Phi(a) = \varepsilon a^{-\gamma}$, where $\gamma > 0$ is constant over the two regimes, while $\varepsilon > 0$ will be allowed to change across regimes; thus, $\Phi'(a) < 0$ is satisfied.

The annual real interest rate is set as 3 percent and the annual depreciation

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[17]I do not use data between 1999 to 2001 because these years are in the transition period under the policy and thus are less able to capture the steady state features of the model. Data before 1990 are largely unavailable; those after 2008 are excluded as well because they could be greatly affected by the global financial crisis, which is beyond the scope of this work.

[18]A caveat of the calibration is that the sample period is too short for the model economy to reach the exact new steady state. Assuming an individual makes the college decision at age 15 and retires at 60, it takes 45 years for the economy to reach the new steady state, which means that data I use for calibrating the new steady state parameters actually contain information of a large fraction of the old- and middle-aged workers who made decisions in the old regime. However, given that data are largely unavailable for such a long span and that, even if they are available, they may be contaminated by other significant institutional changes, the present analysis may be the best that can be done so far.

rate of capital is set as 4 percent as are typical in the literature. Then the interest rate over one model period is the compound interest rate over 20 years; that is, $r = 1.03^{20} - 1 = 0.81$. Similarly, the rental rate of capital is $R = 1.07^{20} - 1 = 2.87$. The (hypothetical) depreciation rate for one model period can then be pinned down by $\delta = R - r = 2.06$. The college tuition fee was about 10,000 RMB yuan in the pre-regime and about 20,000 RMB yuan in the post-regime; these are converted to θ valued 0.17 in ss1 and 0.33 in ss2 (the numbers are calculated as a ratio to ss1 unskilled wage). In addition, the shape parameter of the Pareto distribution t_a is set to be 2.5, in line with the literature, while changing its value from 2 to 5 will only result in small differences in the main quantitative results. For the rest of the parameters, I calibrate them from the model to fit the data. Before turning to that, let me explain the main targets used for calibration.

I use data on employment, wage, and capital for five industries from the China Labor Statistical Yearbook, with all data converted to relative measures to fit the model analysis. These five industries include Manufacturing, Real estate, Finance, Information technology, and Science and technological service. I use the aggregation of these industries as targets of calibration because together they are a good representative of China's industries in terms of skill composition: manufacturing is a large labor-intensive industry with only 6.3 percent of employment with a college degree in 2002, and the remaining four are relatively small and skill-intensive with over 30 percent of employment with a college degree in 2002.[19] [20] These five industries constituted nearly 20 percent of China's urban employment, and their aggregated skill employment share is similar to that computed from the economy-wide aggregate data.

The first set of targets is related to employment. The dataset contains information on the total number of skilled workers (H) and unskilled workers (L), the total number of SOE workers (N^S) and PE workers (N^P), and the fraction of college graduates employed by PEs (h_{fr}^P).[21] With this information, I impute the following data: the fraction of a cohort as unskilled workers, skilled PE workers, and skilled SOE workers, respectively (and hence, the total number of each type of workers in a period), and the fraction of skilled workers in each sector. By normalizing and

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[19]The share of employment with a college degree has increased steadily over the years for most industries. For example, it increased from 6.3 to 9.8 percent from 2002 to 2010 for the manufacturing industry, and from 43 to 55 percent for the IT industry during the same years.

[20]The employment data on Information technology is unavailable before 1997; thus, I assume the employment from 1990 to 1996 equals that of 1997 (for both SOE and PE).

[21]Throughout the paper, I refer to workers with a college degree as skilled workers, and to the rest as unskilled workers.

taking the average, I obtain $F(\tilde{a})$, $F(\hat{a})$, H^P, and H^S for each steady state. It is noted that the relative PE-SOE skilled employment increased substantially over the two regimes. In the pre-regime, the skilled employment in SOE was about fivefold that in PE, while in the post-regime they are very close. Meanwhile, the skill composition of the whole population more than tripled in the post-regime (increased from about 5 percent to 17 percent). Furthermore, the dataset has information on the total unemployment rate and the unskilled share of unemployment, which are used (together with the unskilled share of employment) to impute the unemployment rate of the skilled ($uemp_H$) and unskilled ($uemp_L$, or ϕ_L), respectively.[22]

The second set of targets regards wage ratios between sectors and skills. The dataset contains information on the average wage for each of the state and the private sectors, but has no information about sectoral wages of different skills. Thus, I impute the skilled wage of PE and SOE (i.e., w_H^P and w_H^S), respectively, using the average sectoral wage and the skilled share of employment in each sector (needless to say, all wages are in real terms). Note that the average wage of the state sector in the pre-regime has been adjusted with a 30 percent increase to the raw data because it is documented that the non-wage benefits, such as housing, childcare and schooling, and healthcare, may account for at least 30% over the SOE wage bills before the state sector reform (Liu, 1995). For the unskilled wage (i.e., $w_L = \nu$), I use the average wage of the construction industry as an approximation, since the skilled employment share in construction is among the lowest of all industries (5 percent in 2002) and remains stable over the years.[23] Finally, I normalize the unskilled wage in ss1 to one and convert all other imputed wages as ratios to the ss1 unskilled wage. These estimations result in PE-SOE skilled wage ratios being 1.06 for ss1 and 1.29 for ss2, and skill premium (i.e., skilled-unskilled wage ratio) being 6.8 for ss1 and 3.5 for ss2.[24]

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[22]I take the average of $uemp_H$ and $uemp_L$ of 2005–2008, respectively, for the values of ss2, since the imputed numbers before 2005 are very volatile. Moreover, data on the unskilled share of unemployment before 1997 are largely unavailable, so I impute $uemp_H$ and $uemp_L$ of ss1 using the values of these two variables in ss2 times the ratio of the average total unemployment rate of 1990–1998 to that of 2005–2008.

[23]The construction wage may over-estimate the unskilled wage since some workers in this industry are highly skilled, but may also under-estimate the unskilled wage because a large fraction of construction workers are rural migrants who are usually more under-paid than their urban counterparts. On balance, it can be a reasonable approximation of the unskilled wage.

[24]These estimates are comparable to those from China's household/individual level surveys (the data of most years are unavailable though). For example, the estimate of the PE-SOE skilled wage ratio is 1.19 in the China Household Income Project (2002) for 2001, and 1.42 in the China Family Panel Study ("CFPS", 2010) for 2009; the estimated skill premium is about 4 in CFPS (2010) for 2009.

The last set of targets is the capital ratio between sectors. I use the ratio of total fixed capital investment between the private and the state sectors as the physical capital ratio (K^P/K^S). Then by using the ratio of skilled employment between the two sectors (i.e., H^P/H^S), I obtain the ratio of capital per skilled worker between sectors (k^P/k^S).

With the set of targets regarding employment, wage, and capital ratios, I calibrate the remaining 16 parameters which include four regime-independent parameters a_m, α^P, α^S and γ, and six pairs of regime-dependent ones (hence, 12 parameters) η_0, τ_K, τ_w, A^P, A^S, and ε. The calibration steps are as follows.

First, I calibrate the pairs of τ_K, τ_W, k^P and k^S, and α^P and α^S (that is, 6 parameters and 4 variables) jointly using relative price conditions, loanable funds market, and labor market clearing conditions to match skilled wage in PE and SOE, capital ratio of PE to SOE, and employment share of skilled PE and SOE workers for each regime.[25] This gives τ_K of 0.43 and 0.09 in ss1 and ss2, respectively, and τ_W of 0.68 and 0.36 in the two steady states, respectively. Thus, there are substantial reductions in the measured policy distortions on both physical capital and skilled employment, consistent with what is documented in the literature and the data.[26] I also obtain $\alpha^P = 0.82$ and $\alpha^S = 0.84$; thus, the state sector is more capital-intensive than the private sector. Following this step, I compute the ability-augmenting TFP for each sector and each regime, which will be used to pin down sectoral TFPs after

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[25]The relative price conditions are derived from FOCs of firms' problem and are given by

$$
\frac{w_H^P}{R} = \frac{1-\alpha^P}{\alpha^P} \cdot k^P
$$
$$
\frac{w_H^P(1-\tau_K)}{w_H^S(1-\tau_W)} = \frac{1-\alpha^P}{\alpha^P} \cdot \frac{\alpha^S}{1-\alpha^S} \cdot \frac{k^P}{k^S}
$$

[26] For example, Bai et al. (2000) document that a large number of SOEs maintained their employment of surplus workers only for an obligation to the government and for receiving subsidies, and this situation was largely mitigated by the SOE reform in the late 1990s. Moreover, data from the China statistical yearbook shows that before the SOE reform, over one-third of China's SOEs were taking financial losses. The total loss-to-profit ratio of SOEs was more than 2 in 1998 and was reduced to about 1/8 in 2004.

solving for the average sectoral abilities.[27]

Second, the parameters of the skilled layoff function (γ and two ε's) and the location parameter of Pareto distribution (a_m) are calibrated jointly using the cutoff condition of $\hat{a}$ (given by (7)) and the skilled labor market clearing condition to match the *PE-SOE* skilled wage ratio and the skilled unemployment rate for two regimes. Note that ε, the multiplier of the skilled layoff function, changes substantively across the two steady states (from 1.72 to 0.01), suggesting a large structural change of the labor market. This seems counterintuitive at first glance because a smaller ε means a lower probability to be fired given a skilled worker's ability, while the supply of skills grew significantly over the years. This result, however, can be justified in the following way. First, it turns out that the layoff probability of a skilled *PE* worker at the margin $\hat{a}$ is 0.16 in ss1 and 0.64 in ss2; that the latter is fourfold the former is indeed in line with the real-world situation that college graduates had been facing an increasingly tough job market. Second, even given ability, one should still be more likely to find or keep a private sector job in the post-regime compared with the pre-regime because significant market-oriented policy changes in China along with skill-directed technological change (which is not explicitly modeled in the present paper, though) may have created many more job opportunities for skilled workers in the private sector.

Next, given that the Pareto distribution function $F(a)$ has been determined, I can solve the two cutoff abilities, $\hat{a}$ and $\tilde{a}$, for each steady state. Using these cutoff abilities and the skilled layoff function, I can then compute the average ability of skilled workers in *PE* and *SOE*, respectively, which can then be used to pin down sectoral TFPs (i.e., A^P and A^S) in each steady state. The resulting A^P is 3.39 and 4.30 for ss1 and ss2, respectively, and A^S is 2.11 and 3.86 for the two steady states, respectively. The estimated increase in the state sector TFP over the two regimes (83 percent) is very close to that in Hsieh and Klenow (2009). Moreover, the sectoral TFP ratio (A^P/A^S) is 1.61 and 1.11 in the pre- and post-regimes, respectively; the relative increase in the TFP of *SOE* to *PE* is in line with the literature that finds a closed gap between China's sectoral TFPs following the *SOE* reform (Hsieh and

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[27]The ability-augmenting TFPs for *PE* and *SOE* are given by

$$A^P \left(\frac{\bar{a}^P}{a_m} \right)^{1-\alpha^P} = \frac{w_H^P}{(1-\alpha^P)(k^P)^{\alpha^P}}$$

$$A^S \left(\frac{\bar{a}^S}{a_m} \right)^{1-\alpha^S} = \frac{w_H^S(1-\tau_W)}{(1-\alpha^S)(k^S)^{\alpha^S}}$$

Song, 2015).[28]

Finally, I solve the exogenous disutility cost of college education η using (9) with other calibrated parameters or variables, and obtain the relative measure of disutility $\eta_0 \equiv \frac{\eta}{\bar{w}_H}$, which will be used for evaluating educational policy. This results in η_0 being 1.41 in ss1 and 0.53 in ss2, suggesting a large decline (62%) in the disutility cost of college education following the higher education expansion.

To summarize the calibration results, Table 1 shows the fitness by comparing the model with the main targets, Table 2 briefs the parameterization of the model, and Table 3 presents some wage and employment results.

Table 1. Fitness: model versus target

variable	model		target	
	ss1	ss2	ss1	ss2
H	0.11	0.32	0.10	0.32
L	2.07	1.80	2.07	1.80
H^P	0.01	0.15	0.01	0.15
H^S	0.10	0.16	0.09	0.17
k^P/k^S	1.56	1.58	1.62	1.57
w_H^P	6.60	9.06	7.18	8.96
w_H^S	6.46	6.96	6.76	6.93
$uemp_H$	0.00	0.04	0.02	0.04

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[28]Hsieh and Song (2015) document that the rise in the state sector TFP is mainly driven by the corporatization of surviving state-controlled firms and the establishment of new state-owned firms.

Table 2. Parameterization of the model

parameter	ss1	ss2	target
δ	2.19	2.19	literature, computed
t_a	2.50	2.50	literature
θ	0.17	0.33	college tuition fee
ν	1.00	2.29	unskilled wage, normalized
ϕ_L	0.06	0.10	unskilled employment rate
τ_K	0.43	0.08	joint targets of w_H^P, w_H^S, $\frac{k^P}{k^S}$, H^P, H^S
τ_W	0.68	0.36	
α^P	0.82	0.82	
α^S	0.84	0.84	
ε	1.79	0.01	joint targets of $\frac{w_H^P}{w_H^S}$ and $uemp_H$
γ	7.27	7.27	
a_m	0.20	0.20	
A^P	3.51	4.45	computed
A^S	2.19	4.01	
η_0	1.22	0.32	

Table 3. Wage and employment

variable	ss1	ss2	description
w_L	1.00	2.29	unskilled wage
$\overline{w}_H/w_L$	6.48	3.49	skill premium
w_H^P/w_H^S	1.02	1.30	PE premium (skilled)
$\%l$	94.7	83.4	cohort share of unskilled workers
$\%h^P$	0.8	8.3	cohort share of skilled PE workers
$\%h^S$	4.5	8.3	cohort share of skilled SOE workers

4.2   The measure of human capital

To better study the effects of the policy of interest, I construct a measure of human capital which is informative about labor productivity. This measure incorporates not only ability but also the contribution of ability to production which crucially depends on education. The so-called "effective" human capital is proposed as follows.

For unskilled workers, the human capital of each individual is normalized as one, regardless of her ability. Since the ability of the unskilled has no contribution to production, it is regarded as unproductive and hence does not enter one's (effective) human capital (essentially, every unskilled worker's human capital is the same as the one with the lower bound ability). Therefore, the aggregate unskilled human capital is simply the sum of all unskilled workers, i.e., $HC_L = L$.

For skilled workers, the aggregate human capital in each sector is defined by $HC_H^i \equiv (\bar{a}^i/a_m)H^i$, where $i \in \{P, S\}$; that is, sectoral skilled human capital equals the relative-ability-augmented skilled labor. Note that this measure corresponds exactly to the factor of labor input in the production function (see (1) and (2)). Hence, the skilled human capital increases with ability as it makes one more productive. Accordingly, the aggregate skilled human capital is the sum of that of the two sectors; that is, $HC_H = HC_H^P + HC_H^S = (\bar{a}/a_m) H$, where $\bar{a}$ is the average ability of all skilled workers. Finally, the aggregate human capital of the economy is given by

$$HC = HC_L + HC_H = L + (\bar{a}/a_m)H \tag{22}$$

It should be noted that the human capital distribution is not continuous. An unskilled worker's human capital can be elevated to a significant degree by a college education; this is essentially because higher education enables one to conduct skill-intensive tasks for which ability is much more valued.

5 Quantitative Analysis

With the theoretical model calibrated to fit the data, I have a running numerical model that can be readily used for quantitative analysis including various policy experiments regarding higher education expansion and economic reform.

5.1 Comparative statics

In this subsection, I compute comparative statics to assess the effect of each specific factor related to college expansion and economic reform. The parameters of interest include η_0, τ_K, τ_w, A^S, and A^P.[29] I focus on the effects of these parameters on human

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[29] While the first three parameters are direct measures of the policies of interest, the latter two are also studied because sectoral TFPs can be greatly influenced by economic reform.

capital stock and sectoral allocation, including measures of skilled workers (H and H^P/H) and human capital proposed in the previous section (HC and HC^P/HC), sectoral output share (Y_H^P/Y_H), and average labor productivity (APL).[30] While I conduct the analysis for each of the two steady states, for brevity, I only show the main results of η_0 and τ_K for the first steady state (i.e., pre-regime) in Figure 5.[31]

Figure 5(a) shows the effect of higher education expansion measured by decreases in η_0 on a number of human capital and productivity measures (where 0 on the horizontal axis corresponds to the ss1 value of η_0). As can be seen, a reduction in η_0 does increase the society's level of skilled labor and human capital. For example, a 10% decrease in η_0 from its ss1 value increases H by 18% and HC by 1.4%. The latter is increased to a lesser extent because the average ability of skilled workers is lowered when college expands. However, the PE share of both skilled labor and human capital has an inverse-U relationship with the decrease in η_0. In particular, both shares start to decline when η_0 exceeds 9% over its ss1 value and decline faster when η_0 becomes smaller.[32] A similar pattern applies to the PE output share and APL, with the latter starting to decline when η_0 is above 96% of its ss1 value and declining at a higher rate when η_0 gets smaller. The downward side of the APL curve is essentially caused by the reallocation effect of higher education expansion (as discussed in Section 3.5); that is, with the severity of policy distortions, the intensified misallocation of both human capital and physical capital following college expansion as well as the crowding out of productive capital generate a large negative impact on average labor productivity which dominates the positive growth effect of such a policy.

Figure 5(b) shows the effect of a reduction in physical capital distortion measured by τ_K on the same variables as in (a) (again, point 0 on the horizontal axis corresponds to the ss1 value of τ_K). As can be seen, a decrease in τ_K has a negative effect on both total and SOE skilled labor and human capital, while it has a substantively positive effect on PE skilled labor and human capital. Specifically, a 10% decrease in τ_K from its ss1 value lowers H by 16% and HC by 1.5% (it lowers H^S and HC_H^S more, both by about 25%), while it increases H^P by 65% and HC_H^P by 35%. Conse-

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[30]Since the allocation of unskilled workers is undetermined in the model, the sectoral share of human capital is defined as that of skilled human capital; that is, $HC^i/HC = HC_H^i/HC_H$ for $i \in \{P, S\}$.

[31]The results of the second steady state (post-regime) is qualitatively and quantitatively similar to that of the first steady state, and are available upon request.

[32]More specifically, a 10% decrease in η_0 from its ss1 value increases H^P share by 0.4% and HC^P share by 0.2%, while a 10% reduction in η_0 from the peak point of H^P share lowers H^P share by 1.1% and HC^P share by 0.6%.

quently, the PE share of skilled labor is raised by 95% and that of human capital by 50%, and the PE output share is raised by 79%. The negative human capital effect of the τ_K reduction is mainly driven by a decline in the interest rate because fewer subsidies are required by SOE when distortion is reduced which loosens the loanable funds market; the lower interest rate then reduces the opportunity cost of being unskilled when the skill premium is sufficiently large (see (9)). Despite its negative effect on total human capital, the reduction in capital distortion enhances average labor productivity as it improves allocation efficiency. The last panel of Figure 5(b) shows that a 10% decrease in τ_K from its ss1 value raises APL by 12%, and that further decreases in τ_K will raise APL at a higher rate.

For other parameters of interest which are not shown graphically, the effect of a reduction in τ_w is similar to that of τ_K. A larger A^S increases total skilled labor and human capital as well as those in SOE, but reduces those in PE; it also lowers APL (if it is still lower than A^P) despite the improved TFP of SOE as it causes more resources being allocated to the (still) less-productive SOE. An increase in A^P has the opposite effects.
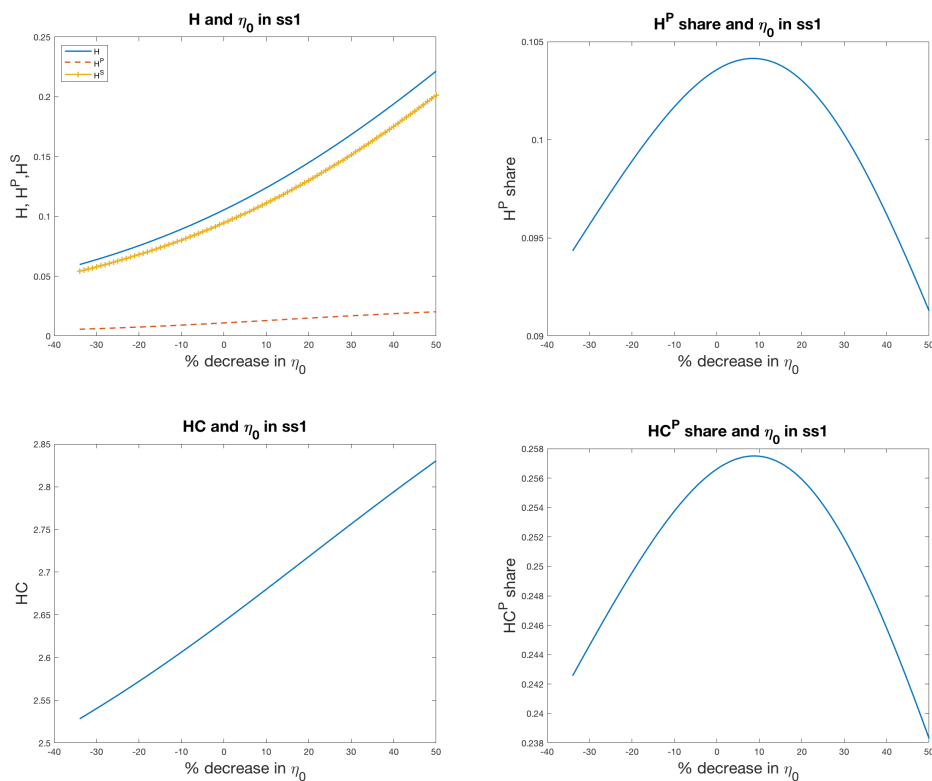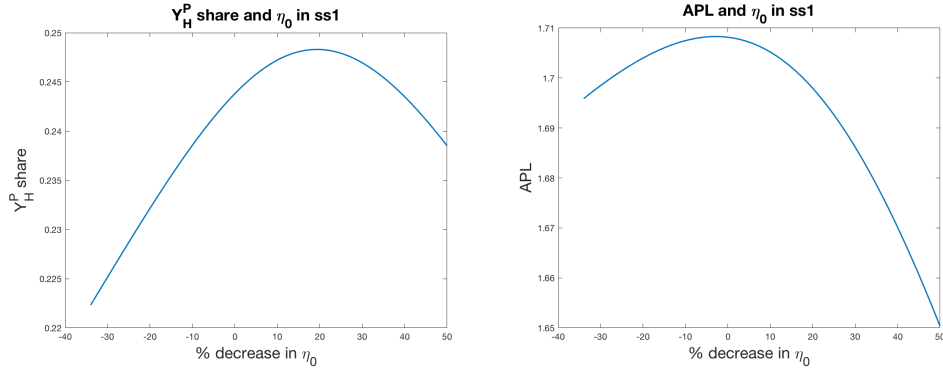
(a) Comparative statics of η_0
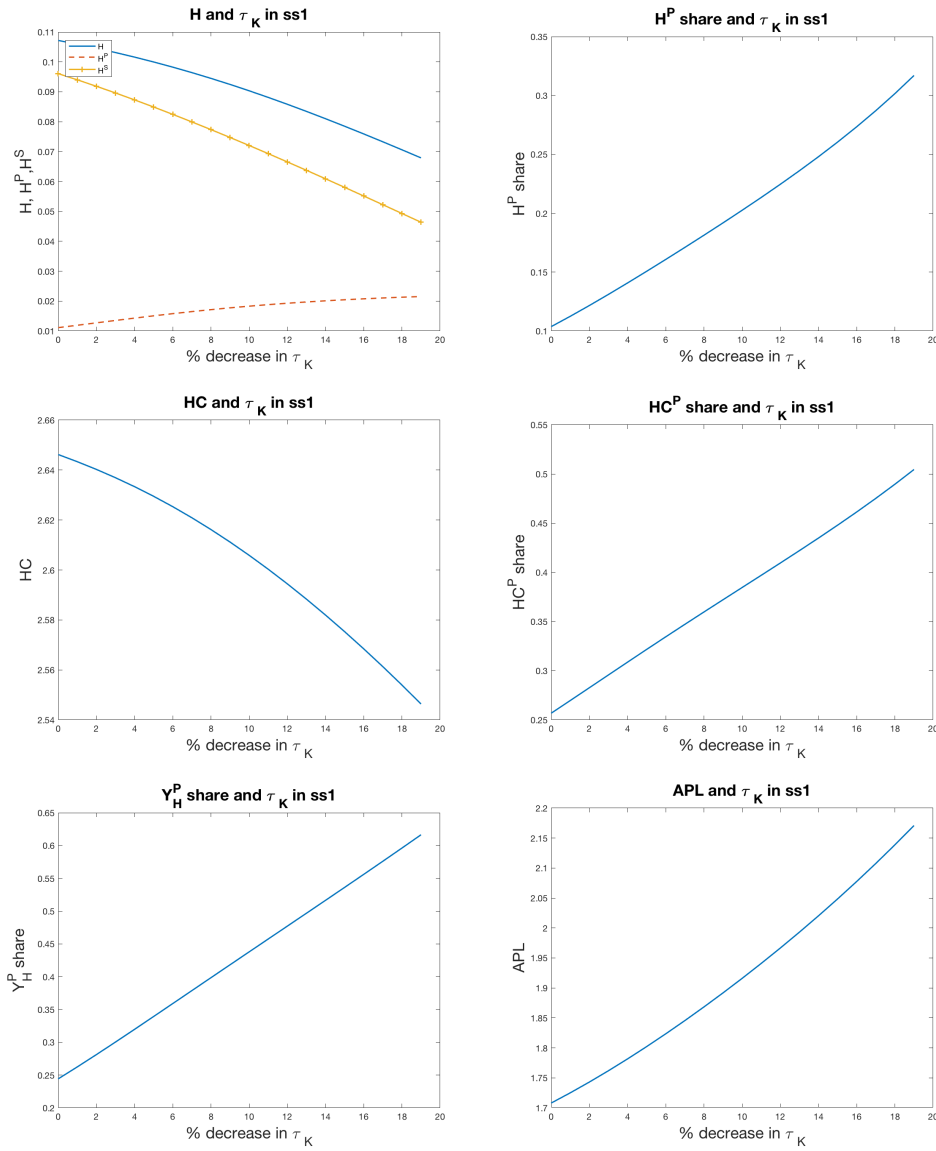
(b) Comparative statics of τ_K

Figure 5. Comparative statics

5.2 Counterfactual analysis

In this section, I conduct a number of counterfactual experiments to further explore the impact of the educational and economic policies of interest.

5.2.1 The impact of the educational and economic policy

In the first experiment, I investigate what would have happened to a number of human capital and productivity measures had there been no college expansion or economic reform. In particular, I run the experiment on the post-regime (ss2) and look at the changes in variables, including total skilled labor (H), human capital (HC) and their PE shares (H^P/H, HC^P/HC), sectoral output share (Y_H^P/Y_H), and average labor productivity (APL and APL_H, where the latter is the average labor productivity of skilled production) by changing the value of η_0, τ_K, τ_W, A^P, and A^S, one or two at a time, to their pre-regime (ss1) values while keeping all other parameter values fixed to their ss2 values. Table 4 shows the percentage changes in the variables from their ss2 values under each parameter change.

As can be seen, had there been no higher education expansion (i.e., no η_0 change, Column 1), total skilled labor would have been lowered by 71 percent and total human capital by 11 percent. However, the PE share of both skilled labor and human capital would have increased substantively, by 54 and 29 percent, respectively. As a result, APL would have increased by 2.5 percent. The result suggests that despite the positive effect of the college expansion on human capital formation, it has a small but *negative* effect on average labor productivity. Again, this is caused by the reallocation effect of the educational policy that magnifies factor misallocation and crowds out productive capital.

The effects of changing τ_K and τ_W back to their ss1 values are somewhat different (Column 2 and 3). On the one hand, had there been no reduction in capital distortion (i.e., no change in τ_K), total skilled labor would have been lowered by 38 percent and total human capital by 4 percent. This result seems different from that in the comparative statics analysis in Section 5.1 which shows that a reduction in τ_K lowers human capital. This is because here by changing τ_K from its ss2 value (0.085) to its ss1 value (0.43), the increase in τ_K is so large that it significantly lowers w_H^S in equilibrium; consequently, even though the interest rate rises, the diminishing skill premium discourages individuals from acquiring a college education. Since the reduction in τ_K appears to have positive effects on both human capital and allocation efficiency, it enhances average labor productivity substantively: had there been no

τ_K reduction, APL would have declined by 42 percent. On the other hand, Column 3 shows that the reduction in human capital distortion (i.e., reduction in τ_W) has a negative effect on total human capital (for a similar reason as discussed in Section 5.1 for the effect of τ_K), while there is a positive effect on the PE share of human capital. Its overall effect on average labor productivity is positive: had there been no reduction in τ_W, APL would have declined by 28 percent.

Column 4 shows the overall effects of the economic reform with both τ_K and τ_W changed back to their ss1 values. It can be seen that had there been no reform (i.e., no reduction in τ_K and τ_W), total skilled labor would have declined by 4 percent while total human capital would have increased by 0.5 percent, and almost all skilled labor would have been allocated to the state sector. As a consequence, average labor productivity would have declined by 48 percent.

Furthermore, the last two columns of Table 4 show the effect of sectoral TFP changes on the same variables. As can be seen, the changes in A^P and A^S have opposite effects on all variables listed. In particular, had there been no improvement in A^P, total skilled labor and human capital would have increased, while their PE share would have declined significantly; thus, misallocation would have been more severe, causing APL to decline. In contrast, had there been no A^S improvement, there would have been less skilled labor and human capital, while a larger fraction of them would have been allocated to the private sector, and APL would have increased.

Table 4. Policy decomposition (% change)

variables	η_0	τ_K	τ_W	τ_K, τ_W	A^P	A^S
H	-70.9	-38.1	51.0	-3.8	15.3	-47.3
H^P/H	53.8	-99.5	-72.6	-99.9	-96.1	107.1
HC	-10.7	-4.1	5.6	0.5	2.6	-6.7
HC^P/HC	28.6	-95.8	-54.3	-98.4	-85.9	53.8
Y_H^P/Y_H	28.3	-99.5	-52.5	-99.8	-96.0	60.2
APL_H	245.9	-31.4	-56.5	-62.2	-34.8	127.2
APL	2.5	-41.7	-28.0	-47.6	-19.6	16.8

5.2.2 Decomposition of the educational policy effect

In order to better understand the channels of the impact of the educational policy, I decompose the policy effect on labor productivity into a number of factors. Model analysis suggests that the following factors count: total skilled labor (thus, human

capital) and its allocation across sectors, average ability of skilled workers in each sector, and physical capital stock and its sectoral allocation. Therefore, in this experiment, I change the values of H, H^P/H, $\bar{a}^P$ and $\bar{a}^S$, K, and K^P/K in $ss2$, one at a time, to be the same as in the case where there is no college expansion (i.e., no decrease in η_0, as in the first counterfactual experiment in Section 5.2.1), and check how APL would be affected in each scenario. The results are shown in Table 5, where the first two columns show the value of each variable in ss2 and in the counterfactual case (i.e., η_0 same as in ss1), respectively, and the last column shows the percentage change in APL from its ss2 value by setting each variable to its counterfactual value.

It is noted that except for the increase in H following the college expansion that has a positive effect on APL (i.e., without the policy APL would have declined by 4.2 percent), changes in all other factors due to the educational policy have negative effects on APL; that is, APL in the post-regime would have increased had these variable values been equal to that in the no-η_0-change case. Among these factors, the reduction in the total physical capital (K) plays the leading role in driving down APL (by 9.8 percent), followed by lowered average ability of skilled workers (4.9 percent). While resource misallocation per se (H^P/H, K^P/K) seems to play a relatively minor role, it can be a cause of the crowding out of productive capital as it raises the amount of subsidies to SOE (to be further illustrated below). Overall, the result suggests that the crowding out effect of the educational policy on productive capital has a substantively negative impact on labor productivity, and that this impact can be so large that it may turn the overall effect of the educational policy on labor productivity to negative.

Table 5. Decomposition of the educational policy effect

variables	E2 (ss2)	E1 (η_0 as ss1)	% change in APL
H	0.32	0.09	-4.24
H^P/H	0.48	0.74	0.85
$\bar{a}^P$, $\bar{a}^S$	0.92, 0.46	1.28, 0.72	4.91
K	3.65	4.23	9.78
K^P/K	0.60	0.78	0.22

One may then ask: what drives the crowding out of productive capital under the educational policy? To answer this question, I compare the supply and the demand sides of the loanable funds market in ss2 with that in the no-η_0-change case and

show the results in Table 6. It can be seen that productive capital (K) in ss2 is about 16 percent lower than that in the in the no-η_0-change case. While a drop in the loanable funds supply from unskilled workers and an increase in tuition fees and loan repayment both tighten the loanable funds market, the rising subsidies to SOE is the major factor that crowds out capital for production. This is essentially caused by the magnified misallocation of human capital and physical capital following the higher education expansion. As a result, capital was reallocated not only from PE to SOE due to factor complementarity, but also from production to unproductive subsidy, further dampening labor productivity.

Table 6. Educational policy effects on the loanable funds market

loanable funds market		E2	E1	E2-E1
		(ss2)	(η_0 as ss1)	
supply	unskilled wage and saving	3.24	3.47	-0.23
	skilled wage (middle-aged)	1.33	1.21	0.12
demand	K: capital for production	3.65	4.23	-0.58
	tuition and loan repayment	0.15	0.04	0.12
	subsidy to SOE	0.77	0.41	0.36

5.2.3 The impact of educational policy under different distortions

The analysis from the previous subsections suggest that, with the prevalence of allocation distortions, a policy that promotes higher education seems to have a very limited effect, if any, on enhancing the labor productivity of a society. What if the distortion was eliminated? In other words, how does distortion matter for the impact of the educational policy? To answer these questions, I reevaluate the policy under two scenarios, one is the pre-regime economy (i.e., ss1) which has large allocation distortion (i.e., $\tau_K = 0.43$ and $\tau_W = 0.68$), and the other a zero-distortion economy (i.e., $\tau_K = 0$ and $\tau_W = 0$) with all other parameters fixed the same as in ss1. The results are shown in Table 7.

While higher education expansion appears to have a much larger positive effect on total skilled labor and human capital in the full-distortion economy than in the zero-distortion one, its reallocation effect cannot be overlooked. When the economy exhibits large allocation distortions, college expansion leads to a 19 percent decrease in the PE share of skilled labor and a 12 percent decrease in the PE share of human capital; its overall effect on APL is again negative (-5.2 percent). In contrast, when

distortion was completely eliminated, all skilled workers would be allocated to the private sector and the labor productivity effect of the college expansion would turn positive (3.3 percent). This result suggests that the impact of a government policy that promotes higher education on aggregate labor productivity depends crucially on the level of allocation distortion in the economy. Thus, in order to improve the effectiveness of the educational policy, policy makers must also implement a complementary economic policy to reduce or remove allocation distortion.

Table 7. Impacts of college enrollment expansion under different distortions

variables	full distortion			zero distortion		
	$\eta_0 - \text{pre}$	$\eta_0 - \text{post}$	% change	$\eta_0 - \text{pre}$	$\eta_0 - \text{post}$	% change
H	0.11	0.26	142.9	0.02	0.03	19.5
H^P/H	0.10	0.08	-18.8	1.00	1.00	0.0
HC	2.65	2.88	8.7	2.38	2.40	0.7
HC^P/HC	0.26	0.23	-11.5	1.00	1.00	0.0
Y_H^P/Y_H	0.24	0.23	-5.6	1.00	1.00	0.0
APL_H	15.39	6.14	-60.1	190.48	167.18	-12.2
APL	1.71	1.61	-5.2	2.95	3.05	3.3

5.2.4 Literature comparison

To compare my estimate of the impact of misallocation on productivity with that in the literature, I look into how APL would be affected were distortions completely eliminated (i.e., by setting $\tau_K = 0$ and $\tau_W = 0$). The first two columns of Table 8 shows that, eliminating allocation distortion raises APL by 73 percent in the pre-regime and 17 percent in the post-regime. While these estimates are comparable to those in Brandt, Tombe and Zhu (2013) (which fall in the range of 6–52 percent for years 1985–2007), they are smaller than those in Hsieh and Klenow (2009), who find the counterpart figures to be 115 and 87 percent, respectively. Two remarks are in order. First, policy distortion is likely to be underestimated in my paper because I do not consider within-sector distortions as Hsieh and Klenow (2009) do, which could be large due to firm-level heterogeneity across regions, industries, and sizes within the state or the private sector.[33] Second, it is also likely that Hsieh and Klenow

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[33]Brandt, Tombe, and Zhu (2013) document large factor market distortions across provinces in China. Bartelsman et al. (2013) also document widespread heterogeneity in firm-level productivity that is associated with firm size heterogeneity, even within narrowly defined industries for a number of European countries and the U.S.

(2009) have overestimated the effect of policy distortion, as they do not take into account the human capital effect of distortion by simply assuming a fixed supply of human capital. Nonetheless, by modeling endogenous educational choices, I find that policy distortion also affects human capital formation by altering individuals' educational decisions through its effect on factor prices. My result shows that while policy distortions do lower the PE share of human capital, they have a positive effect on aggregate human capital stock: eliminating distortion would lower human capital stock by 10 and 7 percent in the pre- and post-regimes, respectively.[34]

Furthermore, to compare my estimate of the effect of human capital misallocation with that in literature, I set policy distortion on human capital to be zero (i.e., $\tau_W = 0$) while keeping physical capital distortion unchanged, and show results in the last two columns of Table 8. Again, I find that eliminating human capital distortion has a negative effect on human capital formation although it improves allocation efficiency. Overall, it has a positive effect on labor productivity (47 and 16 percent for the pre- and post-regimes, respectively). These estimates are larger than those in Vollrath (2014) who finds that eliminating wage wedge between sectors raises aggregate productivity only by less than 5 percent for the 14 developing countries studied (not including China). I argue that this difference can be largely attributed to the fact that Vollrath's analysis is fully based on the assumption of constant physical capital stock and allocation, while using a more-general equilibrium model, my analysis suggests that although human capital misllocation per se has a minor effect on labor productivity, it generates physical capital misallocation and more importantly, the crowding out of productive capital, which turns out to have a substantively negative impact on labor productivity (see Section 5.2.2). In fact, in support of my argument, Vollrath (2014) also points out that incorporating the dynamic response of physical capital accumulation and allocation to human capital allocation could generate a much larger productivity effect of eliminating wage distortion.

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[34]This is again due to the rising interest rate as a result of larger distortions that raises the opportunity cost of being unskilled.

Table 8. The effect of misallocation on productivity (% change)

variables	$\tau_K = \tau_W = 0$		$\tau_W = 0$	
	ss1	ss2	ss1	ss2
HC	-9.8	-6.7	-8.7	-6.3
HC^P/HC	289.4	53.8	241.9	50.1
Y_H^P/Y_H	309.4	60.2	243.4	55.5
APL	72.6	16.8	46.6	16.0

5.3 Dynamics

This section explores the dynamic features of the model. To do so, I first pin down the dynamic path of skilled labor supply using both the model and the data, and then draw implications for the dynamics of sectoral TFPs and average labor productivity from the model.

To obtain the dynamic path of skilled labor, I first take the average skilled labor in the pre- and post-regimes from the model calibration (that is, ss1 and ss2 values of H) and assume them to be the level of skilled labor in 1994 and 2005, respectively.[35] Then I draw the trend of skilled labor in each regime to match that in the data and thereby obtain the decision rules for the "true" steady state for each regime.[36] Next, by making linear combinations of the decision rules of the beginning and the ending points of each regime, I pin down the dynamic path of H. The dynamic path of H^P is determined in a similar way, and that of H^S is obtained by taking the difference between H and H^P.[37]

Once the dynamic path of skilled labor is determined, I solve for the dynamics of sectoral TFPs and APL from the model assuming each year a steady state, using other parameter values from calibration (i.e., ss1 set of parameters for years 1990–1998, and ss2 set of parameters for years 1999–2008). The top panel of Figure

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[35]These are the mid years in the two regimes in my sample.

[36]To do this, I need to extend my sample period to the year when the true steady state can be reached for each regime. In particular, I extend the post-regime to 2042, which is 44 years after the beginning of the post-regime (1998). I also extend the sample of pre-regime backward until the level of skilled labor becomes nonpositive. The first year for H to be positive is 1982, exactly the year when the first group of college graduates since China resumed its college entrance examination entered the labor market. Thus, I view 1981 as the beginning point of the pre-regime. Then I also extend the pre-regime forward until 2025, which is 44 years after 1981 and so can be viewed as the ending point of the pre-regime.

[37]An alternative way to compute the dynamics of skilled labor is to compute the decision rules for each cohort and each year directly from the model. This requires data of more than 40 years before 1990 to pin down other parameters first; such data, however, are unavailable.

6 shows the dynamics of skilled labor and compares it with the data, and the bottom panel shows the dynamics of sectoral TFPs and APL.

As can be seen, the model fits the data well in both the magnitude and the trend of H. The relative growth pattern of H^P to H^S is also consistent with data shown in Figure 2. The dynamics of TFP show a sharp increase in the state firms' TFP following the economic reform in 1998, while the private firms' TFP experiences more stable growth throughout the years. Moreover, APL grows substantively, especially after the economic reform.
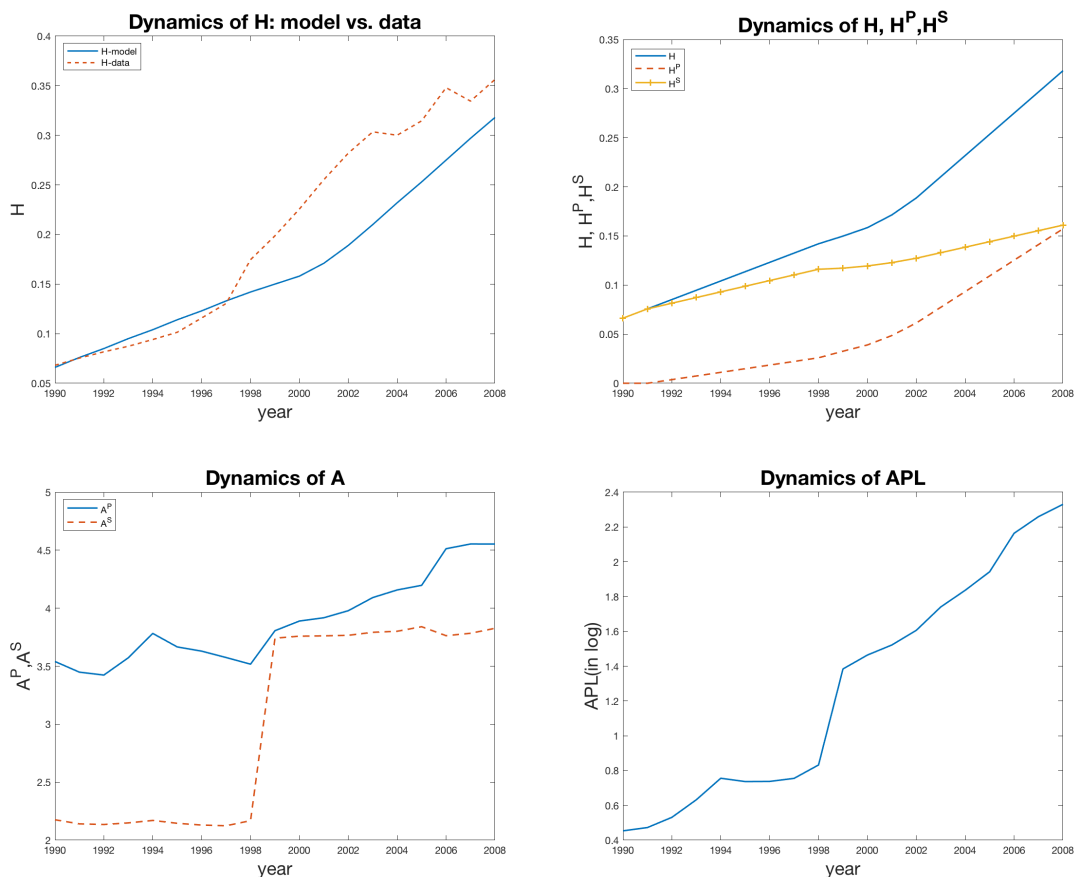

Figure 6. Model dynamics

Finally, I summarize the growth rates of H and APL, and the average level of A^P, A^S, and the $\frac{A^P}{A^S}$ ratio from the model dynamics in Table 9, and compare them with the data or calibration results. The average annual growth rate of H during years 1990–2008 is about 9.1 percent from the model dynamics, which is very close to that in the data (9.6 percent). APL grows at 11 percent annually, close enough to the data as well (9.6 percent, using the average growth rate of real GDP per capita during the same period; data from the World Bank). The sectoral TFPs and their ratio for

each subperiod are also consistent with the steady state estimates from calibration. Hence, despite the parsimonious computational method, the model dynamics turn out to fit well with both the data and calibration.

Table 9. Model dynamics vs. data/calibration

	period	model dynamics	data/calibration
$gr_H(\%)$	1990-2008	9.11	9.63
$gr_{APL}(\%)$	1990-2008	10.99	9.60
A^P	1990-2008	3.58	3.51
	2002-2008	4.43	4.45
A^S	1990-2008	2.22	2.19
	2002-2008	3.96	4.01
A^P/A^S	1990-2008	1.62	1.60
	2002-2008	1.12	1.11

5.4   Social optimal

Along with the productivity goals, policy makers are often concerned about social welfare when making educational and economic policy decisions. In this section, I address this issue by solving the social welfare optimization problem. I assume a social planner who is allowed to determine the educational policy (η_0) and the economic policy (τ_K, τ_W), given all other technology constraints of the post-regime economy including labor market frictions (i.e., layoff functions), aims to maximize social welfare in a stationary equilibrium:

$$U = u_L F(\tilde{a}) + \int_{\tilde{a}}^{\hat{a}} u_H^S(a)dF(a) + \int_{\hat{a}}^{\infty} u_H^P(a)dF(a) \qquad (23)$$

where u_L, u_H^S, and u_H^P represent the lifetime utility of an unskilled worker, a skilled SOE worker, and a skilled PE worker, respectively. I run two experiments. In the first one, the social planner may only choose η_0, given τ_K and τ_W fixed to their ss2 values, and in the second, she can choose all of η_0, τ_K, and τ_W jointly.

Table 10 shows the social planner's optimal choices in these two experiments as well as the results of human capital, productivity, and welfare, and compares them with the ss2 values. As can be seen, when distortion is fixed as in ss2, the social planer chooses to tighten the educational policy (by raising η_0). Although human capital stock is lowered, it can be allocated more efficiently. As a result,

not only APL but social welfare is improved. However, when the social planner is allowed to determine both educational and economic policies jointly, she chooses to expand college education further (by lowering η_0), and meanwhile, reduces allocation distortions (both τ_K and τ_W) down to zero. Consequently, although human capital stock is still lower than its ss2 counterpart as a result of individuals' endogenous response, an even larger share of human capital is employed by the private sector, and both APL and welfare are improved further.[38] This result again underscores the important role of allocation distortion played in the impact of the higher education expansion policy. It suggests that to improve both productivity and social welfare, China should indeed further lower the barrier to its higher education, but this must be accompanied by deepened economic reform that further reduces or completely removes allocation distortions.

Table 10. Social optimal

variable	optimal		ss2
	η_0	η_0, τ_K, τ_W	
η_0	0.88	0.12	0.53
τ_K	0.09	0	0.09
τ_W	0.36	0	0.36
H	0.20	0.27	0.32
H^P/H	0.92	0.67	0.48
HC	2.76	2.79	2.89
HC^P/HC	0.77	0.80	0.65
Y_H^P/Y_H	0.74	0.84	0.62
APL	8.07	9.13	7.72
U	8.55	9.29	7.52

6   Conclusion

In this paper, I have investigated the impact of an educational policy on labor productivity using China's higher education expansion. I argue that in an economy such as China's, where allocation distortions widely exist, educational policy affects labor productivity not only through its effect on human capital stock, but also through its effect on human capital allocation. Thus, its impact could be limited if misallocation

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[38]This result suggests that the goals of enhancing productivity and welfare are largely aligned.

becomes more severe following the policy. I have constructed a two-sector general equilibrium model in which policy distortions favor the less-productive state sector against the private sector. Overlapping generations of households make educational and occupational choices depending on their ability. In addition, government policies regarding higher education and allocation distortion play a key role in altering households' decisions. Importantly, the impact of the educational policy on labor productivity depends on the interaction between the labor market and the capital market. Greater misallocation in the labor market due to the college expansion may intensify misallocation in the capital market, magnifying the negative effect of the educational policy.

I have calibrated the model to fit the data of China. Quantitative results show that, given the allocation distortions, China's higher education expansion had an overall small but negative effect on its labor productivity. Had there been no such a policy, China's average labor productivity would have been raised by 2.5 percent. Although it had a sizable positive effect on China's human capital stock, the policy reallocated relatively more human capital toward the less-productive state sector. This also directed physical capital toward the state sector, intensifying capital misallocation. Moreover, the rising demand for subsidies by the state sector as a result of deepened factor misallocation tightened the loanable funds market, crowding out productive capital. This last channel turns out to have a substantively negative effect on labor productivity. Furthermore, my analysis suggests that the productivity effect of higher education expansion crucially depends on allocation distortions. If such distortions could be further reduced or completely removed, the impact of the college expansion on both productivity and social welfare would turn positive. Thus, in order to improve the effectiveness of the educational policy, it is critical for policy makers to deepen economic reforms.

To this end, I would like to acknowledge the limitations of this study, which may also be viewed as potentially interesting lines of future research. First, there is no skill-directed technological change in this model. Although skilled and unskilled workers use different technologies and an increase in the supply of skilled labor does imply the more-productive technology can be used by more workers, the level of each type of technology does not improve as a response to the increased supply of skills; thus, the positive effect of college expansion may be underestimated. Second, I do not model within-sector firm heterogeneity and policy distortions, which may lead to an underestimation of allocation distortion, and hence an underestimation of the negative productivity effect of college expansion. Finally, my model assumes that

all college graduates work in skilled production, while in reality some may end up with unskilled jobs due to labor market frictions. Some others may emigrate to rich countries where they can match with more advanced technology and receive higher returns to their education. Taking the mismatching or the brain drain into account, the positive effect of college expansion could be even smaller. On balance, I view my estimate of the educational policy effect as a reasonable measure.

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