ESSAYS ON HUMAN CAPITAL AND ENTREPRENEURSHIP

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I certify that I have read this dissertation and that, in my opinion, it is fully adequate in scope and quality as a dissertation for the degree of Doctor of Philosophy.

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Abstract

This thesis analyzes economic models and empirical evidence on the topic of the evolution of labor market and the development of human capital in a rapidly developing country.

The first chapter develops a theoretical model of evolving skills and wages when there is an exogenous increase in return to skill. The model predicts that recent graduates' wages may decrease in the medium and long run even as the demand for skilled workers increases.

The second chapter provides empirical evidence that supports the theory developed in the first chapter. The first half of the chapter analyzes a recent China dataset, and finds that while wages for recent graduates decreased, wages for the experienced graduates increased. The second half of the chapter examines evidence from other developing countries at similar stages of development.

The third chapter develops a model which provides a mechanism of rising return to skill after trade liberalization. By trading with a developed country, the developing country can make its high-skill workers more productive by working with foreign high-skill trainers, or by using cheaper skill-intensive foreign inputs.

The fourth chapter develops a model of technology catch-up and its impact on the return to skill in a developing country. The opportunity for technology catch-up increases the demand for high-skill workers and drives up the return to skill. Moreover, if the new technologies acquired by the developing country are skill-intensive, the return to skill will increase further.

Acknowledgments

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Chapter 1

Evolution of the Labor Market in a Rapidly Developing Economy

1.1 Introduction

Economists have found that human capital accumulation is a critical contributor to economic growth. Human capital is acquired not only in schools, but also on the job where firms provide training and valuable work experience. In addition, certain types of firms can raise the return to education and induce future investment in education. Foreign firms in developing countries play a particularly important role in this regard, because they usually have better technology, demand higher skills, and offer higher pay for education and experience than local firms. This paper studies the evolution of human capital in a rapidly developing country in response to the arrival of foreign firms which hire more high skill workers.

China is a good case study. China was completely closed to foreign direct investment (FDI) before 1978; in the 1980s, it adopted a policy to promote and attract FDI. As a result, FDI took off in China in the 1990s. FDI accounted for only 1% of GDP in 1990, but it rapidly increased to 5% of GDP in 1995, and remained high in the 2000s. Foreign firms brought profound changes to the local labor markets in China. In big cities like Shanghai and Beijing, foreign firms are responsible for more than 15% of skilled labor employment. Typically these foreign firms hire more skilled labor, pay higher wages and have a steeper pay scale than local firms (Zhao (2001)). In doing so, they have significantly raised the return to human capital, and thereby greatly influenced the development of the human capital in China. The return to schooling began to increase rapidly in the 1990s, from 5% in 1993 to 10% in 1999(Zhang et al. (2005)). From 1986 to 1995, college enrollment only increased from 700,000 to about 1 million, but from 1996 to 2005, college enrollment increased dramatically to more than 4 million a year.

In the early years of opening up, the wages of college graduates (both experienced and inexperienced) increased significantly (Zhang et al. (2005)). However, in recent years, the wage premium of young college graduates has declined, even when the overall return to education continues to rise steadily. All the increase in return to education comes from the increase in the earnings of experienced graduates. Using a unique dataset from a leading online recruiting agency, I found that the college premium for the young and the old started to diverge in late 2000. The college wage premium for older graduates (age 28 or older) increased from 40% in early 2000 to 50% in late 2000, while the college premium for younger graduates (age 27 or younger) decreased from 20% to less than to 10%. The most recent graduate cohort (born after 7/1/1982) started their careers at a wage 15% lower than the earlier cohorts, but were able to catch up in average wages after about 5 years after graduation.

I present a theoretical framework to analyze the evolution of human capital development as a result of an increase in demand for skills which require both education and experience. In this model, I will derive the impact of skill-intensive foreign firms on the evolution of wages, return to education, return to experience, and skill mix in the economy. The model predicts that with an influx of foreign firms, the overall return to education and the return to experience will increase, and as a result, will induce a large increase in investment in college education and a rapid accumulation of skills. The wage of inexperienced graduates will go up initially, but over time, it may come down to a level lower than before the influx of FDI. I also present a dynamic model and a numerical solution which shows the evolution of the labor market over time. Initially, all wages will go up. However, in the medium run, there will be an oversupply of inexperienced graduates, and the wage for inexperienced graduates will decline while the wage for experienced graduates will continue to rise. These predictions are found to be consistent with the evidence in China and several other rapidly developing countries.

The model also analyzes FDI's impact on local firms. Some of the local firms that are directly competing with foreign firms for high-skill workers will be worse off, but other domestic firms may benefit from a larger pool of moderately skilled workers. Moreover, the model predicts that a more developed domestic industry can help train more high-skill workers, which would benefit foreign firms and the whole economy.

1.1.1 Related Literature

On the theory side, as far as I know, this is the first attempt to analyze the labor market of a rapidly developing economy in a dynamic setup. Heckman (1998) used a dynamic general equilibrium model to explain the changing wage structure in the recent U.S. labor market. Katz and Murphy (1992) provided a framework to analyze wages and inequality in response to exogenous supply shifts and technology changes. The novelty of this model lies in endogenizing the supply of human capital under the assumption that productive human capital requires both education and work experience. This model also introduces firm heterogeneity which allows me to analyze the effects on different types of firms.

There are many empirical research papers examining the changes in wage structures in the U.S. in the last 30 years. Acemoglu (2002) analyzed the effect of skill-biased technology on the recent labor market. Freeman and Katz (1995) compared the wage structure in the U.S. over the last few decades to that of other OECD countries. Many research papers documented the development of labor markets in emerging countries such as China (Zhang et al. (2005)), Korea (Kwark and Rhee (1993)), and Taiwan (Baraka (1999)).

In addition, there is a great deal of empirical research investigating the effect of FDI on the host country's labor market. Feenstra and Hanson (1997) found FDI contributed a great deal to the increase of return to skill in Mexico. Zhao (2001) found that foreign companies pay almost twice the college premium as local companies in

China.

1.2 Model Setup

Let representative consumer's utility $U = \int_{j\in\Omega} (q_j)^{1-1/\sigma} dj + Q$. The utility function has two terms. The first term is the utility for differentiated goods and the second term is the utility for numeraire. In the first term, q_j is the quantity of good j consumed, and σ is the demand elasticity which satisfies $\sigma > 1$.

There are three types of workers: the low-ability workers denoted by l, medium-ability workers denoted by m (college-educated but inexperienced), and high-ability workers denoted by h (experienced and educated). l ability workers can get a college education to become m, but m may become h only after working for some number of periods. Each period, a portion η of the m workers turn into h workers. Also, in each period, there are $1-\mu$ workers entering and exiting the labor force. The total labor force is normalized to be 1.

The production function for the differentiated goods is given by $q^j = z_l^j + \delta z_m^j + \delta^2 z_h^j$, which says q^j, the production for variety j is a linear function of the quantities of labor hired for l, m, and h-type workers (i.e. $z_l^j, z_m^j, z_h^j)$. h-type workers are δ times more productive than m-type workers, who are δ times more productive than l-type workers. δ is the productivity for the firm. There are a mass of n domestic firms whose δ follows a distribution with c.d.f $F(\delta)$ over the range $(1, \Delta)$. (Assume $0 < f() < \infty$). For simplicity, it is assumed that all firms have zero fixed cost, and the owners of the firms spend their profits on the numeraire only. The number of foreign firms n_f is exogenous. The productivity of the foreign firms is at the upper bound of the productivity distribution Δ.

There is also a numeraire sector that hires only l workers. The production function is given by a constant scale function $Q = z_l'$. The wage for l i.e. w_l is normalized to 1. (Then, the price for numeraire is also 1). This sector can be interpreted as the low-skill sector, such as agriculture, which has low productivity and provides no on-the-job training.

To model a worker's decision to get a college education, I assume different workers have different costs to obtain a college education, and a worker will obtain an education if the reward is greater than the cost. The supply function $G(v)$ denotes the number of workers who will obtain a college education as a function of v. v is the expected wage premium net the common cost of education (denoted by C) which includes tuition, etc. The supply curve can be generated by the assumption that different workers have different effort costs on the top of common cost to obtain an education (the effort cost can be interpreted as innate ability). $G(v)$ can be interpreted as the fraction of people whose effort cost of education is less than the net reward v. (Assume $G'() > 0$)

For simplicity, risk neutrality and no time discounting are assumed.

With the above setup, the equilibrium conditions will be derived in the following section. Then, the comparative statics and transition dynamics will be analyzed when there is an increase in the number of foreign firms n_f.

1.3 Steady State Equilibrium

From the utility function I can derive the demand for goods q^j given price p^j. For simplicity I will drop the index j.

The demand function is $p(q) = Aq^{-\frac{1}{\sigma}}$ where A is a constant. This is a constant elasticity demand function. By the usual analysis for constant elasticity demand functions, I can derive the production quantity, the labor demand and the profit for each firm. If a firm decides to hire workers of type l, with wage 1, the demand function for the workers type l is $z_l = B$, where constant $B \equiv (1 - \frac{1}{\sigma})^\sigma A^\sigma$. If a firm decides to hire workers m, the demand function is $z_m = Bw_m^{-\sigma}\delta^{\sigma-1}$. If a firm decides to hire workers h, the demand function is $z_h = Bw_h^{-\sigma}(\delta^2)^{\sigma-1}$.

Hereafter, I define $w \equiv \frac{w_h}{w_m}$, which can be interpreted as the return to experience. The equilibrium is characterized by wage schedule w_m and w_h (or equivalently w_m and w). I am interested in analyzing solutions where $w > w_m > 1$. In this case, there is a positive matching between workers and firms, i.e. higher-productivity firms hire higher-productivity workers, and the differentiated good sector hires all three types

Table 1.1: A glossary of notation

Symbols	Description	Value Used in Simulation
A, B	constant	
σ	elasticity of demand	1.3
q_j	quantity for variety j	
l, m, h	low, medium, high ability workers	
w_m, w_h	wage for medium and high ability workers	
w	$\equiv w_h/w_m$	
L_m, L_h	stock of m and h workers	
$F()$	distribution of firm productivity	Uniform Distribution on [1,2]
δ	productivity of the firm	
Δ	productivity of the foreign firms	2
n	number of local firms	10
n_f	number of foreign firms	10
η	probability of m becoming h	0.05
μ	probability of staying in the workforce	0.95
k	$\equiv \mu\eta/(1-\mu)$	
C	the common cost of obtaining education	0.2
$G()$	distribution of cost of obtaining education	Normal Distribution ($\mu = 0.4$, $\sigma = 0.1$)
v	return to education	

of workers. Based on the production function $q = z_l + \delta z_m + \delta^2 z_h$, the hiring decision is that firms with $\delta \in (1, w_m)$ will hire l; firms with $\delta \in (w_m, w)$ will hire m; and firms with $\delta \in (w, \Delta)$ will hire h. All foreign firms have productivity Δ by assumption, so they will hire h (assuming there are enough h in the economy to be hired by foreign firms).

In the steady state, the ratio of L_h (the stock of h workers) to L_m (the stock of m workers) is a constant $k \equiv \frac{\mu\eta}{1-\mu}$, because

$$L_h^t = \mu L_h^{t-1} + \mu\eta L_m^{t-1} \tag{1.1}$$

The steady state requires $L_h^t = L_h^{t-1} = L_h$, solving the above equation yields

$$L_h = \frac{\mu\eta}{1-\mu} L_m \tag{1.2}$$

Further, the total supply of m and h is given by $G(v)$

$$L_h + L_m = G(v) \tag{1.3}$$

So, the stock of m and the stock of h are both a constant proportion of $G(v)$, where v is the expected net reward of obtaining a college education (amortized per period). v is given as the following expression:

$$v = \frac{1}{1+k} w_m + \frac{k}{1+k} w_h - 1 - C \tag{1.4}$$

where C is the common cost of education amortized per period.

The labor market clearing condition for L_m is given by the following equation. The left-hand side is the demand for m, which is generated by domestic firms whose δ is between w_m and w. The right-hand side is the supply of m, which is a portion $1/(k+1)$ of the total educated workforce $G(v)$.

$$nBw_m^{-\sigma} \int_{w_m}^{w} \delta^{\sigma-1} dF(\delta) = \frac{1}{k+1} G(v) \tag{1.5}$$

The labor market clearing condition for L_h is given by the following equation. The left-hand side is the demand for h, which is generated by domestic firms whose δ is between w and Δ, and n_f foreign firms. The right-hand side is the supply of h, which is a portion $k/(k+1)$ of the total educated workforce $G(v)$.

$$Bw_h^{-\sigma}[n \int_{w}^{\Delta} (\delta^2)^{\sigma-1} dF(\delta) + n_f (\Delta^2)^{\sigma-1}] = \frac{k}{k+1} G(v) \tag{1.6}$$

The above two equations jointly solve two unknowns w_m and w_h. v is given by equation 1.4, and $w \equiv \frac{w_h}{w_m}$.

The labor employed by the unskilled sector (producing numeraire Q) is calculated as the remaining workers in the economy using the following labor clearing condition.

$$Q = 1 - G(v) - C * G(v) - nBF(w_m) \tag{1.7}$$

Q is calculated as the total labor force minus the labors employed by the skilled sector, the common cost of education (the second last term), and the labor demand for l from the differentiated goods sector (the last term).

Proposition 1 The market clearing equations for m and h have a unique solution: w_m, w_h

Proof in Appendix.

I will analyze the situation where the solutions of the above two equations satisfy $w > w_m > 1$, which leads to a positive sorting such that higher productivity firms will hire higher ability workers and all three types of workers are employed by the differentiated goods sector. This is the most interesting case, otherwise if $w_m < 1$, then no l will be hired by the differentiated goods sector.

1.3.1 Impact on Labor Market with More Foreign Firms

I want to determine how the equilibrium changes if there are more foreign firms, i.e. n_f increases. This could be due to a regulation change to allow FDI in certain sectors previously closed to foreign firms.

Proposition 2 When n_f increases, w,v,and w_h increase.

Proof in Appendix.

With more high-productivity foreign firms, return to experience (w), return to education (v), and the wage for h (w_h) will increase. But the effect on w_m is ambiguous.

Proposition 3 When n_f increases, if $G'()$ is sufficiently small then w_m increases, and if $G'()$ is sufficiently large then w_m decreases.

Proof in Appendix.

Intuitively, we know that more foreign firms will increase the return to education and the return to experience. When the return to experience w increases, some firms cannot afford h any more and will have to hire m, thus increasing the demand for m. On the other hand, when return to education increases, the supply of m increases. When the supply curve is very elastic, the supply effect dominates and w_m decreases. In other words, if the education system is responsive to a higher return to education, more foreign firms in the skilled sector can reduce w_m. In the extreme case, when the supply of m is perfectly elastic at some point v_0, then when w increases, w_m will have

Table 1.2: Impact of foreign firms on existing firms when $w_m^1 < w_m^0$

Firms with $\delta \in$	Workers	Profit Before	Profit After	Comparison
$(1, w_m^1)$	l	$\frac{1}{\sigma-1}B$	same as before	same
(w_m^1, w_m^0)	$l->m$	$\frac{1}{\sigma-1}B$	$\frac{1}{\sigma-1}B(\frac{\delta}{w_m^0})^{\sigma-1}$	better off
(w_m^0, w^0)	m	$\frac{1}{\sigma-1}B(\frac{\delta}{w_m^0})^{\sigma-1}$	$\frac{1}{\sigma-1}B(\frac{\delta}{w_m^1})^{\sigma-1}$	better off
$(w^0, w^0w_m^0/w_m^1)$	$h->m$	$\frac{1}{\sigma-1}B(\frac{\delta^2}{w_h^0})^{\sigma-1}$	$\frac{1}{\sigma-1}B(\frac{\delta}{w_m^1})^{\sigma-1}$	better off
$(w^0w_m^0/w_m^1, w^1)$	$h->m$	$\frac{1}{\sigma-1}B(\frac{\delta^2}{w_h^0})^{\sigma-1}$	$\frac{1}{\sigma-1}B(\frac{\delta}{w_m^1})^{\sigma-1}$	worse off
(w^1, Δ)	h	$\frac{1}{\sigma-1}B(\frac{\delta^2}{w_h^0})^{\sigma-1}$	$\frac{1}{\sigma-1}B(\frac{\delta^2}{w_h^1})^{\sigma-1}$	worse off

to decrease to keep $v = v_0$. On the other hand, if $G(v)$ is perfectly inelastic, i.e. the supply of m, and h is fixed, then as w increases, the demand for m increases while the supply is unchanged, therefore bidding up w_m.

1.3.2 Impact on Existing Firms

In this section, I will consider how the entry of foreign firms impacts the profitability of local firms. We already know that with more foreign firms, w_h increases. The following proposition states that when $G()$ is elastic and w_m decreases, some of the local firms can actually benefit. Table 2 shows different firms' hiring decisions and profits before and after the influx of foreign firms. In the table, w_m^0 and w_h^0 are the equilibrium wages for m and h before the influx of foreign firms, and w_m^1, w_h^1 are the wages for m and h in the new equilibrium after the influx of foreign firms.

Proposition 4 When n_f increases, if w_m decreases in the new equilibrium, then there exists a cut off $\overline{\delta} = w^0 w_m^0/w_m^1$, such that firms with $\delta < \overline{\delta}$ are better off, and firms with $\delta > \overline{\delta}$ are worse off.

Proof: The firms that are still hiring h are worse off, because w_h increases. The firms that continue to hire m are better off since w_m is reduced. The firms that switch from hiring l to hiring m are better off, because previously they make $\frac{1}{\sigma-1}B$, and now they make $\frac{1}{\sigma-1}B(\frac{\delta}{w_m^1})^{\sigma-1}$. The profit is greater if and only if $\delta > w_m^1$, which is true for them to hire m now, therefore they are better off. Now consider the firms with $\delta \in (w^0, w^1)$. They switch from hiring h to hiring m. Previously they made profit $\frac{1}{\sigma-1}B(\frac{\delta^2}{w_h^0})^{\sigma-1}$. Now they make $\frac{1}{\sigma-1}B(\frac{\delta}{w_m^1})^{\sigma-1}$. The firm is worse off if

$\delta > w_h^0/w_m^1 = w^0 * w_m^0/w_m^1$, or better off if $\delta < w^0 w_m^0/w_m^1$. Q.E.D.

I just showed that when more high-productivity foreign firms come in, if the supply function of educated workers $G(v)$ is elastic enough such that w_m is lowered, some of the local firms can actually benefit. Intuitively, because these firms do not compete with foreign firms for high-ability workers, they can benefit from more medium-ability workers. In a sense, the high-productivity foreign firms are complements to the medium-productivity firms.

The converse is also true, i.e. when there are more medium-productivity firms and the supply of education is sufficiently elastic, the foreign firms will actually benefit. This is shown in proposition 4d in the Appendix, which says, more local firms can reduce w_h, thus benefit the foreign firms. Studies on foreign direct investment documented that a well developed local sector makes it a more attractive environment for foreign companies to invest in (Coughlin and Segev (2002)). This model provides a mechanism in which more local firms will induce more education and train high ability workers, and therefore benefit the foreign firms.

1.4 Dynamics and Short-Term Effects

Here I will examine the fully dynamic model. I will analyze the evolution of the labor market when the number of foreign firms increases unexpectedly. This could be due to a new policy to encourage FDI in sectors that were previously closed to FDI, as occurred in China during the 90s. Initially at $t = 0$, no foreign firm is expected to enter, i.e. $n_f \equiv 0$, and L_h^0, L_m^0, w^0, w_m^0 is a steady state equilibrium given the information at time $t = 0$. Now, at $t = 1$ with the unexpected new policy, it becomes public knowledge that n_f^t for $t > 0$ will become positive. I will assume that in every period, only young potential workers can make the decision to obtain a college education, and it takes four years to graduate. As before, I assume, in each period, η portion of the m workers turn into h. I will derive the dynamic equilibrium, i.e. the wage path, w_m^t and w_h^t. The equilibrium is defined so that each person will make an optimal decision to attend college or not.

To simplify the analysis, let's assume the number of foreign firms in each period is exogenous and is given by n_f^t. Further assume that n_f^t stabilizes over time, i.e. becomes a constant after some number of periods. Formally there exist some $\tau > 0$ such that $n_f^t = n_f^{t+1}$ for all $t > \tau$.

The only decision to model is the choice to go to college. By assumption, in each period, $(1-\mu)$ workers leave the workforce, and $(1-\mu)$ young people either join the workforce or go to college. The number of people who go to college in each period is $(1-\mu)G(v^t)$. v^t is the expected future payoff of going to college at time t amortized per period. It is given by the following expression which is a linear combination of future wages weighted by the probability of earning that wage net the unskilled wage and tuition.

$$v^t = [w_m^{t+4} + \sum_{j=1}^{\infty} \mu^j (1-\eta)^j w_m^{t+j+4} + \sum_{j=1}^{\infty} \mu^j (1-(1-\eta)^j) w_h^{t+j+4}](1-\mu) - 1 - C \quad (1.8)$$

The equilibrium $v^t.w_m^t, w_h^t$ can be fully characterized by the following equations. The first two equations model the evolution of stock of h and m workers, and the last two equations are the per period labor market clearing conditions.

$$L_h^t = \mu L_h^{t-1} + \mu\eta L_m^{t-1} \quad (1.9)$$

$$L_m^t = \mu L_m^{t-1} + (1-\mu) * G(v^{t-4}) - \mu\eta L_m^{t-1} \quad (1.10)$$

$$nB(w_m^t)^{-\sigma}[\int_{w_m^t}^{w^t} \delta^{\sigma-1} dF(\delta)] = L_m^t \quad (1.11)$$

$$B(w_h^t)^{-\sigma}[n\int_{w^t}^{\Delta} (\delta^2)^{\sigma-1} dF(\delta) + n_f^t(\Delta^2)^{\sigma-1}] = L_h^t. \quad (1.12)$$

These five equations above fully characterized the equilibrium $\{w_m^t, w_h^t, L_h^t, L_m^t, v^t\}$. Notationally, the new steady state is denoted as $\{w_m^s, w_h^s, L_h^s, L_m^s, v^s\}$.

Proposition 5 With this setup, an equilibrium exists.

Proof in Appendix.

The proof uses Schauder's fixed point theorem, by establishing the following mapping: Given a sequence of enrollment rates $\{g^t\}$, I can compute the evolution of L_m^t and L_h^t, and then using the period-by-period demand and supply equation, I can compute w_m^t and w_h^t from which I can compute v^t, finally I can get a new set of enrollment rates $g'^t = G(v^t)$. Thus I have a mapping from $\{g^t\}$ to $\{g^t\}'$. The equilibrium is just a fixed point such that $\{g^t\} = \{g^t\}'$.

From Proposition 1, I know any convergent equilibrium will converge to the unique steady state equilibrium derived in the previous section. Notationally, as t goes to ∞, $\{w_m^t, w_h^t, L_h^t, L_m^t, v^t\}$ converges to $\{w_m^s, w_h^s, L_h^s, L_m^s, v^s\}$ which satisfies equations 1.5 and 1.6.

Proposition 6 On the equilibrium path, if $G'() > 0$, there exists some period τ, such that $L_m^\tau > L_m^s$.

Proof in Appendix.

This proposition formally states one of the main results of the transition dynamics, i.e., the stock of m workers will overshoot the long-term steady state level. In other words, there will be an over-supply of m at some point. The intuition is that, h will be in short supply for a while because it takes time to train h, therefore, w_h and expected lifetime return to education is higher in the short run than in the long run. To take advantage of this, more people will get an education and more m will pour into the market, creating a seeming oversupply of m.

1.4.1 A Numerical Solution

To solve the 5 equations numerically, I repeatedly apply a mapping similar to the one used in the proof of existence to find the fixed point. I solve the equations numerically under a set of parameters that resemble the Chinese economy. The parameter n_f^t, the number of foreign firms is assumed to be initially growing very fast but stabilizes over time. This assumption resembles the growth of FDI in China since the 90s. The other parameters used are described in Table 1.1.

Figures 1.1, 1.2, 1.3, 1.4 from the numerical solution depict the evolution of the labor market after the arrival of the foreign firms. Figure 1.1 shows the evolution of

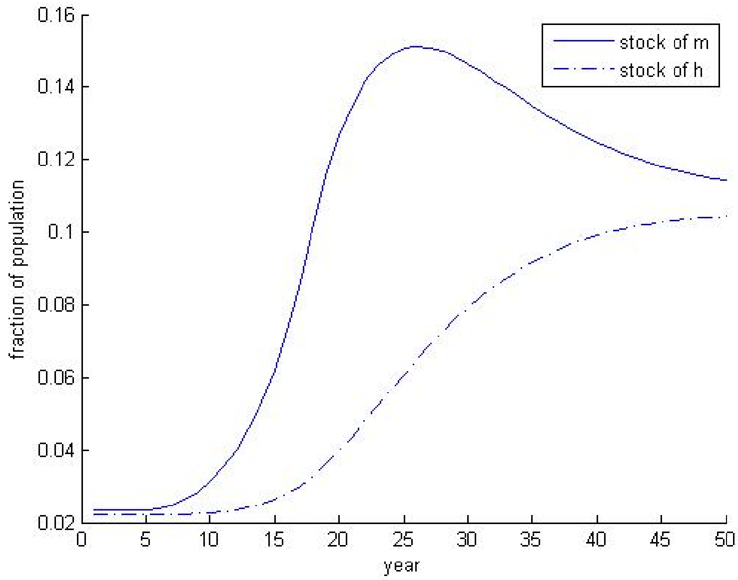


Figure 1.1: Evolution of Stock of h and m

the stock of m and h. It shows that the growth path of L_h is flatter than that of L_m in the earlier periods since it takes longer to train h. As predicted by Proposition 6, the stock of m will overshoot and remain significantly higher than the steady state level for many periods.

Figure 1.2 shows the evolution of wage schedules. The wage for young graduates w_m will go up in the short run as more foreign firms drive up the demand for m, but will quickly reverse the trend and gradually decline to the steady state value which could be lower than the value before the shock. Based on the analysis of the impact of the foreign firms on the domestic firms, we know some of the domestic firms will eventually benefit from the entry of the foreign firms as w_m decreases eventually, but in the short run, as w_m increases, they will be feeling short-term pain.

Return to experience w goes up steeply initially, and continues to go up for a number of periods, before it peaks and comes down and gradually converges to the steady-state value which is higher than w^0. The reason that it takes longer for w to peak is that w depends on the relative ratio of L_m to L_h. In response to a higher return to education, many m pour into the work force in the first few years, and it

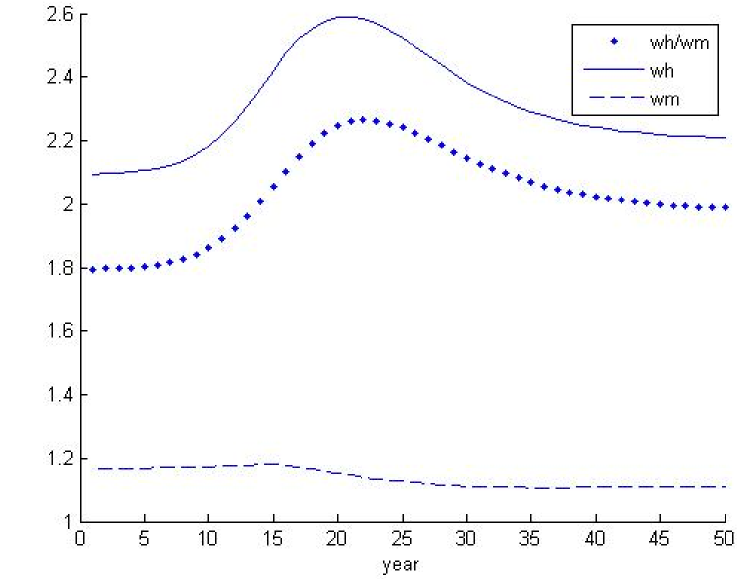


Figure 1.2: Evolution of Wages

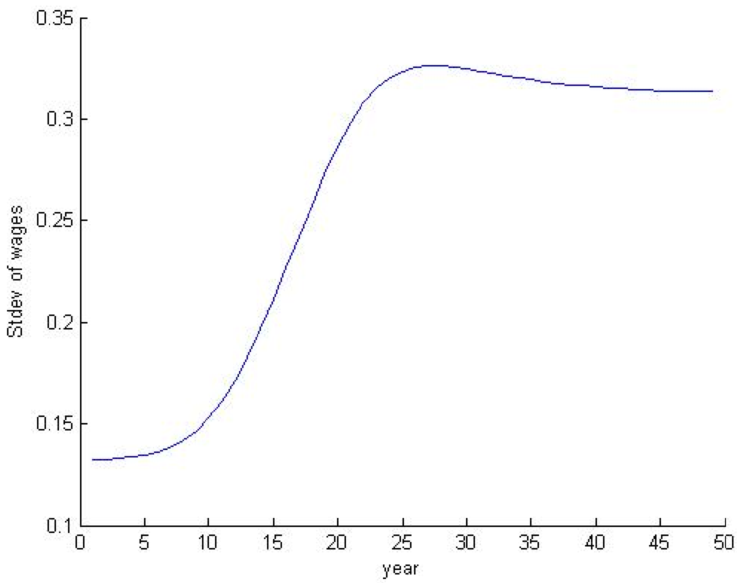


Figure 1.3: Evolution of Inequality (measured by std dev of wage)

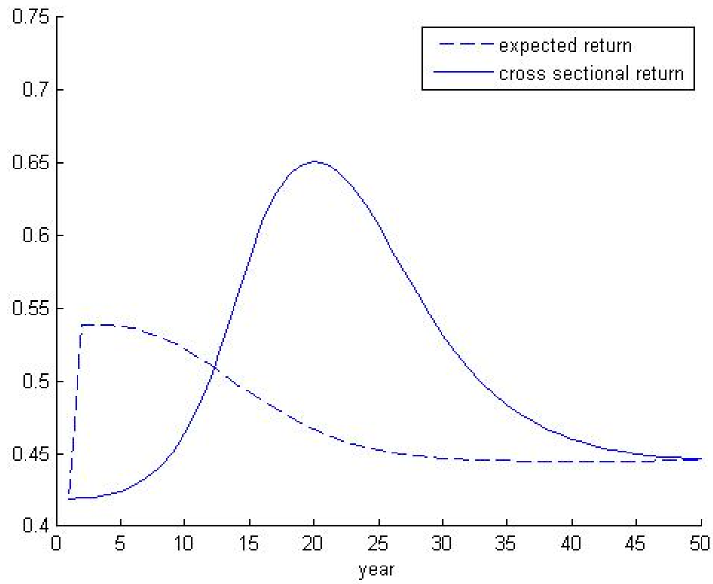


Figure 1.4: Evolution of Return to Education

will take them a while to become h. Therefore, the ratio of L_m to L_h, and hence w, will increase long after w_m starts to decrease. Similarly, w_h will increase for a much longer period than w_m.

Figure 1.3 shows the evolution of cross-sectional inequality measured by the standard deviation of wages. Cross-sectional inequality increases rapidly after the shock, and reaches the peak in the medium run, and then comes down slowly in the long run. There are two reasons why inequality eventually comes down. First, return to experience (i.e. w) comes down in the long run, and second, over time more people will be educated and work in the skilled sector.

Figure 1.4 shows the evolution of return to education. The lifetime return to education (i.e. v_t) shoots up initially, but gradually declines and converges to the steady state value which is higher than v^0. The reason is that the earlier-educated cohorts can take advantage of the temporarily high wages, and thus have a higher return than the later cohorts. Consequently, the college enrollment rate also increases sharply initially, overshooting the steady state value before convergence. The cross-sectional return to education, which is a weighted average of the w_m and w_h, takes quite a different path, and rises for a much longer period than the lifetime return to education.

1.5 Policy Simulations Using the Model

1.5.1 Policies to Subsidize College Education

In this section, I will use this simple dynamic model to analyze ways to subsidize college education. If young people can afford tuition with no credit constraint, and inequality is not a concern, then the government has no reason to subsidize college education, since the private market as analyzed in the base model delivers the optimal outcome. So the goal for subsidizing education is to improve access and reduce inequality.

In general, a tax on the whole population to subsidize college education will raise the return to education, the enrollment rate, and the GDP, but the upward distortion of the return to education will reduce welfare after accounting for the cost of student leisure. Further, because the tax is regressive, it will increase inequality between skilled and unskilled labor.

Another option is to give student loans. It will improve access; however, as indicated in this model, there is a large variance in the realized earnings of graduates. Some of them become highly paid h; but many remain to be m who are relatively low paid, especially when w_m can decrease even in the long run. Loans to m will likely be unpaid.

A better alternative is to tax h, (having a progressive tax on wages), and use the money to fund college education. I will analyze the distortion introduced by such a policy and its effect on inequality. I will not analyze in detail the gain of improving access, but will just assume there is some efficiency gain which motivates the government to subsidize college education.

To introduce taxes into the model, I only need to change the equation for v^t as follows.

$$v_t = [w_m^{t+4}+\sum_{j=1}^{\infty}\mu^j(1-\eta)^j w_m^{t+j+4}+\sum_{j=1}^{\infty}\mu^j(1-(1-\eta)^j)w_h^{\prime t+j+4}](1-\mu)-1-C+(1-\mu)S^t \tag{1.13}$$

The only difference between the above equation and the base model is that there is an extra term S^t (i.e. subsidy for enrolling in period t), and w_h^t is changed to the after-tax wage $w_h^{\prime t} = (1-\tau_h^t)w_h^t$, where τ_h^t is the tax rate for h at time t. There is a per-period budget constraint for the government:

$$\tau_h^t w_h^t L_h^t = S^t * (1-\mu) * G(v^t) \tag{1.14}$$

Assuming the subsidy completely eliminates the credit constraint problem.

Proposition 7 In the steady state, the new equilibrium with a tax on h to subsidize college education creates no distortion on the college enrollment decision.

Proof: I solve S^t using the budget constraint, and substitute into the expression for v^t. After simplification using steady state variables, the tax rate drops out of the equation. Therefore, the return to education is unaffected by the tax rate in steady state. Q.E.D.

The intuition is simple. Since labor supply is fixed in the model, taxing and subsidizing is just an inter-temporal redistribution for people who attend college. Therefore the tax and subsidy cancel out and do not affect the return to education in expectation if the economy is the same in every period in the steady state. However, during the transition, this kind of inter-temporal redistribution creates distortion in the dynamic environment.

I will consider two simple schemes. One is a fixed tax rate and variable subsidy. The other is a fixed subsidy and variable taxes. In the fixed tax rate scheme, compared to the later cohorts, the earlier cohorts receive less subsidy per person. This is because the tax base was smaller in earlier periods as the stock of h was still growing. So, given the same tax rate, the total funding was less in the earlier periods, but the enrollment rate already shot up, hence the per person level of subsidy was smaller. As the earlier cohorts received less subsidy, but faced the same future tax rate, their

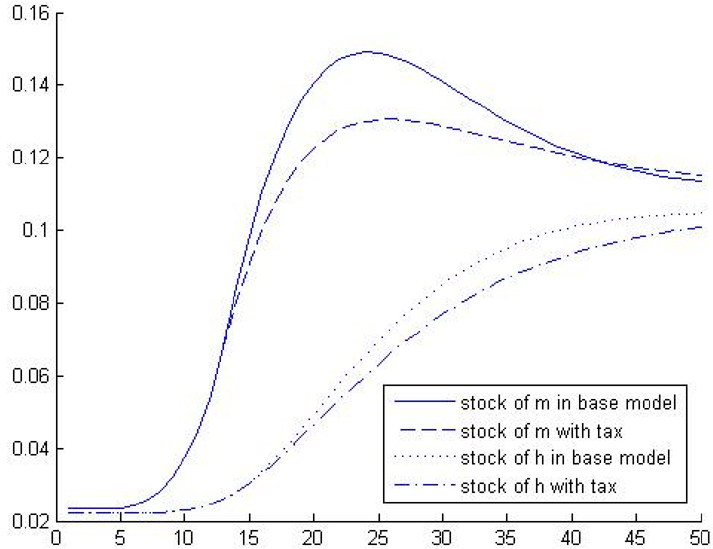


Figure 1.5: Compare the evolution of the stock of m and h with tax to the baseline model

lifetime return to education is lower than that of the later cohorts. By Proposition 7, we know that in the long run, the return to education of the later cohorts is undistorted. Therefore, the lifetime return to education and enrollment rate of the earlier cohorts are distorted downward.

Figure 1.5 shows the effect on skill accumulation of such a fixed tax rate scheme. Compared to the zero tax case, the growth of m and h is slower. Figure 1.6 and Figure 1.7 show the effect on mean wage and inequality. As shown, inequality is reduced but there is an efficiency loss in the short run. Keep in mind, in these graphs, I am not showing any potential efficiency gain from improving access.

Now let's consider the scheme of having a fixed subsidy (S^t is a constant), but variable tax rate. The effect of this scheme is similar. We know in the long run, the lifetime return to education for later cohorts is undistorted. Compared to the later cohorts, the earlier cohorts are given the same level of subsidy, but will face a higher future tax rate. This is because in early periods, the tax base was smaller but the enrollment rate already shot up, so to fund the subsidy, the tax rate had to be higher.

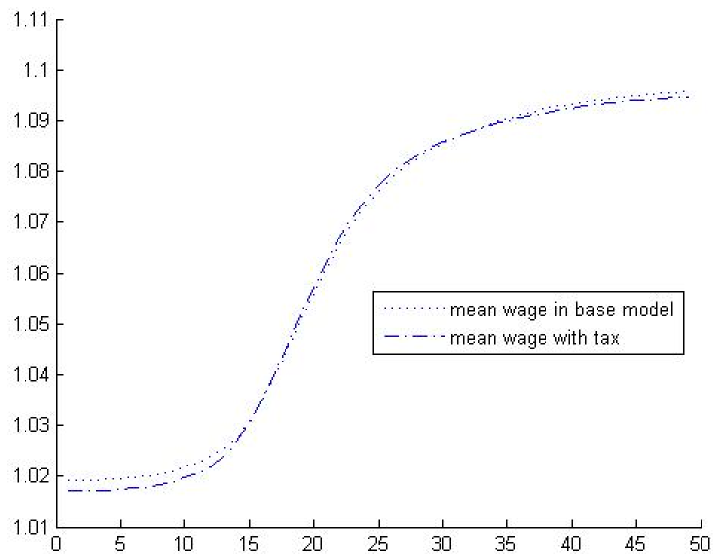


Figure 1.6: Compare average wage with tax to the baseline model

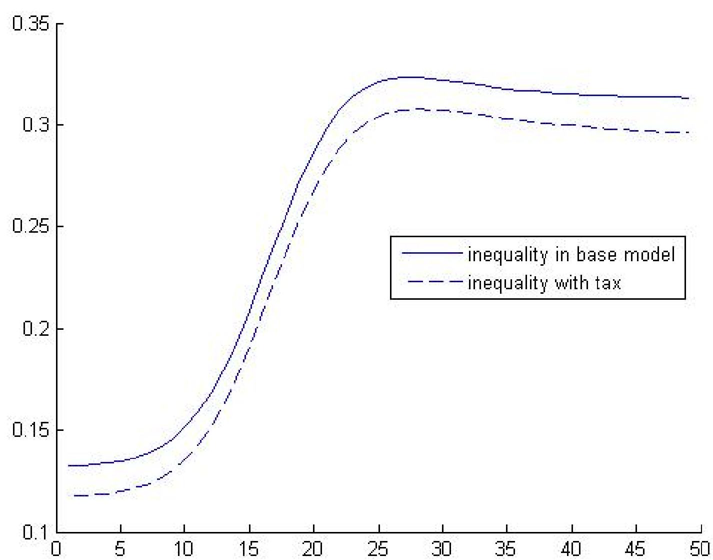


Figure 1.7: Compare variance of after-tax wage to the baseline model

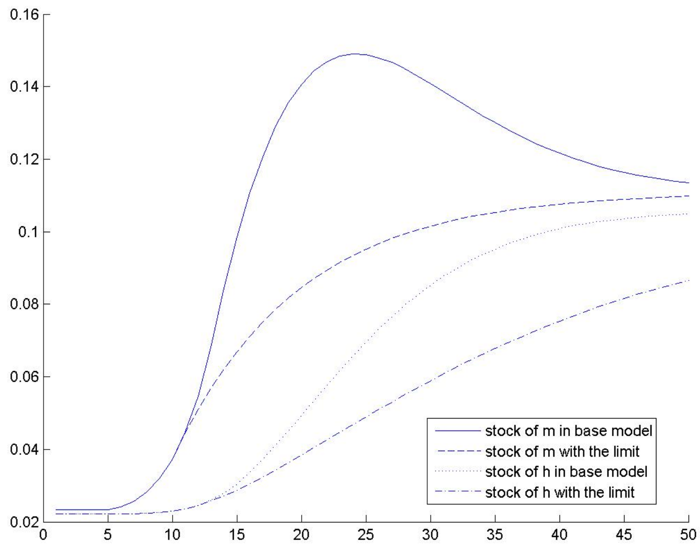


Figure 1.8: Compare the evolution of the stock of m and h with a limit on enrollment to the baseline model

Therefore, the return to education of the earlier cohorts is again distorted downward, creating an efficiency loss.

I have just illustrated that while a subsidy funded by a progressive tax can reduce inequality and improve access, it creates some inefficiency in the short run by reducing the incentive to go to college. Therefore, as the demand for education increases rapidly, the government should not try to fund it through higher taxes if the goal is to maximize efficiency, but instead it should allow more private colleges.

1.5.2 Too Many Graduates in China?

Currently, in view of the declining wages of recent graduates, there are heated debates in China about whether China already has too many college graduates, and whether the government should limit growth in college education. This model shows that the phenomenon can be explained by a fully rational model where the enrollment rate and stock of m overshoot, and w_m decreases quite significantly in the short run.

I would argue, on the contrary, that China probably still has too few college

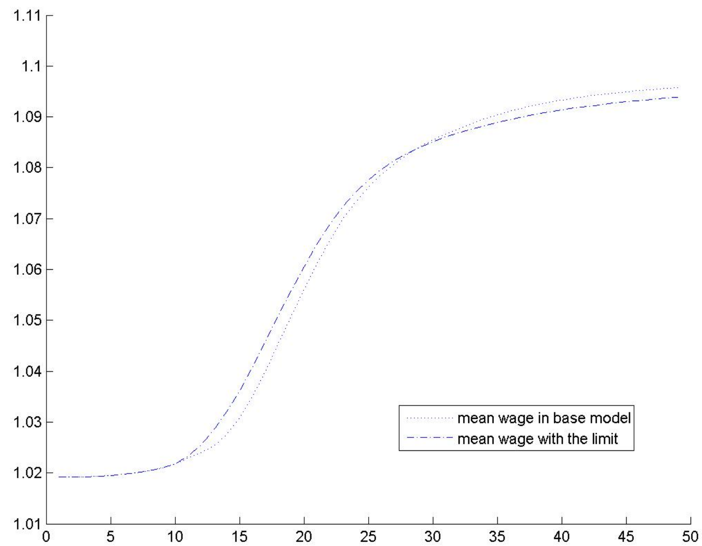


Figure 1.9: Compare average wage with a limit on enrollment to the baseline model

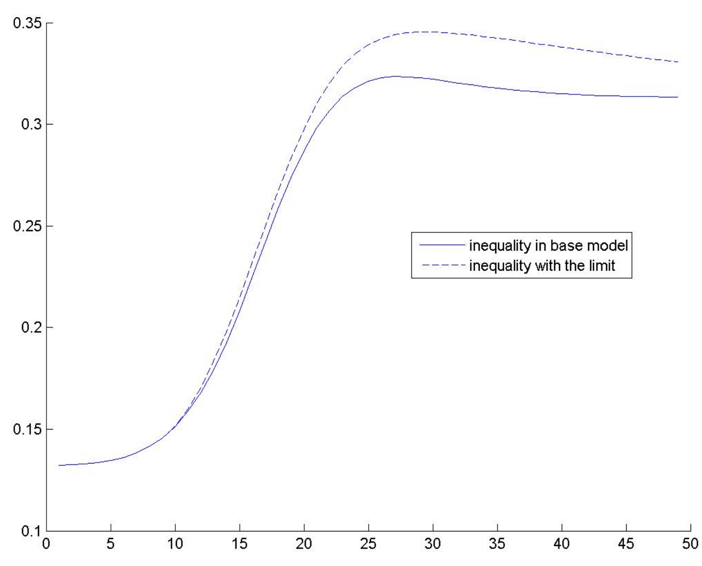


Figure 1.10: Compare variance of wages with a limit on enrollment to the baseline model

graduates. The number of high-school graduates has also increased very rapidly and so is the number of applicants to colleges. As of 2010, still about half of the students who take the notoriously high-pressure entrance exam fail to get into any college including 3-year colleges. Even with the rapid increase in the number of college graduates, the lifetime return to college education is still much higher than in the early reform period. Any policy that limits the growth of college education, such as restricting entry of private colleges, will cause a loss in overall welfare, and more inequality in the long run.

To analyze the welfare effect of limiting college education, I have solved the equilibrium numerically with a limit on the enrollment rate not to overshoot the long term steady state rate (this is effectively setting $G(v) = G(v^s)$ for $v > v^s$). The evolution of the stock of hf and m is shown in figure 1.8. As shown in figure 1.9, with limited enrollment, mean wage increases in the short run but decreases in the long run. More interestingly, as shown in figure 1.10, inequality has increased almost in all periods. Overall inequality has two components: first inequality among the graduates; and second inequality between graduates and non-graduates. For the first component, limiting enrollment will decrease return to experience in the short run, but it will increase return to experience in the long run because limiting the supply of m will exacerbate the shortage of h over time. Therefore, inequality among graduates will be lower in the short run and higher in the long run. For the second component, limiting enrollment will almost unambiguously increase inequality between graduates and non-graduates. A combination of the two kinds of inequality will generate the kind of inequality paths shown in the figure; inequality is higher in all periods in our numerical example.

In this paper, I have assumed that there is no growth in the productivity of local firms. However, in the real world, some local firms may grow more like foreign firms i.e. becoming more productive and skill-intensive. This kind of growth is equivalent to adding more high-productivity foreign firms, since in the model, the only difference between foreign firms and local firms is in productivity. The predictions and implications of the model still stand as long as the productivity distribution of all firms in the economy is shifting to the right.

1.6 Summary

This paper builds a model for the evolution of the labor market in a rapidly growing economy. The model illustrates that with an increase in demand for skill which requires both experience and education, the wages of young graduates may decrease while return to skill increases. The dynamic version of the model also predicts that in the short run, there will be an over-supply of inexperienced college graduates and a higher wage inequality than in the long run. From a policy point of view, the model predicts that there are some negative effects of limiting the growth of college education and subsidizing college education with progressive taxes during the transition.

1.7 Appendix: Proofs in this chapter

Proposition 1 The market clearing equations for m and h have a unique solution: w_m, w_h

Proof: By the definition of v, I know $w_m = \frac{(1+k)(v+1+C)}{1+kw}$, and substitute it in the market clearing equation for m, then I get the following.

$$nB[\frac{(1+k)(v+1+C)}{1+kw}]^{-\sigma}\int_{\frac{(1+k)(v+1+C)}{1+kw}}^{w}\delta^{\sigma-1}dF(\delta) = \frac{1}{k+1}G(v) \tag{1.15}$$

This equation provides a functional relationship between v and w. The left hand side is decreasing in v, and the right hand side is increasing in v. When $v = 0$, the left hand side is positive, the right hand side is 0. When v is very large such that $w_m = \frac{(1+k)(v+1+C)}{1+kw} >= w$, the left hand side is $<= 0$, the right hand side is > 0. Therefore given w, the above equation has a unique solution; in other words, v and w is a one to one functional relationship. Moreover, increasing w shifts the demand curve up, while leaving the supply curve unchanged, therefore the functional relationship can be denoted by an increasing function $w = w^*(v)$.

By the definition of v, I know $w_h = \frac{(1+k)(v+1+C)}{1/w+k}$. I substitute w by $w^*(v)$ to get $w_h = \frac{(1+k)(v+1+C)}{1/w^*(v)+k}$ which is an increasing function of v, denote it as $w_h^*(v)$). Substituting $w_h = w_h^*(v)$ and $w = w^*(v)$ into the clearing condition for h, I get the following equation.

$$B(w_h^*(v))^{-\sigma}[n\int_{w^*(v)}^{\Delta}(\delta^2)^{\sigma-1}dF(\delta)+n_f(w_h^*(v))(\Delta^2)^{\sigma-1}]=\frac{k}{k+1}G(v) \tag{1.16}$$

Given $w_h^*()$ and $w^*()$ are increasing and n_f is decreasing, the whole demand side is decreasing in v, and the right hand side is increasing. Further, when $v=0$, the left hand side is positive, the right hand side is 0; when v is big enough such that $w^*(v)>=\Delta$, then the left hand side is $<=0$, and the right hand side is positive. Therefore a unique solution v exists, and $w=w^*(v)$, $w_h=\frac{(1+k)(v+1+C)}{1/w+k}$, and $w_m=\frac{(1+k)(v+1+C)}{1+kw}$, and the solution w is between (w_m,Δ). Q.E.D.

Proposition 2 When n_f increases, w, v, w_h increase, but w_m is ambiguous.

Proof: I want to show that w, w_h, v all increase. First I will show that w increases. By contradiction, suppose not, if w decreases, observing the equation:

$$nB[\frac{(1+k)(v+1+C)}{1+kw}]^{-\sigma}\int_{\frac{(1+k)(v+1+C)}{1+kw}}^{w}\delta^{\sigma-1}dF(\delta)=\frac{1}{k+1}G(v) \tag{1.17}$$

Decreasing w shifts the left hand side down, thus decreasing v. Then, $w_h=\frac{(1+k)(v+1+C)}{1/w+k}$ also decreases, but this would violate the market clearing condition for h as follows.

$$B(w_h)^{-\sigma}[n\int_{w}^{\Delta}(\delta^2)^{\sigma-1}dF(\delta)+n_f(\Delta^2)^{\sigma-1}]=\frac{k}{k+1}G(v) \tag{1.18}$$

The left hand side increases from the previous equilibrium since w_h decreases, w decreases, and n_f increases, but the right hand side decreases from the previous equilibrium as v decreases. This is a contradiction, so w must increase.

I know w increases. By looking at the supply/demand equation for m, I know that as w increases, the left hand side shift up, so v also increases. Then $w_h=\frac{(1+k)(v+1+C)}{k+1/w}$ must increase too. So I have shown that w, v, and w_h all increases. However, $w_m=w_h/w$ is ambiguous Q.E.D.

Proposition 3 With more foreign firms, if $G'()$ is sufficiently small then w_m increases, and if $G'()$ is sufficiently large then w_m decreases.

Proof: To analyze this further I try to calculate dw_m/dw. I will implicitly differentiate the demand equation for m,

$$nBw_m^{-\sigma}\int_{w_m}^{w}\delta^{\sigma-1}dF(\delta)=\frac{1}{k+1}G(v) \tag{1.19}$$

where $v=w_m(1+kw)/(1+k)-1-C$

This equation establishes a functional relationship between w and w_m. I already know with the arrival of the foreign firms, w increases, therefore to sign dw_m, all I need to do is to sign dw/dw_m. Implicitly differentiating the above equation, I can obtain an expression for dw_m/dw.

$nBw_m^{-\sigma-1}(-\sigma)\int_{w_m}^{w}\delta^{\sigma-1}dF(\delta)+nBw_m^{-\sigma}(-w_m^{\sigma-1}f(w_m))+nBw_m^{-\sigma}w^{\sigma-1}f(w)\frac{dw}{dw_m}=\frac{1}{k+1}G'(v)[\frac{1+kw}{1+k}+\frac{w_mk}{1+k}\frac{dw}{dw_m}]$

After re-arranging and simplification, I get an expression for $\frac{dw}{dw_m}$

$\frac{dw}{dw_m}=\frac{-\sigma nBw_m^{-\sigma-1}\int_{w_m}^{w}\delta^{\sigma-1}dF(\delta)-nBw_m^{-1}f(w_m)-\frac{1}{k+1}G'(v)\frac{kw_m}{1+k}}{\frac{1}{k+1}\frac{1+kw}{1+k}G'(v)-nBw_m^{-\sigma}w^{-\sigma-1}f(w)}$

By examining the above expression, I know that when $G'()$ is sufficiently small, i.e. the supply is very elastic, $dw/dw_m>0$, so when w increases, w_m increases. On the other hand when $G'()$ is sufficiently large, i.e. the supply is very elastic, then $dw/dw_m<0$, so when w increases, w_m decreases.

Proposition 4 If w_m decreases in the new equilibrium, then there exists a cut off $\overline{\delta}=w^0w_m^0/w_m^1$, such that when $\delta<\overline{\delta}$, firms are better off, and when $\delta>\overline{\delta}$ firms are worse off.

Proof:

The firms that are still hiring h are worse off, because w_h increases. The firms that continue to hire m are better off since w_m is lowered. The firms that switch from hiring l to hiring m are better off, because previously they made $\frac{1}{\sigma-1}B$, and now they make $\frac{1}{\sigma-1}B(\frac{\delta}{w_m^1})^{\sigma-1}$. The profit is greater iff $\delta>w_m^1$, which is true for them to hire m now, therefore they are better off.

Now consider the firms with $\delta\in(w^0,w^1)$. they switch from hiring h to hiring m. Previously they made $\frac{1}{\sigma-1}B(\frac{\delta^2}{w_h^0})^{\sigma-1}$. Now they make $\frac{1}{\sigma-1}B(\frac{\delta}{w_m^1})^{\sigma-1}$. The firm is worse off if $\delta>w_h^0/w_m^1=w^0*w_m^0/w_m^1$, or better off if $\delta<w^0w_m^0/w_m^1$. Q.E.D.

Proposition 4a With the arrival of the medium productivity firms, v, w_m all increase, and w decreases.

Proof:

Let's say there are n' more medium productivity firms whose δ is d, and for simplicity, let's assume $w_m < d < w$, such that these medium productivity firms will hire m workers in the new equilibrium. Therefore, the two equations that pin down w_m and w are:

$$B[nw_m^{-\sigma} \int_{w_m}^{w} \delta^{\sigma-1} dF(\delta) + n'\Delta^{\sigma-1}] = \frac{1}{k+1} G(v) \tag{1.20}$$

This is the supply/demand equation for m in the new equilibrium, the only difference is the term of $n'\Delta^{\sigma-1}$ for the new domestic firms. The supply/demand equation for h is unchanged.

$$Bw_h^{-\sigma}[n \int_{w}^{\Delta} (\delta^2)^{\sigma-1} dF(\delta) + n_f(\Delta^2)^{\sigma-1}] = \frac{k}{k+1} G(v) \tag{1.21}$$

I will show w will decrease by contradiction. Suppose not, w increases. Substitute $w_h = \frac{(1+k)(v+1+C)}{1/w+k}$ into the above equation, and I get:

$$B[\frac{(1+k)(v+1+C)}{1/w+k}]^{-\sigma}[n \int_{w}^{\Delta} (\delta^2)^{\sigma-1} dF(\delta) + n_f(\frac{(1+k)(v+1+C)}{1/w+k})(\Delta^2)^{\sigma-1}] = \frac{k}{k+1} G(v) \tag{1.22}$$

If w increases, it will shift the left hand side down, thus v will decrease. Then $w_m = \frac{(1+k)(v+1+C)}{1+kw}$ will decrease, but this would violate the supply-demand equation for m. In the equation, the left hand side increases from the previous equilibrium as w_m decreases and there is a new positive term for the demand from the new firms, but the right hand side decreases as v decreases, which a contradiction. So w must decrease.

Again using the clearing condition for h, a decreasing w shifts the left hand side up, therefore v increases, and $w_m = \frac{(1+k)(v+1+C)}{1+kw}$ must also increase. Q.E.D.

Proposition 4b With the arrival of the medium productivity firms, w_h is ambiguous. When $G()$ is sufficiently inelastic, w_h increases; when $G()$ is sufficiently elastic, w_h decreases.

Proof: Substitute $v = \frac{w_h(k+1/w)}{1+k} - 1 - C$ into the demand equation for h,

$$B(w_h)^{-\sigma}[n\int_w^{\Delta}(\delta^2)^{\sigma-1}dF(\delta) + n_f] = \frac{k}{k+1}G(\frac{w_h(k+1/w)}{1+k} - 1 - C). \qquad (1.23)$$

This equation establishes a functional relationship between w and w_h, I already know that with the arrival of the medium firm, w decreases, then to sign dw_h, all I need to do is to sign dw/dw_h. Implicitly differentiating the above equation by w, I will get an expression dw_h/dw. It can be shown that when $G'()$ is sufficiently small, i.e. the supply is very inelastic, then $dw_h/dw < 0$, therefore with the new arrivals, w decreases, then w_h must increase. On the other hand when $G'()$ is sufficiently big, i.e. the supply is very elastic, then $dw_h/dw > 0$, therefore with the new arrivals, w decreases, then w_h must decrease.

Intuitively, when w decreases, there are two effects. The first effect is that it increases the demand on the left hand side of the equation, which tends to increase w_h; the second effect is shifting supply curve up, which tends to reduce w_h. When the supply curve is very elastic, the second effect dominates, w_h decreases. This says that, if the education system is efficent at producing m workers, more moderately-productive local firms can reduce w_h thus benefit more high ability firms as well. In the extreme case, when supply of m is perfectly elastic at some point v_0, then when w decreases, w_h must also decrease to keep $v = v_0$. On the other hand, if $G(v)$ is perfectly inelastic, i.e. the supply of m, and h is fixed, then as w decreases, the demand for h increases, therefore bidding up w_h.

Proposition 4d When there are more local firms of medium productivity and supply of education is sufficiently elastic, there exists a productivity cutoff, such that all local firms with a higher productivity will be better off. All existing foreign firms are better off.

From Proposition 4b, I know w_m increases, but w_h decreases.

As w_h decreases, clearly every foreign firm which hires h is more profitable.

The domestic firms that are still hiring m are worse off, because w_m increases. The firms that continue to hire h are better off since w_h is lowered. The firms switching from hiring m to hiring l are worse off, because now they make $\frac{1}{\sigma-1}B$, and previously

Table 1.3: Impact of additional medium productivity firm on existing firms when $w_h^1 < w_h^0$, and $w_m^1 > w_m^0$

Firms with $\delta \in$	Workers	Profit Before	Profit After	Comparison
$(1, w_m^0)$	l	$\frac{1}{\sigma-1}B$	same	same
(w_m^0, w_m^1)	$m->l$	$\frac{1}{\sigma-1}B(\frac{\delta}{w_m^0})^{\sigma-1}$	$\frac{1}{\sigma-1}B$	worse off
(w_m^1, w^1)	m	$\frac{1}{\sigma-1}B(\frac{\delta}{w_m^0})^{\sigma-1}$	$\frac{1}{\sigma-1}B(\frac{\delta}{w_m^1})^{\sigma-1}$	worse off
$(w^1, w^1 * w_m^1/w_m^0)$	$m->h$	$\frac{1}{\sigma-1}B(\frac{\delta}{w_m^0})^{\sigma-1}$	$\frac{1}{\sigma-1}B(\frac{\delta^2}{w_h^1})^{\sigma-1}$	worse off
$(w^1 * w_m^1/w_m^0, w^0)$	$m->h$	$\frac{1}{\sigma-1}B(\frac{\delta}{w_m^0})^{\sigma-1}$	$\frac{1}{\sigma-1}B(\frac{\delta^2}{w_h^1})^{\sigma-1}$	better off
(w^0, Δ)	h	$\frac{1}{\sigma-1}B(\frac{\delta^2}{w_h^0})^{\sigma-1}$	$\frac{1}{\sigma-1}B(\frac{\delta^2}{w_h^1})^{\sigma-1}$	better off

they made $\frac{1}{\sigma-1}B(\frac{\delta}{w_m^0})^{\sigma-1}$. The profit is smaller iff $\delta < w_m^0$, which is true for them to hire l initially, therefore they are worse off.

Now consider the firms with $\delta \in (w^1, w^0)$ that switch from hiring m to hiring h. Now they make profit $\frac{1}{\sigma-1}B(\frac{\delta^2}{w_h^1})^{\sigma-1}$. Previously they made $\frac{1}{\sigma-1}B(\frac{\delta}{w_m^0})^{\sigma-1}$. The firm is better off if $\delta > w_h^1/w_m^0 = w^1 * w_m^1/w_m^0$ or worse off if $\delta < w^1 w_m^1/w_m^0$. Q.E.D

Proposition 5 A dynamic equilibrium exists.

Proof: I denote enrollment rate $g^t \equiv G(v^t)$, I will establish a mapping between g^t to $g^{t\prime}$, by the following procedure: from the enrollment path g^t, I can compute the evolution of L_m^t and L_h^t, and then using the period by period demand and supply equations, I can compute w_m^t and w_h^t from which I can compute v^t, finally I can get a new set of $g'^t = G^{-1}(v^t)$.

I define a Banach space for all sequences bounded by $[0, 1]$ with a sup norm. Clearly this space is compact and convex. The above-defined mapping can be easily shown to be a continuous self-mapping. Therefore I can use the Schauder Fixed Point Theorem to establish the existence of a fixed point. Q.E.D.

Lemma 1 In period by period demand/supply equations for h and m, if both L_h and L_m decrease, and one of them decreases strictly, then w_m and w_h increases strictly. (Conversely if both L_h and L_m increase, and one of them increases strictly then w_m and w_h decreases strictly.)

Proof: By contradiction. If w_m decreases, then by the equation for m, w must also decrease, to keep L_m decrease, therefore $w_h = ww_m$, must also decrease. However, if w decreases, then w_h must increase to keep L_h decrease, which is a contradiction.

Therefore, w_m increases,

Similarly, to show that w_h increases, I also use proof by contradiction. Suppose w_h decreases, then by the equation for h, the left hand side increases, but the right hand side (L_h) decreases, which is a contradiction. Therefore, w_h increases. The converse can be easily shown similarly. Q.E.D.

Lemma 2 Given the period by period demand and supply equations, denote W_m as the solution for the wage for m given argument L_m and L_h. Then, the partial $-\frac{\partial W_m}{\partial L_h}$ is bounded below.

Proof: The two equations are:

$$nBw_m^{-\sigma}\int_{w_m}^{w_h/w_m}\delta^{\sigma-1}dF(\delta) = L_m \tag{1.24}$$

$$Bw_h^{-\sigma}[n\int_{w_h/w_m}^{\Delta}(\delta^2)^{\sigma-1}dF(\delta) + n_f(\Delta^2)^{\sigma-1}] = L_h \tag{1.25}$$

Denote function $M(,)$ as $M(w_m, w_h) = nBw_m^{-\sigma}\int_{w_m}^{w_h/w_m}\delta^{\sigma-1}dF(\delta)$,

and denote function $H(,)$ as $H(w_m, w_h) = Bw_h^{-\sigma}[n\int_{w_h/w_m}^{\Delta}(\delta^2)^{\sigma-1}dF(\delta)+n_f(\Delta^2)^{\sigma-1}]$

and implicitly differentiate both equations on both sides by L_h, holding L_m constant. I have

$M_1\frac{\partial w_m}{\partial L_h} + M_2\frac{\partial w_h}{\partial L_h} = 0$

$H_1\frac{\partial w_m}{\partial L_h} + H_2\frac{\partial w_h}{\partial L_h} = 1$

I solve the above equations to get, $\frac{\partial W_m}{\partial L_h} = (H_1 - H_2M_1/M_2)^{-1}$.

I know $M_1 < 0$, $M_2 > 0$, $H_1 < 0$ and $H_2 > 0$, and by Lemma 1, I know $\frac{\partial W_m}{\partial L_h} < 0$

I know the absolute values of M_1, M_2, H_1 and H_2 are bounded below and above (by assumption, all the wages are bounded between $[1, \Delta^2]$, and $f() < \infty$) . Therefore the absolute value $H_1 - H_2M_1/M_2$ is bounded from above, and hence, the absolute value of $\frac{\partial W_m}{\partial L_h}$ is bounded below.

Lemma 3 If $v^t > v^s$ and both L_m^t and L_h^t converge from below then

$$\lim_{t\to\infty}\frac{L_h^s - L_h^t}{L_m^s - L_m^t} = \infty \tag{1.26}$$

Proof: Expanding the recursive formula for L_h I have $L_h^t = \sum_{j=1}^{t} \eta\mu^j L_m^{t-j}$, and hence $L_h^s - L_h^t = \sum_{j=1}^{t} \eta\mu^j (L_m^s - L_m^{t-j})$.

Also I know that $L_m^s - L_m^t < \mu(1-\eta)(L_m^s - L_m^{t-1})$ for all t. This is because $L_m^s - L_m^t = \mu(1-\eta)(L_m^s - L_m^{t-1}) + (1-\mu)(G(v^s) - G(v^t))$, and $G(v^t) > G(v^s)$.

Recursively applying the above inequality, I have

$$L_m^s - L_m^{t-j} > \mu^{-j}(1-\eta)^{-j}(L_m^s - L_m^t) \tag{1.27}$$

I substitute the above inequality into the expression for $L_h^s - L_h^t$ to get $L_h^s - L_h^t > (L_m^s - L_m^t)\sum_{j=1}^{t}(1-\eta)^{-j}$ therefore $\frac{L_h^s - L_h^t}{L_m^s - L_m^t}$ will go to infinity as t goes to infinity. Q.E.D.

Proposition 6 With this setup, if $G'() > 0$, there exists some period τ, in which $L_m^\tau > L_m^s$.

Proof:

By contradiction, suppose L_m never overshoots, i.e. $L_m^t <= L_m^s$ for all t, then L_h also never overshoots($L_h^t <= L_h^s$ for all t). Actually, the inequality is strict, as long as $L_h^0 < L_h^s$ (this can be shown easily by induction on equation (8)).

Then, I will show that for some τ large enough, for all $t > \tau$, $w_m^t > w_m^s$ and $w_h^t > w_h^s$. To show this, since the demand for labor n_f^t will be a constant for t large enough ($t > \tau$) by assumption, and since the supply never overshoots, ($L_m^t <= L_m^s$ and $L_h^t < L_h^s$, for $t > \tau$), by Lemma 1, the wages will always be higher than the long term values for t large enough. i.e $w_m^t > w_m^s$, $w_h^t > w_h^s$, $v^t > v^s$

Next, I will show this is not possible when $G'() > 0$.

In the first step, I will establish that

given $L_m^{t+1} < L_m^s$ for all t, I have

$$\frac{G(v^{t-4}) - G(v^s)}{L_m^s - L_m^t} < \frac{\mu(1-\eta)}{1-\mu} \tag{1.28}$$

This follows from simple algebra as follows:

$L_m^{t+1} = (1-\mu)G(v^{t-4}) + \mu(1-\eta)L_m^t < L_m^s$

Re-arranging, I get

$(1-\mu)G(v^{t-4}) < L_m^s - \mu(1-\eta)L_m^t = \mu(1-\eta)(L_m^s - L_m^t) + (1-\mu+\mu\eta)L_m^s$

Given $(1-\mu+\mu\eta)L_m^s = (1-\mu)G(v^s)$

I have $G(v^{t-4}) - G(v^s) < \frac{\mu(1-\eta)}{1-\mu}(L_m^s - L_m^t)$.

Second, I know that $v^{t-4} - v^s > (1-\mu)\mu^4(1-\eta)^4(w_m^t - w_m^s)$, by the formula for v_t, for all $t > \tau$, $w_m^t > w_m^s$ and $w_h^t > w_h^s$.

Third, apply the mean value theorem, $w_m^t - w_m^s = (-\frac{\partial W_m}{\partial L_m})(L_m^s - L_m^t) + (-\frac{\partial W_m}{\partial L_h})(L_h^s - L_h^t)$. Here W_m is the function that solves w_m taking argument L_m and L_h in the period by period supply and demand equations. The partials are evaluated at some values between L_m^t, L_h^t and L_m^s, L_h^s.

Combining the second and third step, I have

$v^{t-4} - v^s > (1-\mu)\mu^4(1-\eta)^4[(-\frac{\partial W_m}{\partial L_m})(L_m^s - L_m^t) + (-\frac{\partial W_m}{\partial L_h})(L_h^s - L_h^t)]$.

and again applying the mean value theorem on $G()$, I get:

$G(v^{t-4}) - G(v^s) > G'()(1-\mu)\mu^4(1-\eta)^4[(-\frac{\partial W_m}{\partial L_m})(L_m^s - L_m^t) + (-\frac{\partial W_m}{\partial L_h})(L_h^s - L_h^t)]$

Dividing both sides by $L_m^s - L_m^t$, I have

$$\frac{G(v^{t-4}) - G(v^s)}{L_m^s - L_m^t} > G'()(1-\mu)\mu^4(1-\eta)^4[(-\frac{\partial W_m}{\partial L_m}) + (-\frac{\partial W_m}{\partial L_h}).\frac{L_h^s - L_h^t}{L_m^s - L_m^t}] \quad (1.29)$$

By Lemma 2 $-\frac{\partial W_m}{\partial L_h}$ is uniformly bounded from below. Also by Lemma 3, $\frac{L_h^s - L_h^t}{L_m^s - L_m^t}$ goes to ∞. Observing the above equation, as long as $G'() > 0$ evaluated near v_s, $\frac{G(v^{t-4})-G(v^s)}{L_m^s - L_m^t}$ will go to ∞. This contradicts to the first step where I have shown that $\frac{G(v^{t-4})-G(v^s)}{L_m^s - L_m^t} < \frac{\mu(1-\eta)}{1-\mu}$ for t big enough. Therefore L_m^t will overshoot. Q.E.D

Chapter 2

Empirical Analysis

In this chapter, I will use a China dataset to analyze the recent change in age-earnings profiles in China. I will then examine evidence from other developing countries.

2.1 Matching with Recent Wage Patterns in China

2.1.1 Dataset

In view of the lack of a high-quality public wage dataset, I obtained a unique wage dataset from a leading online recruiting firm in China. The dataset contains about 200,000 resumes posted to the company's website in the month of July, 2010. Each resume contains basic demographic information including age, sex, and education. For the education category, applicants select one of five education levels: advanced degree, 4-year college degree, 3-year college degree, high school graduate, or below high school. Applicants also report the name of the education institution, majors and graduation dates.[1] In addition to basic demographic information, each resume contains information about current and previous jobs held by the applicant. For each job, applicants report employment period, company name, industry, and salary range

[1]In China, job applicants generally report education levels accurately, because many employers require copies of diplomas upon hiring

Table 2.1: Summary Statistics

Variables	Remarks
age	Mean 28.6 , Std Dev 4.9
sex	63% male
wage	Mean 3589, Std Dev 2624 (monthly wage in RMB)
education	41% four-year college, (among them, 5% from elite colleges) 40% three-year college 17 % high school or equivalent
N	376809

which is selected from nine salary ranges.[2] All the following analysis will use the mid-point of the range as the reported salary. About 15% of the jobs did not include salary range information, and were deleted from the sample. Altogether, the dataset includes 376,809 job observations.

Table 2.1 presents selected summary statistics of the dataset. Figure 2.1 shows the age distribution of the job applicants in the sample. Given how the data are collected, the sample consists of mostly young and middle-aged urban workers that are using the internet for job search. This is the only dataset that I can find that allows the calculation of lifetime return to education for the recent graduates in China. Due to the limitation of the dataset, there might be sample selection issues, but the time patterns of the wages of different age and eduction groups are still indicative of the overall wage trend. Later in the paper, I will discuss the potential selection biases in details and compare the results with other wage datasets.

Figure 2.2 compares the recent wages for the recent college graduates (age 22 to 25) to the wages for the experienced graduates (age 26 to 29). As shown, in the early 2000s, both wages went up; however, in the late 2000s, while tfhe wages for the experienced graduates continued to rise, the wages for the recent graduates declined significantly.

To analyze the lifetime return to education for different age cohort, I compute the age earnings profiles for four different cohorts: late graduates (born after 7/1/1982),

[2]Applicants may inflate current wages somewhat, but as long as the degree of inflation is roughly the same across demographic categories and level of education, the estimate of college premiums and time trend patterns will not be significantly affected.

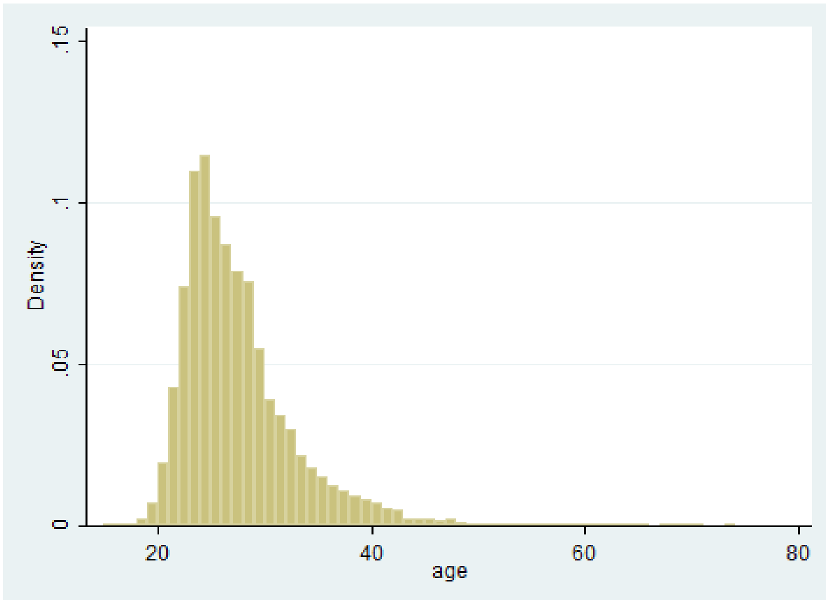


Figure 2.1: Age Distribution of the Job Applicants

Figure 2.2: wage trends for recent and experienced college graduates

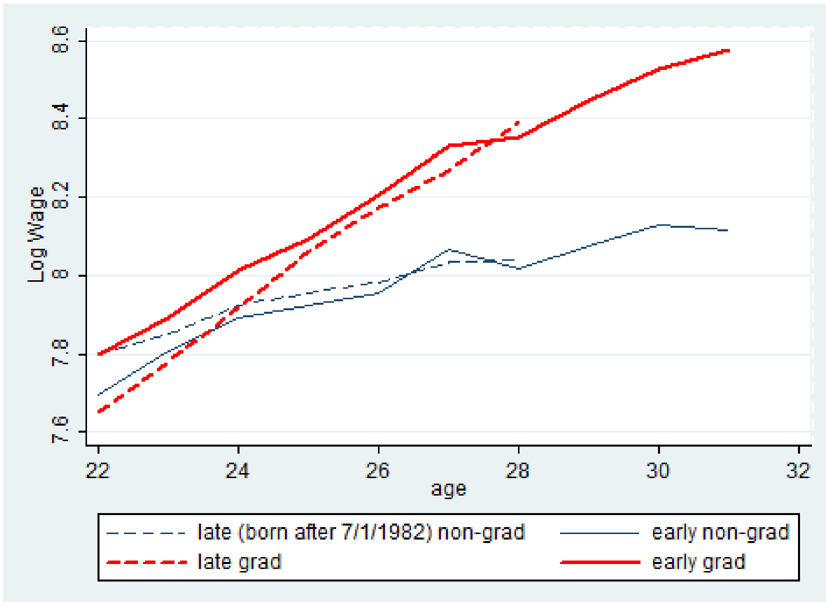


Figure 2.3: Cohort Wage Analysis
Note: Wage is computed as the average monthly wage in RMB for each age group

early graduates, late non-graduates and early non-graduates in Figure 2.3. An average real monthly wage in RMB is computed for each age group in each cohort, and the log average wage is displayed for each age group from age 22 to 31. For the two non-graduates cohorts, age-earnings profiles are about the same. On the other hand, the age-earnings profile for late graduates is much steeper than for early graduates. The late graduates cohort started their careers at significantly lower wages than the early cohort but were able to catch up after about 6 years.

2.1.2 Wage Regression

The wage regression is a Mincerian-type regression with an interaction term between age and the college dummy variable. The following OLS regression is performed on all the job observations and on job observations of different cohorts.

$$Log(Wage_{ij}) = a + bA_{ij} + cA_{ij}^2 + d * College_i + e * A_{ij}College_i + u_{ij} \tag{2.1}$$

$Wage_{ij}$ is the wage for individual i at job j. $College_i$ is a dummy variable which is set to one for college graduates (both 3-year and 4-year college graduates). A_{ij} is the actual age minus 22 for individual i at job j. With this age normalization, the coefficient on the $College_i$ is the estimated college premium at age 22 ($A_{ij} = 0$).The reason that I use age instead of actual experience in the regression is that I am more interested in comparing wages between graduates and non-graduates at the same age. [3]

Table 2.2 shows the result of the above wage regression using all observations and using observations of different cohorts. The first column shows the result of the regression using all observations. As shown, the coefficient on the college dummy, indicating the college premium at age 22 (or $A_{ij} = 0$) is actually negative. The coefficient on the interaction term is quite large, showing a strong complementarity between experience and education. The second and the third column compare the regressions performed separately for the early cohort (born before 7/1/1982) and for the late cohort. Again as predicted, the college premium at age 22 changed from positive for the early cohort to negative for the late cohort, but the coefficient on the interaction term is much larger for the late cohorts, showing an even stronger complementarity between experience and education for the late cohorts.

I also run the following wage regression with a person fixed effect:

$$Log(Wage_{ij}) = a_i + bA_{ij} + cA_{ij}^2 + e * A_{ij}College_i + u_{ij} \tag{2.2}$$

The result is shown in table 2.3. With fixed effects, the coefficient on the college dummy variable (i.e. college wage premium at age 22) is not identified. The coefficient on the interaction term between college dummy and age is highly significant, and is much larger for the late cohorts than for the early cohorts, indicating that the age-earnings profiles have shifted steeper for the late cohorts.

[3] One can easily back out the wages by experience and compare graduates and non-graduates wages at the same experience level. For a typical 4-year college graduate, A_{ij} is the experience, and for a typical high school graduate, the experience is $4 + A_{ij}$.

Table 2.2: Wage Regression without Fixed Effects

Dep:log(wage)	(1) All Observations	(2) Early Cohorts Born before 7/1/1982	(3) Late Cohorts Born after 7/1/1982
College	-0.189***	0.0185	-0.258***
	(0.00491)	(0.0154)	(0.00597)
A	0.0968***	0.0586***	0.107***
(age-22)	(0.00166)	(0.00373)	(0.00291)
A^2	-0.00576***	-0.00120***	-0.0101***
	(0.000139)	(0.000264)	(0.000389)
College*A	0.0674***	0.0421***	0.0910***
	(0.00101)	(0.00194)	(0.00201)
_cons	7.586***	7.567***	7.609***
N	376809	128316	248493

Robust standard errors clustered by person are in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 2.3: Wage Regression with Fixed Effects

Dep:log(wage)	(1) All Observations	(2) Early Cohorts Born before 7/1/1982	(3) Late Cohorts Born after 7/1/1982
A	0.0961***	0.0714***	0.144***
(age-22)	(0.00219)	(0.00346)	(0.00370)
A^2	-0.00303***	-0.000279	-0.0140***
	(0.000157)	(0.000250)	(0.000433)
College*A	0.0490***	0.0404***	0.0714***
	(0.00171)	(0.00209)	(0.00286)
_cons	7.418***	7.445***	7.367***
N	376809	128316	248493

Robust standard errors clustered by person are in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

2.1.3 Age-Earnings Profile of Different Types of Colleges

Figure 2.4 shows the age-earnings profiles for graduates from three types of colleges, i.e. the 3-year colleges, the 4-year colleges, and the elite colleges [4]. Consistent with the assumption that ability and experience are complements, the age-earnings profile of the 4-year college graduates is steeper than that of the 3-year college graduates, and the age-earnings profile of the elite college graduates is the steepest.

Figure 2.5 compares age-earnings profiles of the early cohorts (born before 7/1/1982) to those of the late cohorts across the three types of college graduates. All three age-earnings profiles shifted steeper for the later cohorts (born after 7/1/1982). The profile of the 4-year college graduates shifted more than that of the 3-year college graduates, and the wage of the young 4-year college graduates decreased more than that of the young 3-year college graduates. This is consistent with the model prediction that when the wage of experienced 4-year graduates increases relative to that of experienced 3-year college graduates, the wage of young 4-year college graduates will decline relative to that of young 3-year college graduates if the supply of 4-year graduates is elastic. Also as shown, the wages of young elite graduates did not decrease much, because the supply of elite college graduates is inelastic.

2.1.4 Inequality among the graduates

I will look at earning inequality within different age groups. According to the theory, earning inequality will be higher for older groups, because more of the older graduates will become H (high ability workers) and earn w_h than the younger groups. Figure 2.6 shows the standard deviation of wages as a percentage of the average wage of different age groups. As shown in the figure, in general, the earning inequality is higher for the older age groups. However, the earning inequality for age 22 and age 23 is quite high. The reason for high inequality among the recent graduates could be that it may take one or two years for the young graduates to find a decent paying job or some companies may pay very low internship wages for the first year. But at age 24, the inequality settles down to the lowest point, and then consistently moves up

[4]this refers to the top 30 colleges ranked by graduates' earnings.

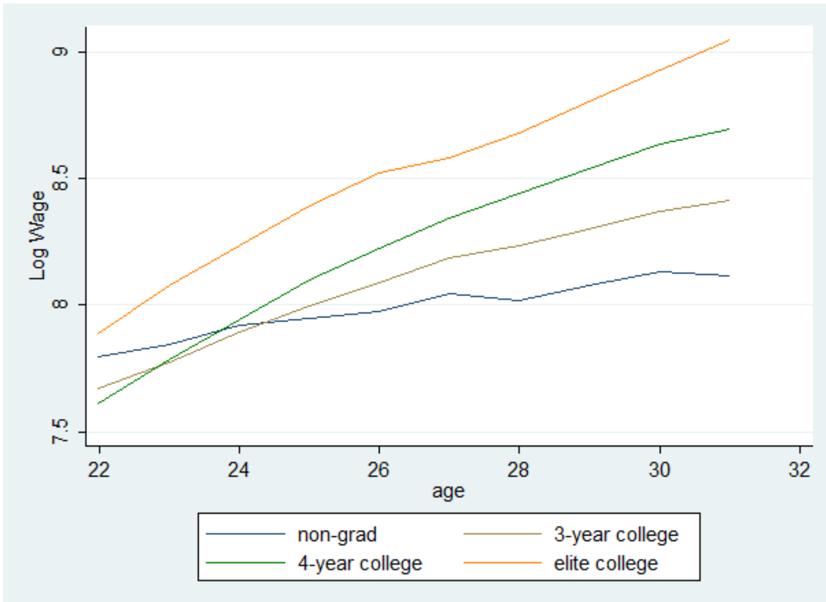


Figure 2.4: Age-Earnings Profile for Three Types of Colleges

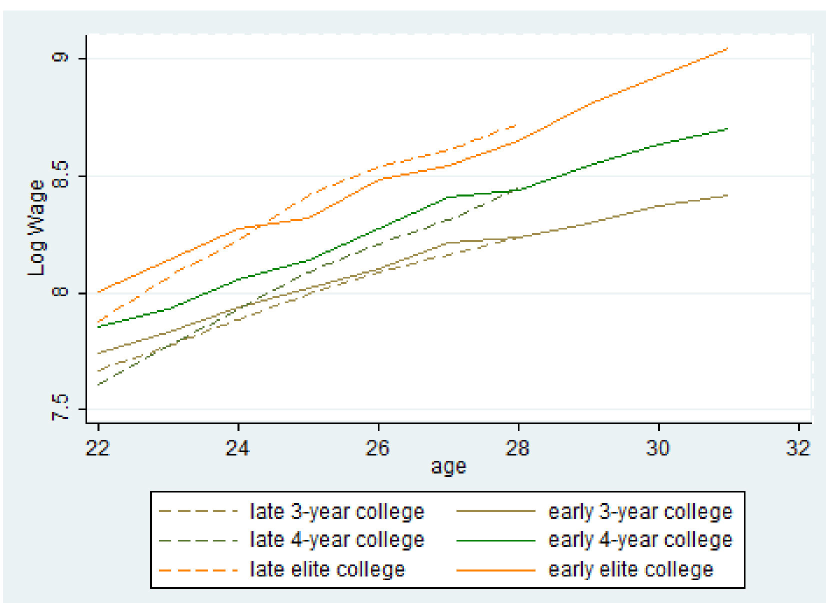


Figure 2.5: Cohort Comparison of Age-Earnings Profile for Different Types of Colleges

Figure 2.6: Earnings inequality of graduates of different ages

with more experience.

Particularly, after age 29, inequality increases a great deal. Typically, this is the period when most graduates have learned the jobs and demonstrated their abilities. Therefore, this is also usually the period when companies will selectively promote some of them into junior level management positions. In the figure 2.6, as expected, the earning inequality moves up rapidly after age 29. The standard deviation of wages increases from 80% of the average wage at age 28 to 115% of the average wage at age 31.a

Figure 2.7 compares earnings inequality of the 3-year college graduates and 4-year college graduates. The earnings inequality are roughly the same before around age 30, but after around age 30, the earnings inequality of the 4-year college graduates increases faster than that of 3-year college graduates. A possible explanation for this is that the 4-year college graduates have more potential high ability workers, and at around age 30, more of them are promoted, resulting in a higher inequality at age 30 for the 4-year college graduates cohorts than the 3-year college graduates cohorts.

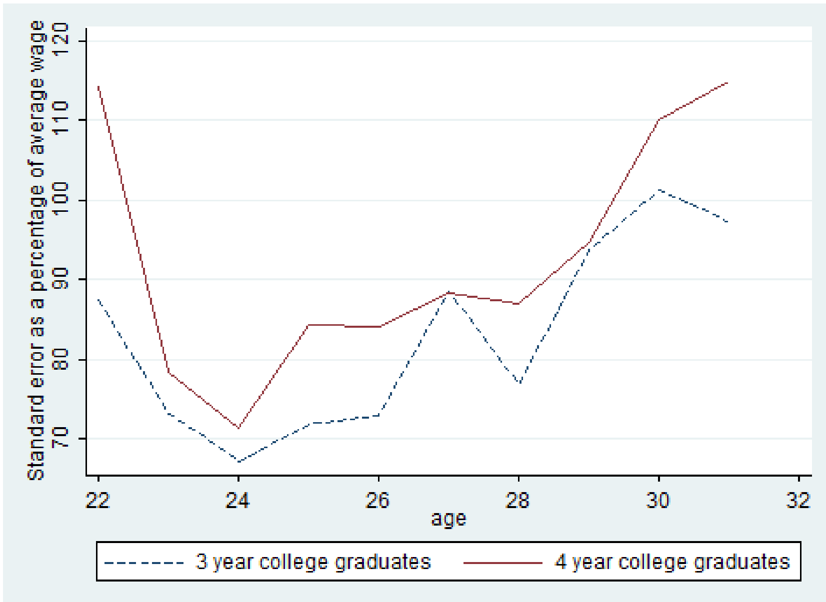


Figure 2.7: Comparing earnings inequality of different types of graduates

2.1.5 Earnings profiles for Males and Females

Figure 2.8 shows the earning profiles of the four groups: the male graduates, the male non-graduates, the female graduates and the female non-graduates. Similar to the general population, the earnings profiles for graduates both male and female are much steeper than those of the non-graduates. For the non-graduates, the male wage premiums are similar across different age groups; however, for the graduates, the male wage premiums are much larger for the older age groups than for the younger age groups. Particularly, the male wage premiums increases rapidly after age 29. This is consistent with the conjecture that at around age 30, the first batch of promotion opportunities emerge and more male graduates are promoted than female graduates.

Figure 2.9 compares the earnings profiles of the four groups: the male 3-year college graduates, the male 4-year college graduates, the female 3-year college graduates, and the female 4-year college graduates. As expected, for both types of college graduates, the earnings profiles of males are steeper than those of females. But, what is interesting is that the earnings profile for the male 3-year college graduates are much steeper than the female 3-year college graduates. The slope of the male 3-year college

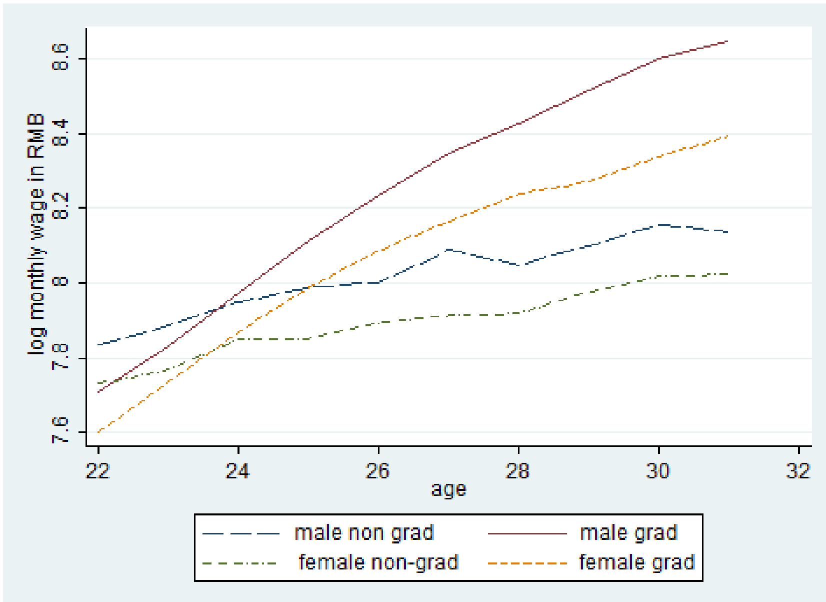


Figure 2.8: Earnings profile for male and female graduates

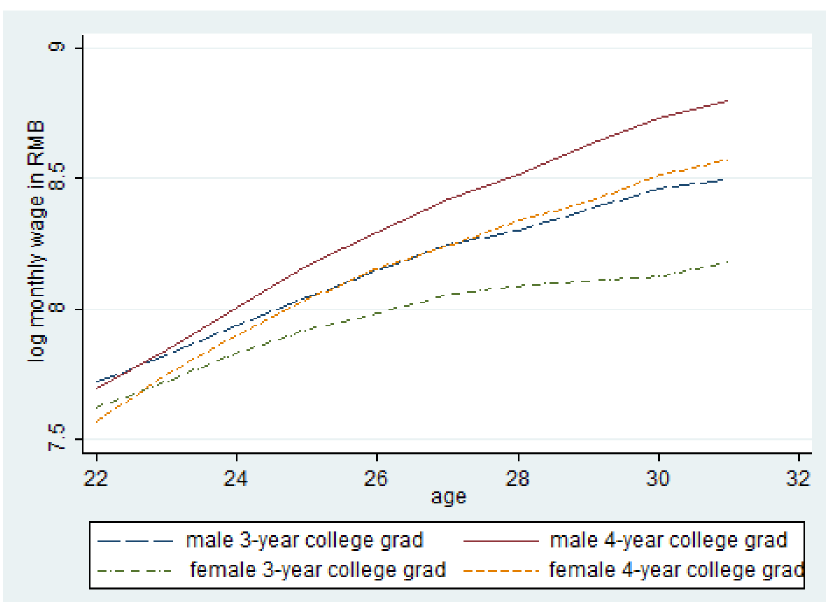


Figure 2.9: Earnings profile for male and female graduates of different types

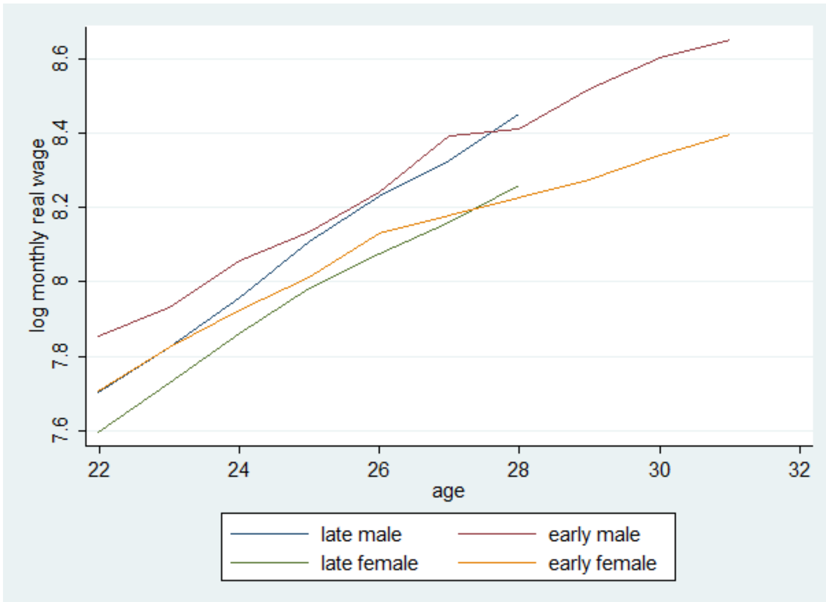


Figure 2.10: Earnings profile for male and female graduates

graduates is almost as steep as the female 4-year college graduates; on the other hand, the age-earnings profiles of the female 3-year college graduates are almost flat after age 28.

Figure 2.10 shows how the wages for males and females changed during the late 2000s, with the earnings profiles for the four groups of graduates: early male graduates (who were born before 7/1/1982), late male graduates, early female graduates, and late female graduates. As shown in the figure, the later male and female cohorts, have a much steeper earnings profiles than the earlier cohorts, therefore the pattern of steeper earnings profile is across workers of both genders.

Table 2.4 shows the Mincerian-type wage regression for male and female graduates. $YoungC$ is a dummy variable which is set to one for all the people who were born before 7/1/1982. In the table, the coefficients on $YoungC * College$ are negative for both male and female workers, indicating the later cohorts have a negative college wage-premium at experience 0. Further, the coefficients on $YoungC * College * Exp$ are positive for both male and female workers, indicating that both earnings curves shifted steeper.

Table 2.4: Wage Regressions by Gender

Dep Var: Log Wage		
	Male	Female
College	-0.083*	-0.094*
	(0.010)	(0.013)
Exp (age-22)	0.059*	0.075*
	(0.0025)	(0.0034)
Exp*Exp	-0.0021*	0.0049*
	(0.00022)	(0.00031)
College*Exp	0.059*	0.049*
	(0.0013)	(0.0020)
YoungC*College	-0.13*	-0.11*
	(0.0090)	(0.011)
YoungC*Exp	0.0087*	-0.0027*
	(0.0019)	(0.0030)
YoungC*College*Exp	0.024*	0.032*
	(0.0069)	(0.0091)
constant	7.66	7.56
R squared	0.24	0.17
N	231004	145805

Note: * Signficant at 5% level
Dummy variable: YoungC is set to 1 for workers born after 7/1/1982.
Dummy variable: College is set to 1 for college graduates

2.1.6 Wage Profiles by Industry

Here, I will run the wage regressions for each industry to examine if the shifting of age-earnings profile is across all industries. In the dataset, almost every job in every resume is associated with an industry code which ranges from 1 to 40. (About 5% of the jobs are without an industry classification, and are omitted from the following analysis). I ran the following Mincerian-type regression separately for each industry.

$$Log(Wage_i) = b_0 + b_1 C_i + b_2 E_i + b_3 E_i^2 + b_4 E_i C_i + b_5 Y_i C_i + b_6 Y_i E_i + b_7 Y_i E_i^2 + b_8 Y_i E_i C_i + u_i \quad (2.3)$$

In the regression equation, C_i is a dummy variable which is set to 1 for college graduates; E_i is potential experience which is actually age-22; Y_i is a dummy variable which is set to 1 for the younger cohorts (born after 7/1/1982).

I will report four coefficients b_1, b_4, b_5 and b_8 in the following table. For each industry, b_1 is the college premium at experience zero for the older cohorts (born before 7/1/1982), and b_4 is the college experience premium per year for the older cohorts. b_5 is the change of college premium at experience zero for the younger cohorts (born after 7/1/1982), and b_8 is the change of college experience premium per year for the younger cohorts.

Table 2.5 lists these four coefficients for each of the 40 industries. As shown in the table, the numbers in the third column, which are college premiums at experience zero for those who were born before 7/1/1982, are mixed, indicating before 2005, about half of the industries still offered a positive college premium for recent graduates. The numbers in the fourth column, which are college experience premiums per year, are positive for almost all industries (except the tourism and retail industry), demonstrating that experience and college education are complementary in general.

The numbers in the fifth column, which are the changes in college premiums at experience zero for the later cohorts, are negative for almost all industries with the only exception of agriculture, indicating that college premiums for recent graduates decreased for almost all industries after 2005. The numbers in the last column, which are the changes in the college experience premiums per year, are positive for almost all industries with the only exception of agriculture, indicating that the age-earnings profiles shifted steeper for the college graduates after 2005.

2.1.7 Wage Profiles by Major

Here I analyze the wage profiles of graduates of different majors to examine if the shift of earnings profiles is across all majors. In the data set, each applicant chooses a major for the colleges attended, and I will use the major of the last college attended. I will compare engineering graduates with non-engineering graduates. In the dataset, there are about 10% to 15% of the applicants majoring in an engineering field.

Figure 2.11 shows the earnings profiles for four groups: the old engineering graduates (those born before 7/1/1982), the old non-engineering graduates, the young engineering graduates, and the young non-engineering graduates. As shown in the figure, for the older cohorts, the wage profile of the engineering graduates is slightly steeper than the non-engineering graduates. Both profiles shifted much steeper for both the younger cohorts, and both younger cohorts earn significantly less than the older cohorts at experience zero. Therefore the pattern of shifting of age-earnings profiles is similar for the engineering majors.

I further classified the majors into the following categories, the engineering major, the econ/business major, the computer/internet major, and all other majors. I ran the wage regressions separately for each category. Table 2.1.7 shows the result. As shown in the table, the coefficients on YoungC are all negative, indicating the wages at experience zero have decreased for all majors. Also, the coefficients on YoungC*Exp are all positive, indicating the slopes of age-earnings profiles have shifted steeper for the younger cohorts. Therefore, the patterns of the shift are similar across all majors.

2.1.8 Comparing to the Simulation Results

Figure 2.12 shows the evolution of college premium for the young and old graduates. The college wage premium for the young graduates actually since 2005, while the college wage premium for the old graduates continued to increase. This pattern matches the simulation result well as shown in figure 2.13.

Table 2.5: Wage Regressions by Industry. (Dep Var:Log Wage)

Code	Industry	C_i	$E_i * C_i$	$Y_i * C_i$	$Y_i * C_i * E_i$	Obs
1	Real Estate	-0.06	0.05	-0.18	0.22	32537
2	Financial	-0.24	0.07	-0.09	0.02	10080
3	Telecom	0.03	0.05	-0.28	0.05	12221
4	Oil	0.01	0.04	-0.24	0.04	6795
5	Auto	0.14	0.02	-0.37	0.05	12126
6	Electronics	0.08	0.04	-0.17	0.02	14354
7	Manufacturing	-0.08	0.03	-0.11	0.01	19374
8	Software	0.09	0.07	-0.17	0.04	10328
9	Biz Service	0.18	0.03	-0.44	0.09	4598
10	IT Service	-0.03	0.06	-0.13	0.02	6903
11	Consumer(non-dura)	-0.05	0.04	-0.20	0.04	23686
12	Equipment	-0.11	0.05	-0.06	0.00	9753
13	Consumer(durables)	-0.00	0.04	-0.20	0.04	17808
14	Pharm/Biotech	0.00	0.03	-0.21	0.02	12629
15	Comp. Hardware	-0.09	0.05	-0.16	0.08	10328
16	Mining	-0.02	0.04	-0.10	0.01	2852
17	Internet	0.26	0.02	-0.30	0.03	8074
18	Trading	0.07	0.02	-0.22	0.02	10362
19	Transportation	0.00	0.03	-0.24	0.04	10098
20	Multi-industry	0.03	0.06	-0.36	0.04	1983
21	Ind. Instrument	-0.12	0.05	-0.07	0.01	4737
22	Retail	-0.11	-0.0	-0.16	0.03	15382
23	Media	0.19	0.01	-0.59	0.10	8698
24	Education	-0.09	0.03	-0.12	0.03	14458
25	Power	-0.16	0.07	-0.08	0.03	3886
26	Government	-0.06	0.03	-0.34	0.04	4412
27	PR and Adver	0.20	0.02	-0.49	0.08	8426
28	Insurance	-0.27	0.06	-0.08	0.05	4380
29	Hotel/Restaurant	0.02	0.02	-0.32	0.04	15888
30	Medical	-0.16	0.04	-0.18	0.01	5965
31	Research	0.05	0.02	-0.38	0.14	795
32	Med. Equip.	-0.08	0.05	-0.12	0.03	3235
33	Environment	-0.08	0.07	-0.23	0.03	2007
34	Interm. Service	-0.36	0.07	-0.04	0.00	3663
35	Airline	-0.12	0.05	-0.07	0.04	1108
36	Print/Paper	-0.01	0.04	-0.23	0.03	3738
37	Agriculture	-0.14	0.05	0.02	-0.05	2286
38	Property Mgt	-0.01	0.04	-0.14	0.00	5251
39	Ent/Sports	0.06	0.03	-0.21	0.04	3187
40	Tourism	0.04	-0.02	-0.42	0.15	3035

Note: Dummy variable Y_i is 1 for workers born after 7/1/1982.
Dummy variable C_i is 1 for college graduates, E_i is age-22.

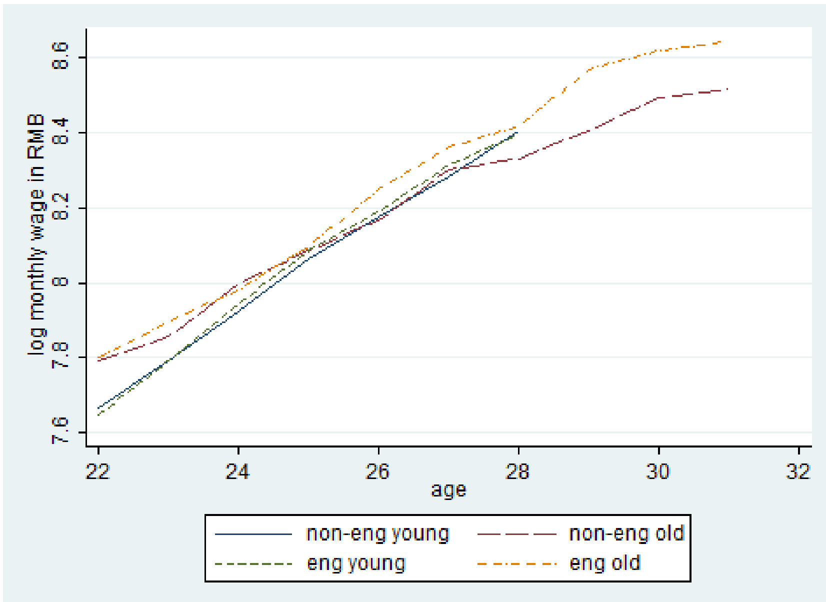


Figure 2.11: Earnings profile for engineering and non-engineering graduates

note: young are those born after 7/1/1982

Table 2.6: Wage Regressions by major. (Dep Var:Log Wage)

Major	Engineering	Econ/Business	Comp/Internet	Other Majors
Constant	7.5	7.6	7.4	7.5
Exp	0.13	0.09	0.14	0.08
Exp^2	-0.003	-0.001	-0.004	-0.001
$YoungC$	-0.18	-0.24	-0.07	-0.19
$YoungC * Exp$	0.08	0.09	0.06	0.08
$YoungC * Exp^2$	-0.008	-0.005	-0.008	-0.008
N	22098	77714	36073	240920
R Square	0.27	0.21	0.19	0.19

Note: dummy variable YoungC is set to 1 for those born after 7/1/1982
Exp is age-22

Figure 2.12: College Premium from Data

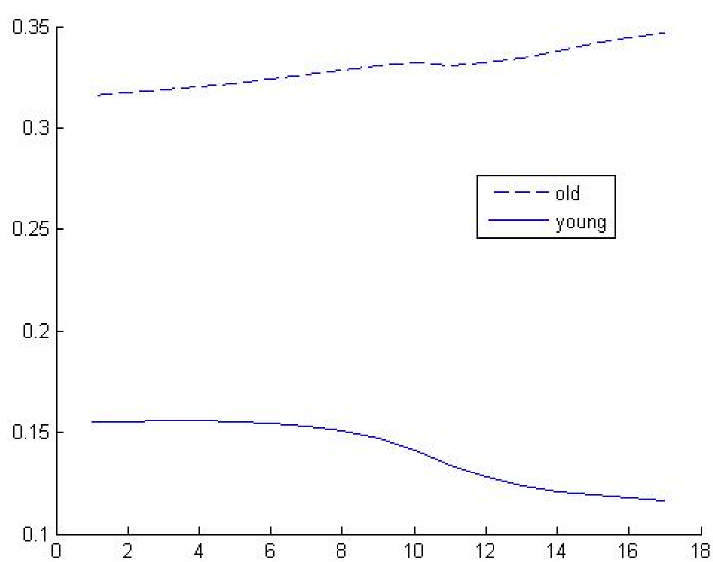


Figure 2.13: College Premium from Model

2.1.9 Potential Selection Bias

The sample consists of young and middle-aged urban workers who are by no means representative of the whole Chinese population. First, unskilled migrant workers, usually with an education even lower than high school, are not in the sample. Second, the people in the sample are more educated than the general urban population; almost everybody (98%) is a high school or a college graduate. Further more, high school graduates are under-represented in the sample, which could be because high school graduates are less inclined to use the Internet for job searches. If only the high-ability high school graduates are using the Internet for job search, the high school graduates in the sample are likely to be positively selected in terms of ability. Therefore, wages for non-graduates in the sample are probably higher than those of the general population, and the college premium estimated here is a lower bound for the college wage premium for the general population. In this light, the empirical exercise this dataset supports is actually that of comparing the wages of the young graduates to the wages of relatively high-ability young urban non-graduates. Although the college premium is estimated from a subset of the population, the time pattern of college premium, particularly the divergence in college premium between the young and the experienced remain indicative of the overall college premium trend.

In further consideration of the issue of sample selection, I checked the college premium findings against data from the Urban Household Income and Expenditure Survey (UHIES). The UHIES survey is conducted by China National Statistics Bureau for the purpose of monitoring income and expenditure changes. The survey uses a diary record to collect individual earnings, other forms of income, household income and expenditure related data. It only includes those households whose household registrations (Hukou) are located in urban areas, so it does not include college graduates with rural backgrounds who work in cities after graduation, and it does not include migrant workers. There was a change in the survey method in 2002, so comparing data before 2002 to data after 2002 is not possible; currently only data before 2006 is available. Given that only 5 years of the data are available, I can not do synthetic cohort analysis, and am limited to cross-sectional analysis. Figure 2.14 shows the college premium trend pattern for young and experienced graduates. Similar to the

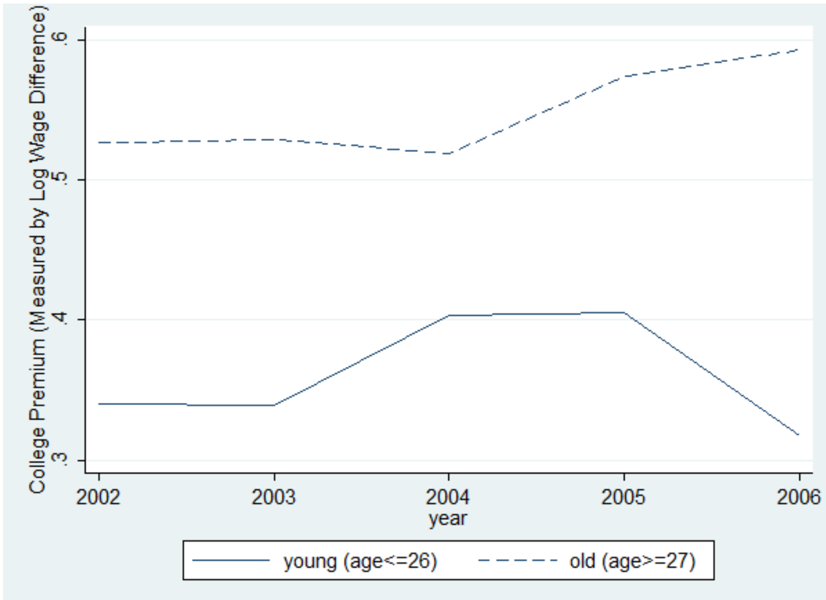


Figure 2.14: College Premiums from the Survey Data

findings from the resume dataset, the cross-sectional college wage premium started to diverge in 2005 and 2006.

2.2 Evidence from Other Rapidly Developing Countries

In this section, I will discuss evidence from other rapidly developing countries. Similar to what happened in China, I expect when something (such as a surge in FDI or exports) triggers a large increase in the demand for skill, in the medium run (i.e. 5 to 10 years), the college premium for the young graduates will decrease while the college premium for the old is still increasing. I will examine all the large economies that experienced rapid industrialization in the last 30 years. There are 4 large economies (with over 20 million in population) that achieved an annual growth rate over 7% during the period. They are Korea, Taiwan, Malaysia, and Thailand. India's growth rate was only 5-6% before 2003, and accelerated to around 9% only after 2004. I will also discuss the India case separately.

I searched for all the papers that reported the college wage premium by experience and education in these countries. The following is the list of papers I found:

- Taiwan
  - Baraka (1999)
- Korea
  - Kwark and Rhee (1993)
  - Choi and Jeong (2003)
- Malaysia
  - No relevant study is found
- Thailand
  - Mehta et al. (2007)

I will summarize the relevant findings on wage premium from these papers. I will also present the college enrollment and GDP growth data in relevant periods in these economies.

Figure 2.15 shows the growth of GDP per capita in the four economies (Korea, Taiwan, Thailand, and China). Figure 2.16 shows the growth of college enrollment rate in these four countries in the relevant periods. The small triangles on the curves indicate the points where these economies are at a similar stage of development as China in the late 1990s when GDP per capita reached around $3000 USD, and the demand for skill started to rise rapidly. In Korea and Taiwan, after the initial stage of moving from agriculture to labor-intensive industries in the 60s, both economies started to push into exported-oriented knowledge-intensive and capital-intensive industries. Meanwhile, Korean and Taiwanese governments adopted policies to actively promote the development of these industries such as building high-tech parks and subsidizing private R&D. With the successful development of these high value-added industries, both economies continued to grow rapidly throughout the 80s, as a result, the demand

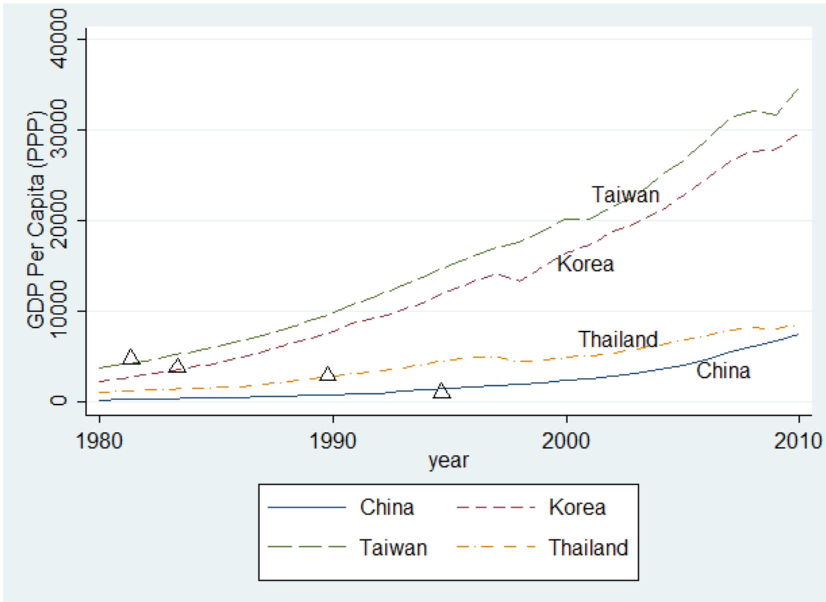


Figure 2.15: Growth of GDP per capita PPP

for skill rose rapidly and so did the college enrollment rate. The case of Thailand is similar, only with a starting point about 15 years behind Korea, and about 5 years ahead of China. In the 80s and early 90s, Thailand moved away from labor intensive industries into high value-added industries, with a rapid growth in FDI, export, and per capita GDP. Similarly, the increase in demand for skill triggered a large increase in college enrollment rate in Thailand in the late 1990s. The college enrollment rates of these four countries started to rise rapidly at about the same stage of development when GDP per capita grew from around \$3000 to \$5000 USD.

Figures 2.17, 2.18, and 2.19 show the college wage premium for the young and the old. In all three countries, the college premium for the young declined as the college premium for the old rose. Compared to China, the magnitude of divergence in college premiums was smaller, because the economy and the enrollment in the three countries did not grow as fast as in China in the relevant periods.

In one of the papers, Mehta et al. (2007) also examined the college wage premium in India. From 1993 to 2004, the college wage premium for both the young and the old increased by about 10%, so there was no divergence of college wage premiums

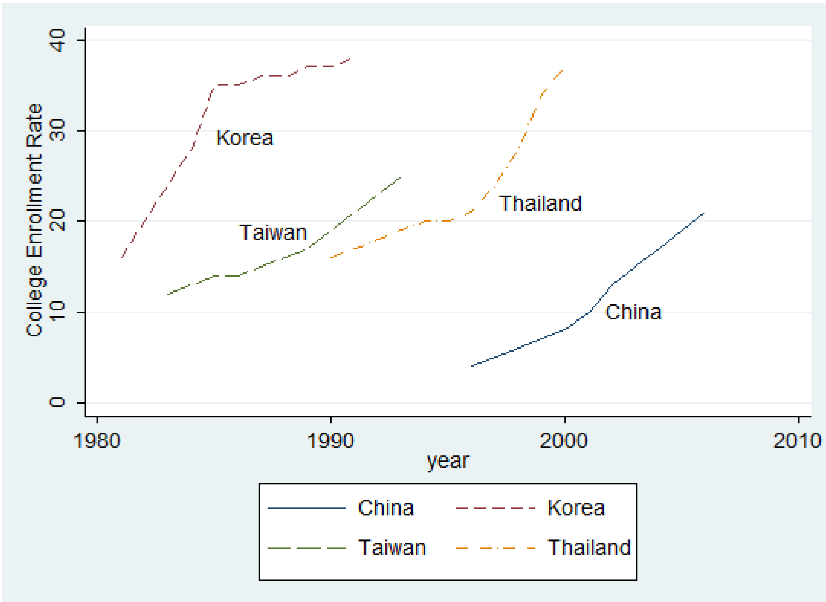


Figure 2.16: Growth of Enrollment Rate in %

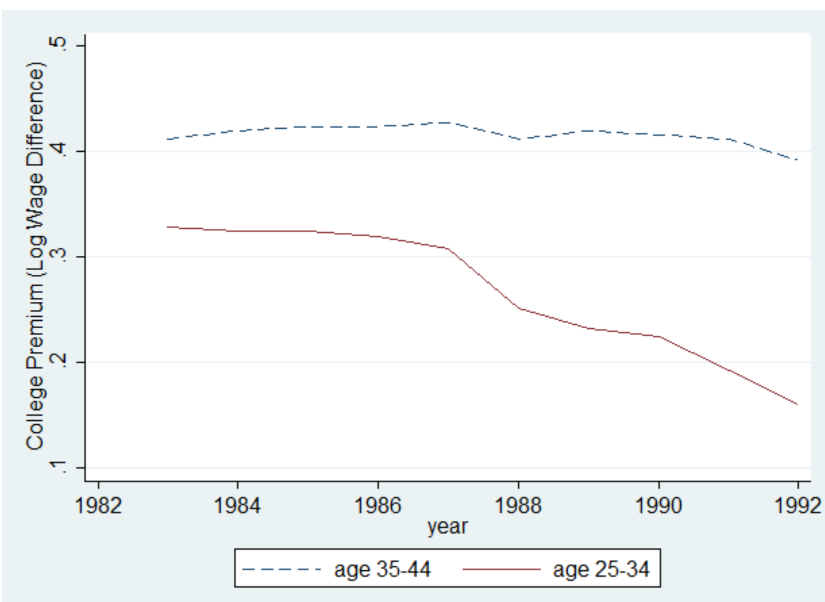


Figure 2.17: College Wage Premium (Young vs. Old) in Korea

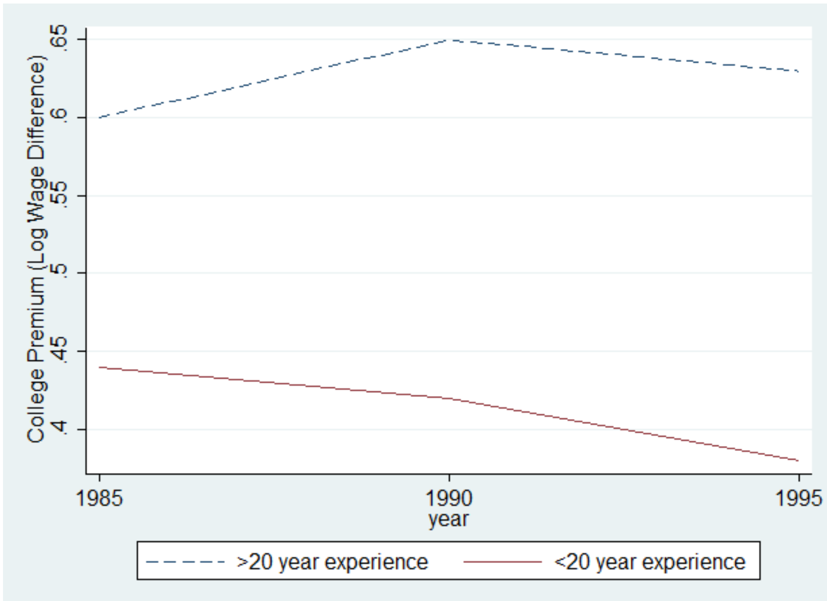


Figure 2.18: College Wage Premium (Young vs. Old) in Taiwan

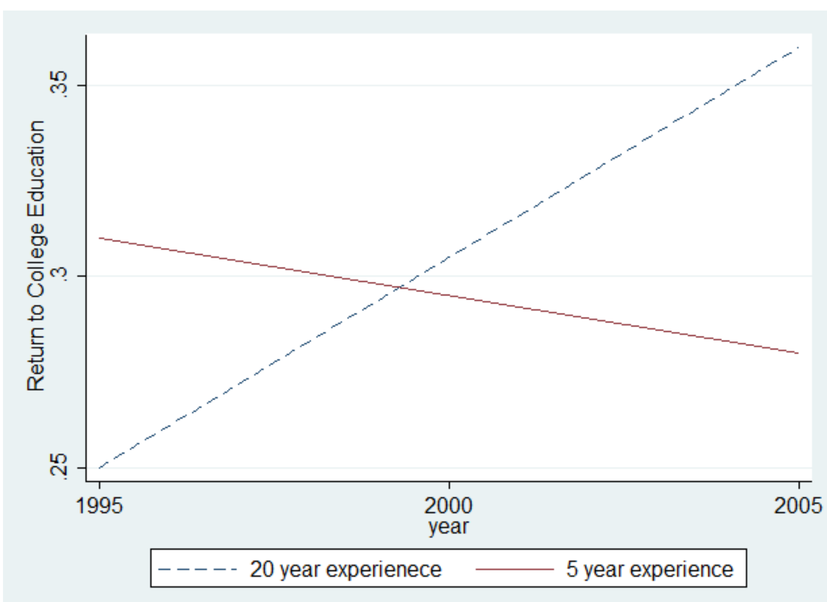


Figure 2.19: College Wage Premium (Young vs. Old) in Thailand

in India at least until 2004. I did not find any more recent studies on Indian wage structure. India started economic liberation in early 1990s, and GDP per capita grew at 5-6% annually from 1994 to 2003, which is still significantly slower than the four rapidly developing countries in almost all periods. [5] College enrollment rate in India grew even more slowly, by only 6 percentage points (from 6% to 12%) in the last 20 years. In contrast, the four countries increased their college enrollment rate by at least 13 percentage points in just 10 years. Therefore, it is not surprising that we did not observe a decline of college wage premium for young graduates in India yet. However, in the later half of 2000s, India's economy picked up speed, attaining an annual growth rate of over 9%, and by 2010 India's GDP per capita PPP reached $3000, the same level of China in 1990s, so in the near future, the familar pattern might emerge. The rising demand for skill could trigger a rapid increase in college enrollment, and the college premium for the young could decline.

2.3 Summary

In this chapter, using a unique China dataset, I found the predictions of theory are consistent with the recent wage data for China's labor market. Further, I also found supporting evidence from several other rapidly developing countries in the last 30 years.

[5] Thailand was growing at 10% before the Asian crisis, but slowed down afterwards

Chapter 3

Human Capital and Trade

3.1 Introduction

Standard trade theory predicts when a low skill country trades with a high skill country, the returns to skill in the low-skill country would decrease. This is the result of the classical Heckser-Ohlin model: the price for the relative scarce factor (i.e. high-skill workers) will decrease in the low-skill country after trading with the high-skill country. However, in reality, the opposite usually occurs. Many countries see their returns to education increase after trade liberation, and subsequently experience a rapid increase in college enrollment and human capital development. Gradually, the workforce in the developing country becomes better educated and more productive, generating a virtuous cycle of economic development.

China is a case in point. Before the economic reform in 1978, China was a very closed economy and all foreign trade had to be conducted through a handful of state-owned trading companies (Naughton (2006)). Before 1978, China's total export-to-GDP ratio was only about 5%, which was far below the world average. In the next 15 years, China rapidly opened up to the world. Many institutional barriers to trade were removed. Meanwhile, price and foreign exchange control were gradually lifted. Special Economic Zones (SEZ) were set up in coastal cities to make it easier for firms to engage in foreign trade. As a result, trade grew rapidly, at a rate much faster than the overall GDP growth. By 1993, both imports and exports ratio to GDP

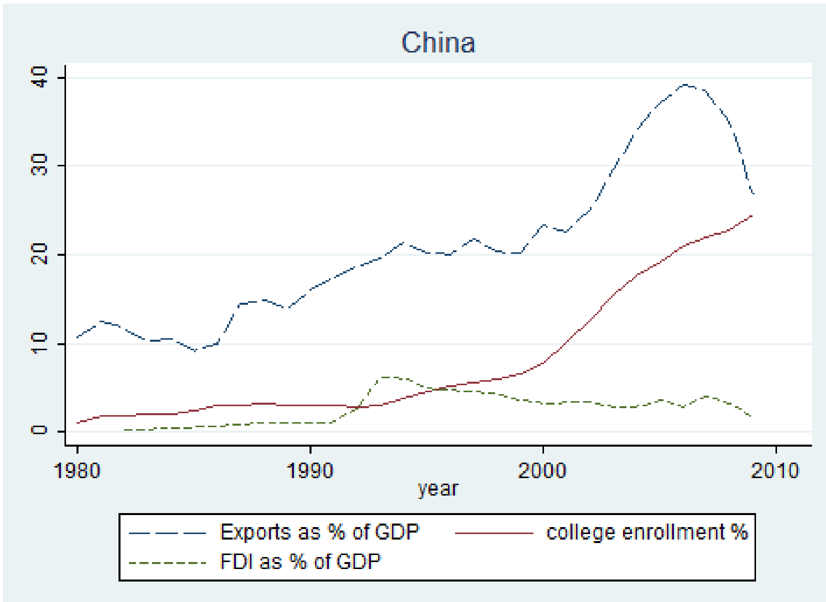


Figure 3.1:

exceeded 20%, making China one of the most open large economies in the world. Foreign companies played a major role in China's trade boom. Foreign directed investment increased rapidly from almost nothing to 5% of GDP in 1995, and by late 1990s, foreign companies accounted for more than half of all exports, and the share of foreign content in China's exports is at about 50% (Koopman et al. (2008)).

In the early years of opening up, the exporting firms were typically making labor intensive products such as clothing and toys. Most of the management, design and marketing were done by expatriates or outside of the country, and key high-tech components were imported. However, gradually, more of the high-value added activities were done locally often with the help of imported equipments and under the guidance of expatriates. Over time, these exporting firms hired more high-skill local workers and paid higher wages for education and experience (Zhao (2001)). In doing so, they significantly raised the return to human capital and thereby greatly influenced the development of the human capital in China. The return to education started to rise rapidly in the 1990s, from 5% in 1993 to 10% in 1999. College enrollment increased from about 1 million a year in 1995 to more than 4 million a year in 2005. Even with such a big increase in supply of college graduates, the return to college education remained high. The wages for young graduates declined, but they were still able to earn high returns for education later in their career. Some of them became entrepreneurs, inventors, and executives who spawned local high-tech firms to compete in the world market. In recent years, successful local firms such as Huawei have become big hirers of college graduates.

Historically, almost all the new technologies were invented in developed countries. This is partly because the developed countries have a much better educated workforce. Further, applying these new technologies typically demands a more educated workforce. Some of the recent technological inventions, such as information technology, are particularly skill-biased (SBTC). By trading with these rich countries, a developing country can learn to adopt these technologies and become more skill-intensive. There are many channels through which a developing country can increase the return to skill by trading with a rich country. The following is a short list:

- Local firms use imported high-tech components in the final product. Integrating the high-tech components in the final product typically demands more skills from the local workers.
- Local firms use imported high-tech equipments which typically require high-skill workers to operate.
- To meet the requirements of the customers in the rich countries, the exporting firms need to hire foreign designers, marketers, consultants, etc. To work with and learn from these high-skill foreign workers, local workers must also be highly educated.
- In an FDI arrangement, the expatriate managers and engineers train the local managers and engineers who need to be also highly educated.

In this paper, we will develop a simple trade model with the following features:

- The return to education may increase after trading more with high-skill foreign country. In other words, foreign high skills are complementary to local high skills.

- An increase in return to skill will trigger an increase in human capital development, creating a more educated workforce over time.
- In the medium run, the age-earnings profile steepens.
- The market share of tradables for the developing country will expand over time
- High skill foreign workers initially benefit a lot but not so much in the long run.

3.2 Related Literature

The following is a list of related theory papers on the topic of trade and human capital:

- Dornbusch et al. (1977) built a classical trade model of comparative advantage with a continuum of goods.
- Antras et al. (2006) built a model of offshoring and generated the result that after trading with the high-skill northern country, the southern workers' skill premium will increase because they are matched with better northern managers. However, the model cannot explain the empirical fact that southern managers usually also do better relatively after trade liberation.
- Yeaple (2005) built a model of trade with heterogeneous workers, and generated the result that after trade liberation, the moderately skill workers will do worse relative to the highly skilled and low skilled. This model explains the rising inequality in the developed country, but cannot explained the rising return to skill of the moderated skilled workers in the developing country.
- Zhu and Trefler (2005) analyzed a trade model with exogenous technology changes both in the developing country and in the developed country. Their model predicts that the skill premium can increase if the technology progress in the developing country is faster than in the developed country.

The following is a list of empirical papers on the topic of trade and human capital:

- Zhao (2001) found that foreign direct investment contributed significantly to the recent rise in the return to skill in China.
- Kwark and Rhee (1993) found return to college increased rapidly in Korea in the 1980s after the trade boom.
- Oostendorp and Quang (2011) examined the recent rise of return to skill in Vietnam after trade liberalization.
- Outside of Asia, there are many papers that have documented an increase in return to skill after trade liberation in Latin American countries such as Chile (Beyer et al. (1999)), Mexico (Hanson and Harrison (1999)), Brazil (Green et al. (2000)), Argentina (Bustos (2006)), and Eastern Europe countries such as Slovakia and Czech Republic (Chase (1997)).
- Amiti and Konings (2007) found a 10% point reduction in input tariffs leads to a 3% productivity gain for manufacturing firms in Indonesia.
- Acemoglu (2002) found that recent rising return to skills in the U.S. is primarily due to skill-biased technology change.

3.3 Theoretical Analysis

3.3.1 Model Setup

There are three types of workers: L low-skill worker, M local high-skill worker (later referred as medium-skill), and H foreign high-skill worker. The location of different types of workers can be arbitrary, but to begin our analysis, we will assume, initially, all M reside the developing country or locally, and all H reside in the developed country.

Demand system:

$$U = \beta \int log[X(j)]dF(j) + (1-\beta)logZ \tag{3.1}$$

As shown, U is a Cobb-Douglas function with two types of goods: $X(j)$ and Z. Z is a homogeneous good produced one for one by unskilled labor L.

$X(j)$ is a continuum of goods indexed by j. $X(j)$ could be either produced by H with a production $X(j) = jH_j$, or could be produced by a combination of M and H, with a production function $X(j) = Min(M_j, sH_j)$ where H_j and M_j are the amount of H and M employed. By assumption, each M must be combined with a constant s units of H. j is the productivity advantage of using all high skill workers (or high-techness of variety j), and is distributed with a c.d.f. $F(j)$.

This production function can be interpreted as foreign high-skill workers are training the local medium-skill workers in a FDI arrangement, or alternatively, imported foreign intermediatary inputs and local medium-skill workers are strong complements.

3.3.2 Solution and Comparative Statics

For each variety j, a firm faces the choice either to produce with H only, or with mostly M. The firm will produce using mostly M, iff

$$w_m + sw_h < w_h/j \tag{3.2}$$

Solving the above inequality yields $j < w_h/(w_m + sw_h) = w/(1 + sw)$, where $w \equiv w_h/w_m$, so for $j < w/(1 + sw)$, the firm will use mostly M and some H to produce the variety, and the measure of such variety is $F(w/(1 + sw))$.

Table 3.1 illustrates the trade flow of different goods between the two countries.

The wage for low skill labor is normalized $w_l = 1$. The world-wide income $Y = Mw_m + Hw_h + L$. The budget equations for M, H, and L are:

$$M(w_m + sw_h) = F(w/(1 + sw))\beta Y \tag{3.3}$$

$$(H - sM)w_h = (1 - F(w/(1 + sw)))\beta Y \tag{3.4}$$

$$L = (1 - \beta)Y \tag{3.5}$$

Table 3.1: Trade Flow

Goods	Production	Consumption	Trade
Developed Country Income $Y_f = Hw_h$			
Low Skill Good	0	$(1-\beta)Y_f$	Import
$j < w/(1+sw)$	0	$\beta F Y_f$	Import
$j > w/(1+sw)$	$(H - sM)w_h$	$(1-\beta)FY_f$	Export
Component/Trainer	sMw_h		Export
Developing Country Income $Y_e = Mw_m + L$			
Low Skill Good	L	$(1-\beta)Y_e$	Export
$j < w/(1+sw)$	$M(w_m + sw_h)$	$\beta F Y_e$	Export
$j > w/(1+sw)$	0	$(1-\beta)FY_e$	Import
Component/Trainer	0	sMw_h	Import

Divide the first equation by the second:

$$\frac{M(1/w+s)}{H-sM} = \frac{F(w/(1+sw))}{1-F(w/(1+sw))} \tag{3.6}$$

Proposition 1: Given M, H, s, and $F()$, the above equation has a unique solution w.

Proof: In Appendix.

Proposition 2: w decreases in H, w increases in M, and w decreases in s.

Proof: In Appendix.

Proposition 2 states, quite intuitively, w (i.e. the foreign wage skill premium) decreases in the supply of foreign skills, increases in the supply of local skills, and decreases in s.

With w, we can solve the analytical expression for w_h and w_m. Using the third budget equation, we have $Y = L/(1+\beta)$. Using the second budget equation, we can solve w_h,

$$w_h = \beta/(1-\beta)L\frac{1-F(w/(1+sw))}{H-sM} \tag{3.7}$$

Once we have w_h, we can solve w_m using the first budget equation,

$$w_m = \beta/(1-\beta)L\frac{F(w/(1+sw))}{M} - s\beta/(1-\beta)L\frac{1-F(w/(1+sw))}{H-sM} \tag{3.8}$$

We will examine the comparative statics of w_m and w_h (i.e. return to skill in the developing and developed country), when there is more M or H.

When H increases

Proposition 3 when H goes up, w_h goes down.

Proof: in Appendix

This is intuitive, that when the supply of foreign skill increases, the return to foreign skills will go down.

However, the effect of more H on w_m i.e. the returns to skill in the developing country is ambiguous, and under certain conditions w_m can go up. This is the interesting situation that returns to skill will increase in the developing country after trading with a high-skill country.

To analyze the effect of more H on w_m, first we consider the special case of $s = 0$, which is equivalent to the traditional comparative advantage trade model. When H increases, we already know that $w \equiv w_m/w_h$ decreases, (i.e. the local medium skill is becoming more expensive relative to foreign high skill), so the market share of tradable goods $F(w/(1+sw))$ decreases. From the analytical solution for w_m, with $s = 0$, w_m will decrease, i.e. return to education will go down. This is the same result from the standard DFS model.

Now we consider the general case of $s > 0$.

Proposition 4 When $F()$ is sufficiently inelastic, w_m will go up as H goes up.

Proof: In Appendix.

There are two effects of trading with the high skill country, the first effect is the displacement effect, i.e. more H will reduce w_h which will make the foreign high-skill workers more competitive thus taking more market share away from local M. But there is a second training effect, with cheaper foreign high-skill workers as trainers (or cheaper foreign inputs), the local workers are more productive, and therefore, w_m

is higher. When the market share $F()$ is inelastic, the trainer effect dominates the displacement effect, so w_m is higher, i.e. the return to education in the developing country will go up after trading with foreign country.

This is evident from the expression $w_m = \beta/(1-\beta)L\frac{F(w/(1+sw))}{M} - sw_h$, the first term is the displacement effect, i.e. the market share of the developing country will decrease with a lower w. The second term is training effect. As we know w_h will decrease by proposition 3, $-sw_h$ will increase. The training effect can dominate when the displace effect is not large. Typically, when a poor country just starts to open up, the market share of high-skill tradables is usually very low, so there would not be much displacement effect, therefore, the effect on w_m is likely to be positive.

When M increases

Proposition 5 When M increases, w_m will go down.

Proof: In Appendix.

Proposition 3 states, quite intuitively, that when the supply of M increases, the wage for M, w_m will down; but w_h can go either ways.

Proposition 6 When M increases, and $F()$ is sufficiently inelastic, w_h will go up.

Proof in Appendix.

From the expression $w_h = \beta/(1-\beta)L\frac{1-F(w/(1+sw))}{H-sM}$, we can see there are two effects of more M. First, $1 - F(w/(1+sw)$ i.e. the market share for H, tends to decrease as more M raises w, which is the displacement effect. Second, in the denominator, $H - sM$ will decrease with more M. In other words, more M increases the demand for H, thus raises w_h. So the overall effect is ambiguous, and when $F()$ is inelastic, the trainer effect dominates and w_h will increase.

Trade liberation from the developed country's point of view is equivalent to having more M, so this proposition states that when the developed country can still keep the market share stable, it will benefit from trade liberation by enjoying a higher w_h, as more M increases the demand for trainers H. This is typically the case in the short term, when the technology gap is rather large, and the developing country has yet built up its own high-skill workforce.

3.3.3 The Effect of Tariffs

A Tariff on All Imports

Now, the developing country imposes an ad valorem tariff d on all imports. For simplicity, we will just do a partial equilibrium analysis by assuming w_h is given and fixed. Also, for simplicity, also assume all the tariff collected are spent by the government on L goods. [1].

For each variety j in the developing country, a firm will face the choice of either producing locally with mostly M or importing from the developed country. It will produce locally using mostly M, iff

$$w_m + sw_h d < dw_h/j \tag{3.9}$$

Solving the above inequality yields $j < dw_h/(w_m + sdw_h)$. So the market share of the local firm in the local market as a function of w_m and d is $E_l(w_m, d) \equiv F(w_h d/(w_m + sdw_h))$. Notice $E_l()$ is increasing in d, as the tariff makes the local firms more competitive in the local market.

For each variety j in the developed country, a firm will face the choice of either producing locally or importing from the developing country. It will import, iff

$$w_m + sw_h d < w_h/j \tag{3.10}$$

Solving the above inequality yields $j < w_h/(w_m + sdw_h)$, So the market share of the local firm in the export market as a function of w_m and d is $E_x(w_m, d) \equiv F(w_h/(w_m + sdw_h))$. Notice $E_x()$ is decreasing in d, as the tariff makes the local firms less competitive in the foreign market because the components are more expensive.

Now the total budget equation for the medium-tech goods is:

$$M(w_m + sdw_h) = \beta[E_x(w_m, d)Hw_h + E_l(w_m, d)(Mw_m + L)] \tag{3.11}$$

[1] alternatively, we can assume there is a non-tariff barrier that incurs an iceberg cost of $d - 1$ on all imports

We can solve for w_m

$$w_m = \frac{\beta[E_x(w_m, d)Hw_h + E_l(w_m, d)L]}{M(1 - \beta E_l(w_m, d))} - sdw_h \tag{3.12}$$

This equation uniquely solves w_m, because the left-hand side is increasing in w_m, and the right-hand side is decreasing in w_m. Also evident from the equation, there are three effects of increasing tariff d. The first effect is the local market share effect. Increasing d will raise the local market share by increasing $E_l(w_m, d) \equiv F(dw_h/(w_m + sdw_h))$. The second effect is the export market share effect. Increasing d will reduce the export market share by decreasing $E_x(w_m, d) \equiv F(w_h/(w_m + sdw_h))$ as the trainers becomes more expensive. When the export market is big relative to the local market, the second effect tends to dominate the first effect. The third effect is the trainer effect. Increasing d will decrease the last term in the equation $-dw_h$, which tends to reduce w_m. When $F()$ is inelastic, the market shares change little and the third effect dominates i.e. w_m, the returns on education will decrease. Thus, the effect of increasing tariff is very similar to reducing H, the trainer effect could dominate and lower the return to education.

A Tariff only on Final Products

Now let's consider the case where the developing country only tax the final product, but not the components or trainers. For each variety j in the developing country, a firm will face the choice of either producing locally with mostly M or importing from the developed country. It will produce locally using mostly M, iff

$$w_m + sw_h < dw_h/j \tag{3.13}$$

Solving the above inequality yields $j < dw_h/(w_m + sw_h)$. So the market share of the local firm in the local market as a function of w_m and d is $E_l(w_m, d) \equiv F(w_h d/(w_m + sw_h))$. Notice $E_l()$ is increasing in d, as the tariff makes the local firms more competitive in the local market.

For each variety j in the developed country, a firm will face the choice of either producing locally or importing from the developing country. It will import, iff

$$w_m + sw_h < w_h/j \tag{3.14}$$

Solving the above inequality yields $j < w_h/(w_m + sw_h)$, So the market share of the local firm in the export market as a function of w_m and d is $E_x(w_m, d) \equiv F(w_h/(w_m + sw_h))$. Notice $E_d()$ does not change with d, as a tariff on final imported products does not impact the export competitiveness.

Now the total budget equation for the medium-tech goods is:

$$M(w_m + sw_h) = \beta[E_x(w_m, d)Hw_h + E_l(w_m, d)(Mw_m + L)] \tag{3.15}$$

We can solve for w_m

$$w_m = \frac{\beta[E_x(w_m, d)Hw_h + E_l(w_m, d)L]}{M(1 - \beta E_l(w_m, d))} - sw_h \tag{3.16}$$

Evident from the equation, the tariff on final products raises E_x, and has no impact on E_l, therefore raises w_m. Most countries do in fact offer tariff exemption for intermediate inputs. However, in reailty, the practice of justing taxing the final products has many drawbacks. First, Sometimes it is difficult to distinguish between intermediate inputs and final products. Computers are both final consumer products and key inputs to productive workforce. Even a tariff on high-qualify imported food may increase the cost of living for foreign expatriates. Moreover, raising tariff often invites retaliation from foreign countries, which will reduce the market share of the local exporters.

For the rest of the paper, we will assume free trade i.e. $d = 1$.

3.3.4 Endogenizing M and H

Setup

For simplicity, we assume in the developed country, the supply of high skill workers i.e. H is fixed. We will allow the supply of M to accumulate as the developing country starts to put more people into college in response to a higher return to education.

At each period, there is $1-\mu$ potential new workers. A worker can either go to college and become an M after 4 years, or not go to college and become a L for the rest of the career. To model a worker's decision to get a college education, I assume different workers have different costs to obtain a college education, and a worker will obtain an education if the reward is greater than the cost. The supply function $G(v)$ denotes the number of workers who will get a college education as a function of v. v is the expected life-time wage premium net the common cost of education (denoted by C) which includes tuition, etc. The supply curve can be generated by the assumption that different workers have different effort costs on the top of common cost to obtain an education (the effort cost can be interpreted as innate ability). $G(v)$ can be interpreted as the fraction of people whose effort cost of education is less than the net reward v. (Assume $G'() > 0$)

Further, we will assume that, in the long run, the developing country will have some H being trained as well. We will use H_e to denote H in the developing (emerging) country, and H_f to denote H in the developed (foreign) country. We assume, a fixed portion η of M turn into H_e each period after the initial training period of t_e. Also, in each period, $1-\mu$ workers enter and exit the labor.

For simplicity, I assume no time discounting and risk neutrality.

Steady State Equilibrium

By this set up, in the long run, the number of H_e will be proportional to M, i.e. $H_e = kM$ where $k \equiv \mu\eta/(1-\mu)$ is a constant. So the total H in the world is given by $H_f + kM$.

Before we endogenize M, we first to see how the equilibrium wages change with a given M. In the steady state, given M and $H = H_f + kM$, the following three equations characterize the equilibrium:

$$\frac{(1/w+s)}{H_f/M+(k-s)} = \frac{F(w/(1+sw))}{1-F(w/(1+sw))} \tag{3.17}$$

$$w_h = \beta/(1-\beta)L\frac{1-F(w/(1+sw))}{H+(k-s)M} \tag{3.18}$$

$$w_m = \beta/(1-\beta)L\frac{F(w/(1+sw))}{M} - s * w_h \tag{3.19}$$

Proposition 7 In the steady-state equilibrium, w increases in M.

Proof in Appendix.

Proposition 8 In the steady-state equilibrium, w_m decreases in M.

Proof in Appendix.

Proposition 9 In the steady-state equilibrium, if $k > s$, then w_h decreases as M increases

Proof in Appendix.

This is because if $k > s$, there will be more than enough H in the long run in the developing country to meet the demand of trainers, so there will be more H available in the world after netting the trainers, so w_h will go down. However, when $k < s$, w_h could go up. For example, when $k = 0$, we already proved in proposition 6, that w_h could go up, as M goes up.

Now, let's see how v changes with M, where v is the life time return to education. With this set up, after graduating from college, it is k times as likely to earn w_h as to earn w_m, so the life-time reward to education is given by $v = 1/(1+k)w_m + k/(1+k)w_h - 1 - C$. Substituting w_m and w_h with equation 3.19 and 3.18, we have the following equation for v:

$$v = \beta/(1-\beta)/(1+k)L[\frac{F(w/(1+sw))}{M} + (k-s)\frac{(1-F(w/(1+sw))}{H_f+(k-s)M}] - 1 - C \tag{3.20}$$

Even though w_h could go up, v which is a linear combination of w_m and w_h, will always decrease as M increases. The result is proven in the following proposition.

Proposition 10 In the steady state equilibrium, v decreases in M.

Proof in Appendix.

Now, we will endogenize M using the assumption that $1/(k+1)$ portion of the educated workforce will become M, with the following equation:

$$M = G(v)/(1+k) \tag{3.21}$$

Proposition 11 There is a unique steady-state equilibrium.

Proof: In the steady state, we have $M = 1/(1+k) * G(v)$. Observing this expression, the left-hand side is increasing in M, and the right-hand side is decreasing in M according to proposition 10, so there is a unique steady-state equilibrium M and v. Q.E.D.

Proposition 12 In the steady-state equilibrium, when $k < s$ and $F()$ is inelastic, v will increase in H_f.

Proof in Appendix.

Intuitively, more H_f lowers w_h, and when there is little displacement effect, w_m will go up. The return to education is a linear combination of w_m and w_h. When $k < s$, the effect of a higher w_m dominates the effect of a lower w_h, v increases. This proposition states, trade liberation will result in an increase in return to education in the long run under certain conditions.

Dynamic Equilibrium

For simplicity, let's assume before opening up, $H_e^0 = 0$, $M^0 = 0$. [2]

The only decision to model is the choice to go to college. By assumption, in each period, $(1-\mu)$ workers leave the workforce, and $(1-\mu)$ young people either join the workforce or go to college. The number of people who go to college in each period is $(1-\mu)G(v^t)$. v^t is the expected future payoff of going to college at time t amortized per period. It is given by the following expression which is a linear combination of future wages weighted by the probability of earning that wage net the unskilled wage and tuition.

[2] Alternatively, we can assume the country only have some M_g locked in the non-tradable or government sector. So, initially, $w_m^t = G^{-1}(M_g)$, given M_g is low, w_m is initially very low.

$$v^t = [w_m^{t+4} + \sum_{j=1}^{\infty} \mu^j (1-\eta)^j w_m^{t+j+4} + \sum_{j=1}^{\infty} \mu^j (1-(1-\eta)^j) w_h^{t+j+4}](1-\mu) - 1 - C \quad (3.22)$$

The above equation, together with the following 6 equations will fully characterize and solve the dynamic equilibrium: $v^t.w_m^t, w_h^t$. The next two equations model the evolution of stock of h and m workers.

$$H_e^t = \mu H_e^{t-1} + \mu\eta M^{t-t_T} \quad (3.23)$$

$$M^t = \mu M^{t-1} + (1-\mu) * G(v^{t-4}) - \mu\eta M^{t-t_T} \quad (3.24)$$

The next four equations are the per-period equilibrium conditions.

$$w_h^t = \beta/(1-\beta) L^t \frac{1 - F(w^t/(1+sw^t))}{H_f + H_e^t - sM^t} \quad (3.25)$$

$$w_m^t = \beta/(1-\beta) L^t \frac{F(w^t/(1+sw^t))}{M^t} - s\beta/(1-\beta) L \frac{1 - F(w^t/(1+sw^t))}{H_f + H_e^t - sM^t} \quad (3.26)$$

$$\frac{M^t(1/w^t + s)}{H_f + H_e^t - sM^t} = \frac{F(w^t/(1+sw^t))}{1 - F(w^t/(1+sw^t))} \quad (3.27)$$

$$L^t + M^t + H^t = 1 \quad (3.28)$$

3.3.5 Simulations

We will use the parameters as shown in table 3.3.5 for the simulation:

Figure 3.2 shows the evolution of stock of H and M in the developing country. By assumption, initially there is very few M and H. After trade liberation, an increase in the return to education triggers a large rise in college enrollment and a rapid build-up of the stock of M. After the initial training period of 10 years, some of M turn into

Symbols	Description	Value Used in Simulation
$F(w)$	Market share given $w \equiv w_h/w_m$	F(w)= 1-1/w
η	probability of m becoming h	0.02
μ	probability of staying in the workforce	0.95
k	$\mu\eta/(1-\mu)$	
$G()$	Education Supply Function	$G() \equiv 0.2$
v	lifetime return to education	
t_T	duration of training period	10
H_f	number of foreign high-skill workers	0.03
M^0	initial number of local M workers	0.03
H_e^0	initial number of H in the developing country	0

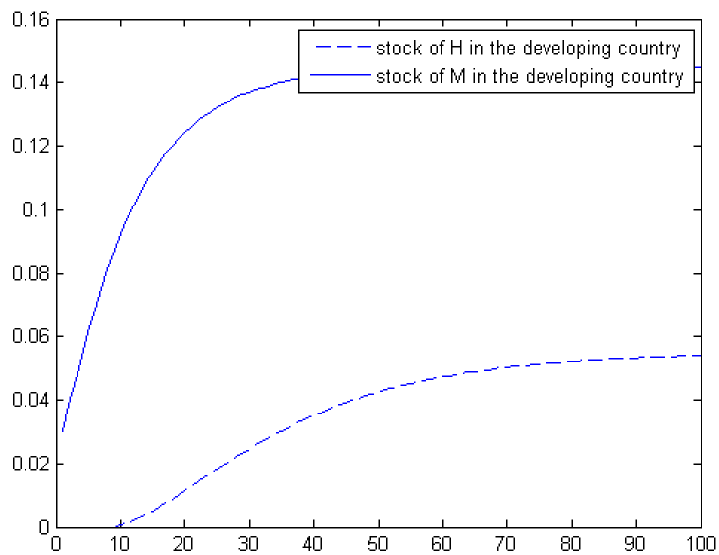


Figure 3.2:

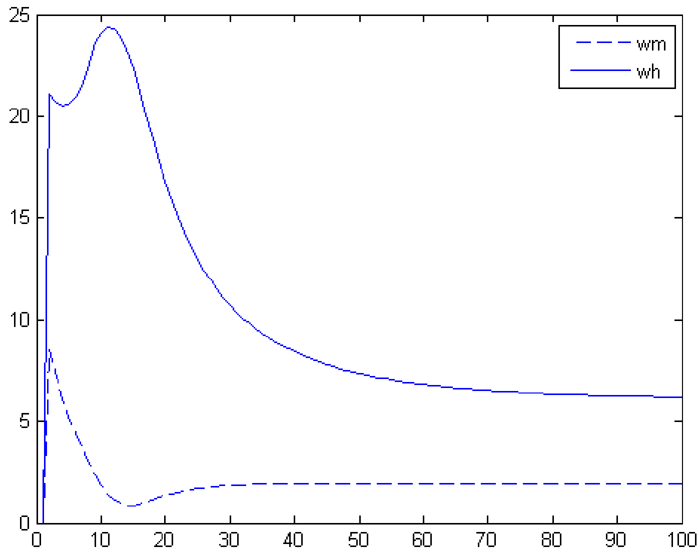
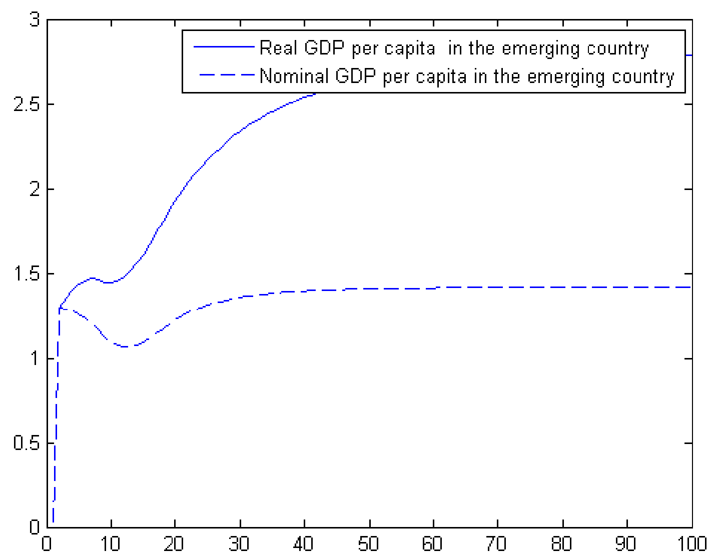


Figure 3.3:

H, and gradually accumulates to create an inventory of H in the developing country.

Figure 3.3 shows the wage paths of M and H. Immediately after trade liberation, w_m shoots up to the market value. Then, as college enrollment rate shoots up and more graduates are produced, w_m will decline quite rapidly. w_h will go up in the short run due to a higher demand for trainers generated by a larger stock of M. A higher w_h further reduces the wage for w_m, as the cost of training M is higher. So, in the medium run, there is a divergence between w_m and w_h, and as a result, the age-earnings profile is steepened in this phase. Over the long run, as more H are minted from M, the wage for w_h will decline. In contrast, w_m will recover a little bit, because it becomes relatively cheaper to train M.

Figure 3.4 shows the evolution of the GDP of the developing country. The GDP figures are shown in both nominal terms and in real terms as adjusted by the price index of the tradables. (The price index of the tradables will decline over time as w_m and w_h decrease.) After trade liberation, real GDP growth in the developing country will move up rapidly, as it starts to build up more M and captures more market share. In the medium run, the real GDP will slow down as the wage of its inexperienced



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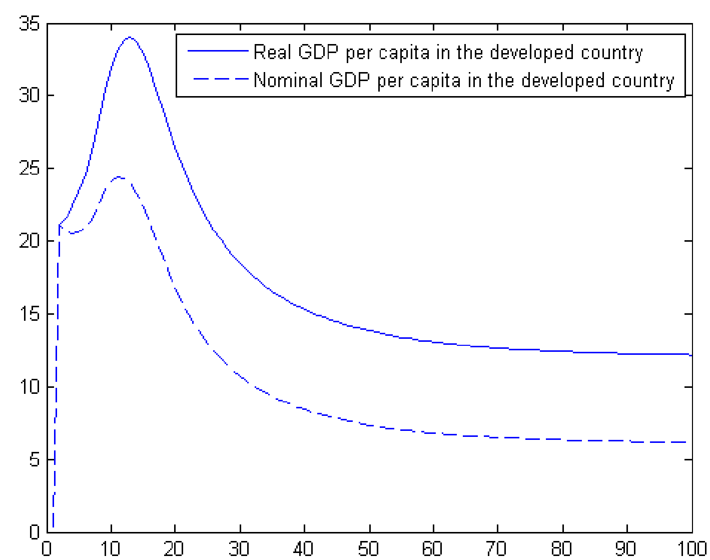

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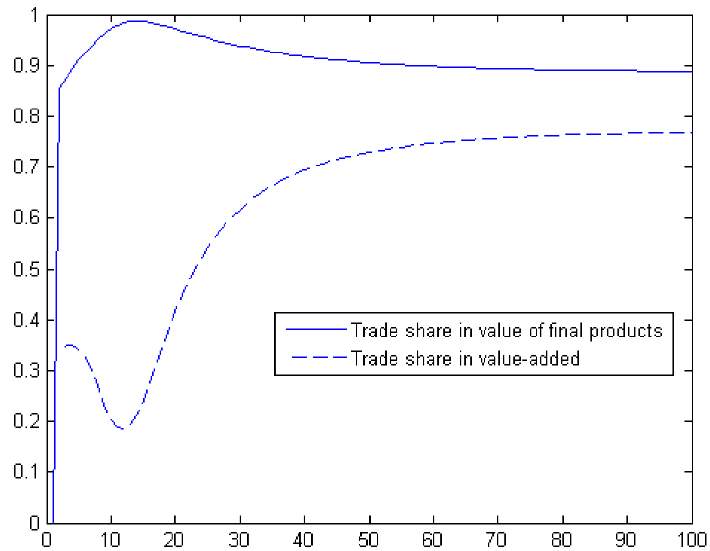


Figure 3.6: Trade Share for the developing Country

workforce goes down and the imported trainers H become quite expensive. Over the long run, the growth rate of the GDP will pick up again, as the country starts to build up its own stock of H.

Figure 3.5 shows the evolution of the GDP of the developed country. In the short run, the real GDP of the developed country will grow rapidly as it benefits from the rise of w_h. However, over the long run, as the developing country builds up its own stock of H who are competing in the market of high-tech goods, the real GDP of the developed country will decline over the long run.

Figure 3.6 shows the trade shares of the developing country. The value-added share of the tradables for the developing country initially moves up as it captures more market share, but will decline in the medium run, as the foreign input becomes more expensive. Over the long run, as it builds up its own stock of H, it will again increase its share of value-added in the tradeables. The share of final products shows a quite different pattern, it increases to a very high level in the medium run, even though at this period, the value-added share actually declines. This is the period that the developing country has a lot of M and everything seems to be made there

– although, in fact, most of the value-added are created by foreign components H. Over time, as H becomes cheaper, the developed country will actually reclaim some of the final product shares, but the overall value-added share will continue to decline.

3.4 Evidence from other developing Countries

In this section, I will discuss evidence from other developing countries. Similar to what happened in China, I expect a surge in trade will trigger a large increase in the demand for skill and college enrollment ratio. I will examine all the large developing economies that had a rapid growth in trade in recent years. Besides China, there are four large developing countries (> 20 million in population) that had a trade boom which is defined as having achieved more than 20 percentage points increase in export-to-GDP ratio from 1980 to 2008. They are Korea, Vietnam, Malaysia, and Thailand.

Korea started its trade boom in the 1970s. The export to GDP ratio grew from 13% in 1970 to 32% in 1980. The return to college education went up significantly during this period. Following the trade boom, college enrollment rate grew from 13% in 1980 to 36% in 1990. Unlike most other developing countries, foreign direct investment did not play a major role in the trade boom.

Thailand started its trade boom in the late 1980s. The export to GDP ratio grew from 20% in 1985 to 40% in 1995. In the late 1990s, there was also a boom in foreign direct investment which grew from 2% of the GDP in 1995 to a peak of 6% of GDP in 1998. Following the trade and FDI boom, the college enrollent rate grew rapidly from 20% in 1995 to 44% in 2000.

The story of Malaysia is quite similar to that of Thailand. The trade boom started in the late 1980s. The export to GDP ratio grew from 50% in 1985 to 90% in 1995. (The export-to-GDP percentages were considerably higher than those in Thailand and Korea, because Malaysia is a much smaller country in population than both Thailand and Korea). In this period, there was also a boom in foreign direct investment which grew from 2% of the GDP in 1985 to a peak of 7% of GDP in 1995. Following the trade and FDI boom, the college enrollent rate grew rapidly from 11% in 1995 to 25%

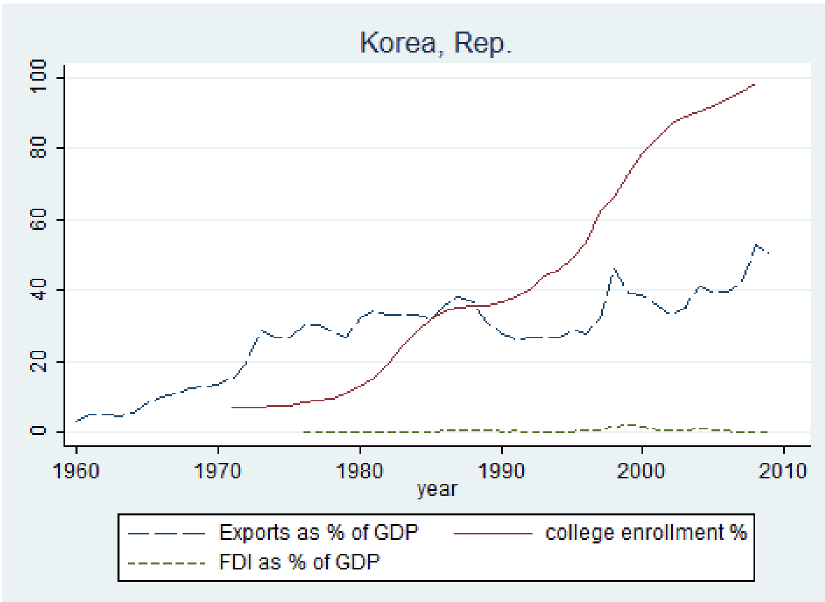
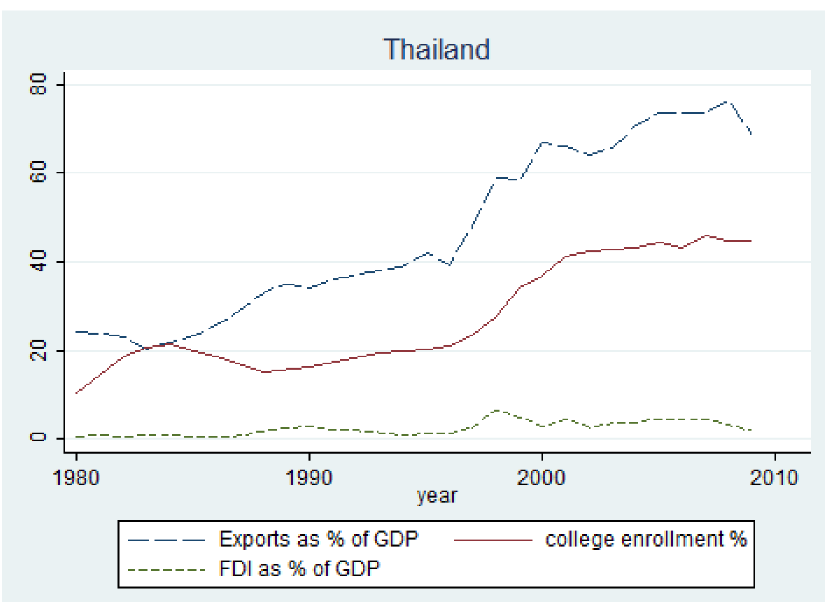


Figure 3.7:



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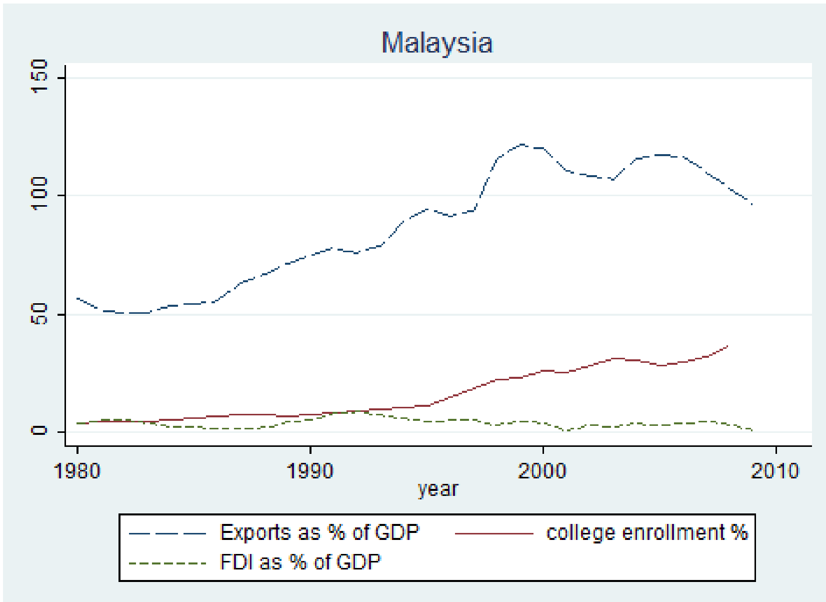

Figure 3.9:

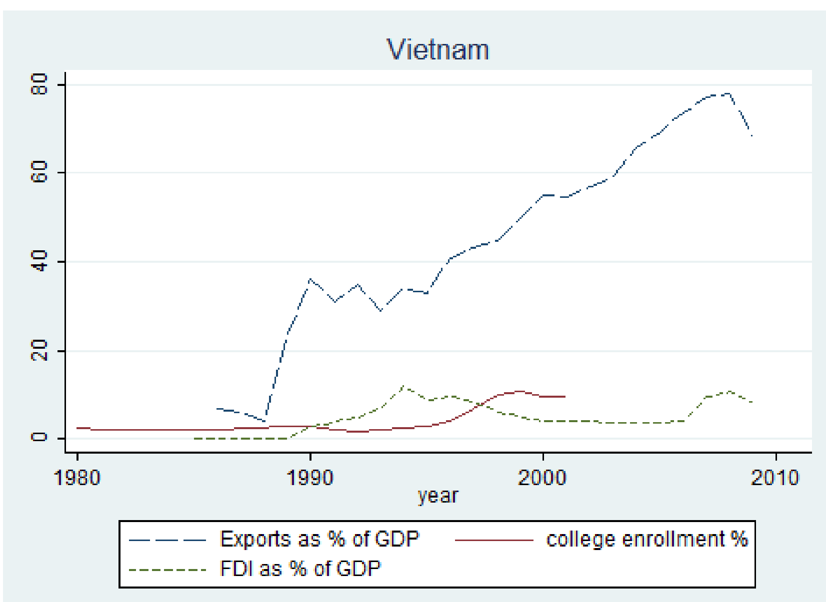

Figure 3.10:

in 2000.

Lastly, the story of Vietnam is very similar to that of China with about a 10 year delay. After the economic reform in late 1980s, exports grew rapidly from only 6% in 1986 to over 30% in 1996. Foreign direct investment grew from almost nothing in 1986 to almost 8% of its GDP in 1996. Subsequently, college enrollment rate grew rapidly since late 1990s, from less than 3% in 1995 to 10% in 2000.

In summary, in all these countries (which are all the large economies that had a trade boom in the last 30 years), the college boom occurred a few years after the trade boom. In all the countries except Korea, there was also a FDI boom before the college boom.

Let's also examine India. By our definition of a trade boom ($>$ 20 percentage increase in export-to-GDP ratio), India did not have a trade boom. But it did increase its trade significantly after the economic reform in early 1990s. After years of stagnation, its export-to-GDP ratio grew from around 10% in mid 1990s to over 20% in mid 2000. The growth rate was much slower than the other five countries, but still quite fast by historial standards. Subsequently, college enrollment rate started to increase from 6% in 1995 to about 12% in 2005. The growth rate is high by historical standards, but still much slower than the other countries that had a trade boom.

3.5 Summary

Here, we developed a model which assumes that local high-skill workers are highly complementary to foreign workers or foreign inputs. With this assumption, the model predicts that trade liberalization could induce an increase in return to education due to cheaper inputs (if the effect is bigger than the opposite effect of comparative advantage). The model has specific predictions of final goods vs. components trading dynamically. Empirically, we found a boom in trade and foreign direct investment usually precedes a boom in college enrollment.

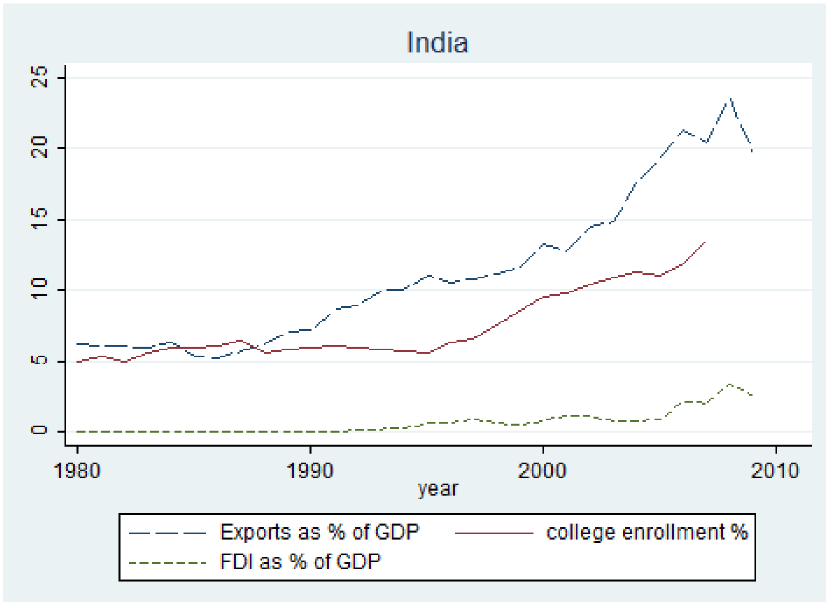

Figure 3.11:

3.6 Appendix: Proofs in this Chapter

Proposition 1: Given M, H, s, and $F()$, the equation $\frac{M(1/w+s)}{H-sM} = \frac{F(w/(1+sw))}{1-F(w/(1+sw))}$ has a unique solution w.

Proof: The left hand side is decreasing in w, and the right hand side is increasing in w, therefore there is an unique solution w. Q.E.D

Proposition 2: w decreases in H, w increases in M, and w decreases in s.

Proof: In the equation $\frac{M(1/w+s)}{H-sM} = \frac{F(w/(1+sw))}{1-F(w/(1+sw))}$, M shifts the downward curve up, therefore w will increase in M, similarly H shifts the downward curve down, therefore w decreases in H. Lastly, s shifts the upward curve down, therefore w decreases in s. Q.E.D.

Proposition 3 when H goes up, w_h goes down.

Proof: From the budget equation we have $w_h = \beta/(1-\beta) * L/(M/w + H)$, as we already know w decreases in H, so $M/w + H$ increases in H, so w_h decreases in H. Q.E.D.

Proposition 4 When $F()$ is sufficiently inelastic, w_m will go up as H goes up.

Proof: From the equation $w_m = \beta/(1-\beta)L\frac{F(w/(1+sw))}{M} - sw_h$, we know the first term is nearly unchanged, when F() is sufficiently inelastic, but we also know from the previous proposition that w_h will go down, so the combined the effect is that w_m will go up. Q.E.D.

Proposition 5 When M increases, w_m will go down.

Proof: From the budget equation, we have $w_m = \beta/(1-\beta) * L/(M + wH)$. We know w will go up, as M increases, so $M + wH$ will go up as M increases, and w_m will decrease. Q.E.D.

Proposition 6 When M increases, and $F()$ is sufficiently inelastic, w_h will go up.

Proof:From the equation, $w_h = \beta/(1-\beta)L\frac{1-F(w/(1+sw))}{H-sM}$, we know the numerator is fixed, as $F()$ is inelastic, and the denominator decreases, so w_h increases with more M.

Proposition 7 In the steady state equilibrium, w increases in M.

$$\frac{M(1/w+s)}{H-sM} = \frac{F(w/(1+sw))}{1-F(w/(1+sw))} \tag{3.29}$$

In the above equation, substituting H by $H_f + kM$, we have

$$\frac{(1/w+s)}{H_f/M+(k-s)} = \frac{F(w/(1+sw))}{1-F(w/(1+sw))} \tag{3.30}$$

So the left hand side shifts up as M increases, therefore w increases.

Proposition 8 In the steady state equilibrium, w_m is decreasing in M.

Proof: From the budget equation, we have $w_m = \beta/(1-\beta) * L/(M + wH)$. Substituting H by $H_f + kM$, we have

$$w_m = \beta/(1-\beta) * L/(M + w(H_f + kM)) \tag{3.31}$$

As we know, w increases in M, so the denominator is increasing in M, therefore w_m will go down.

Proposition 9 In the steady state equilibrium, if $k > s$, then w_h decreases as M increases

From the equation, $w_h = \beta/(1-\beta)L\frac{1-F(w/(1+sw))}{H+(k-s)M}$, we know that w increases when M increases, so $1 - F(w/(1 + sw))$ decreases, and the denominator $H + (k - s)M$

increases, when $k > s$, so w_h decreases. Q.E.D.

Proposition 10 In the steady state equilibrium, v decreases in M.

Proof: We know $w_m = \beta(1-\beta)L/(M + (kM + H_f)w)$, and by definition, $w_h = w_m w$, then $w_m + kw_h = \beta(1-\beta)L\frac{1+kw}{(1+kw)M+wH_f} = \beta(1-\beta)L\frac{1}{M+\frac{H_f}{1/w+k}}$. Since w is increasing in M, $1/w+k$ is decreasing in M, so $\frac{H_f}{1/w+k}$ is increasing in M, and therefore $w_m + kw_h$ is decreasing in M. Now we have $v = 1/(1+k)(w_m + kw_h) - 1 - C$ also decreases in M. Q.E.D.

Proposition 12 In the steady-state equilibrium, when $k < s$ and $F()$ is inelastic, v will increase in H_f.

Proof: From equation 3.20, when $k < s$ and $F()$ is inelastic, it shifts right-hand side of the v (of M) curve up, , therefore the equilibrium v and M goes up.

Chapter 4

Human Capital and Technology Catch-up

4.1 Introduction

The classical Heckser-Ohlin trade theory of comparative advantage predicts when a low-skill country trades with a high-skill country, the return to skill in the low-skill country will decrease. However, in reality, the opposite often occurs. For many developing countries, returns to education increase after trade liberation. The traditional theory of comparative advantage breaks down because it depends on the crucial assumption that the two countries have the same technology. In reality, high-skill countries have much better technology, and can produce many high-tech goods that the developing country does not know how to produce yet. With a large gap in technology, many forces could be driving the increase of return to education after trade liberalization.

Specifically in this paper, we analyze two forces, one is an increased demand for local high-skill to reverse-engineer or to imitate the technologies of the rich country, the other is a higher skill-intensity of newly acquired technologies in the emerging country. These two forces can drive up the return to education in the local country after trade liberation, and subsequently trigger a rapid increase in college enrollment and human capital development. Over time, the workforce in the developing country becomes better educated and highly skilled, and gradually catches up to the rich country's technology, generating a virtuous cycle of economic development.

The main results of the model are as follows:

- By trading with the rich country, the emerging country can start a technology catch-up process.
- Technology catch-up requires high skill labor to do reverse-engineering, which drives up the demand and the return to education initially.
- If the new technology of the rich country grows at a constant rate, the technology of emerging country may also grow at a constant rate with a constant technology gap holding the supply of high-skill workforce fixed.
- If new technologies are relatively more skill intensive, then the return to education may continue to increase after the initial shoot-up.

4.2 Theoretical Analysis

4.2.1 Model Setup

Notationally, L is the number of low-skill workers in the local emerging country, and L_* is the number of low-skill workers in the foreign rich country. M is the number of local high-skill workers, and H is the number of foreign high-skill workers.

Utility function:$U = Y$

Y is the final good which is produced by the production function: $Y = (\int [X(i)]^\beta di + A_L Z^\beta)^{\frac{1}{\beta}}$.

Z is the low-tech intermediate tradable good which is produced only by low-skill workers with the production function $Z = L_L$. $X(i)$ is a continuum of medium-tech to high-tech intermediate tradable goods. The integral is over the set of all the X's that have been invented. Each good is either produced locally by the production function $X_i = L_i^{1-\alpha} M_i^\alpha$, or in the foreign country by the production function $X_i = L*_i^{1-\alpha} H_i^\alpha$. The location of the production depends on the wages and whether the country knows how to produce the good.

The rich country knows how to produce goods $i \in [0, B_t]$ at time period t. Each good $i \in [0, B_t]$ can be produced competitively by many firms. The emerging country knows how to produce goods $i \in [0, A_t]$ ($A_t <= B_t$). Each good $i \in [0, A_{t-1}]$ can be produced competitively by many firms. But, for the goods that have been recently imitated i.e. $i \in [A_{t-1}, A_t]$, the good can be produced by only one firm who buys the know-how from the research sector. [1]

Before the trade liberalization (at $t = 0$), the emerging country does not use any goods beyond A_0, and cannot do any reverse engineering, so effectively $B_0 = A_0$. [2] But after trading with the rich nation, B_t jumps to the technology frontier of the rich country, and the research firms in the emerging country can reverse-engineer the invention of the rich country, and produce some of the goods that previously only the rich country knows how to produce.

The production function for reverse-engineering is given by

$$\Delta A \equiv A_t - A_{t-1} = \kappa M_R^{\epsilon}(B_t - A_{t-1}) \tag{4.1}$$

In the equation, M_R is the quantity of high skill labor used, κ is the research efficiency, and B_t is the technology frontier of the rich country thus the limit of re-engineering. Here for simplicity, we assume that the firm with the know-how can only reap monopoly profit for one period (probably because other firms will figure out how to do it not much later), so the research firm can sell the know-how at a price equal the monopoly profit for one period. [3] We also assume there is free entry of research firms, and more research firms will reduce the overall efficiency of the research sector i.e. $\epsilon < 1$, so in aggregate, the research sector will earn zero net profit. Initially, we assume B_t is a constant, but later we will assume that the research firms in the rich

[1] Alternatively, we can allow a longer period of monopoly by replacing A_{t-1} by A_{t-k}, and almost all the results will go through unaffected.

[2] Alternatively, we can assume that the developing country can produce goods beyond A_0 at a very low productivity. Then, there will be some demand for high skill workers to produce goods beyond A_0 before liberalization; However, the analysis after the trade liberalization will be unaffected.

[3] This is not a bad assumption for the catching up country which usually has a weak intellectual protection institution. The imitating firms usually can go around the copy-rights with their own research effort, and their imitation blueprints cannot have copy rights protection either so they can not enjoy a monopoly for a long time.

country conduct frontier research to invent new goods, and B_t grows at a constant rate.

We further assume that $w_h > w_m/\beta$, i.e. the wage of high-skill labor is much higher in the rich country, so that once the emerging country figures out how to produce the good, it will get all the world market share for that good. This special case is a good approximation of the recent experience with China trading with rich countries like the U.S. and Japan. Firms in China are climbing the technology ladder by imitating their technologies with a much cheaper skilled labor force, whereas U.S. and Japan are increasingly focusing only on frontier research, and export only very high-tech goods, very little low-tech or medium tech goods.

4.2.2 Solving the model

Each good $i \in [0, A_{t-1}]$ is produced competitively in the emerging country by high-skill labor M_{1i} and low-skill labor L_{1i}. The price of the good is w_m/α, where w_m is the wage for M.

Each good $i \in [A_{t-1}, A_t]$ is produced monopolistically in the emerging country by high-skill labor M_{2i} and low-skill labor L_{2i}. Because this firm faces a downward sloping demand curve with an elasticity of $1/(1-\beta)$, it will charge a market up of $1/\beta - 1$. The price of the good will be $w_m/(\beta\alpha)$, and the profit for the firm is $(1/\beta - 1)w_m/\alpha$.

Each good $i \in [A_t, B_t]$ is produced competitively in the rich country by high-skill labor H_i and low-skill labor L_{*i}. The price of the good is w_h/α.

The low-tech good is produced competitively in the emerging country.

So the production function for the final good is

$$Y = [\int_0^{A_{t-1}} (L_{1i}^{1-\alpha} M_{1i}^{\alpha})^{\beta} di + \int_{A_{t-1}}^{A_{t-1}+\Delta A} (L_{2i}^{1-\alpha} M_{2i}^{\alpha})^{\beta} di + \int_{A_{t-1}+\Delta A}^{B_t} (L_{*i}^{1-\alpha} H_i^{\alpha})^{\beta} di + A_L L_L^{\beta}]^{1/\beta} \tag{4.2}$$

Denote M_1 as the aggregate of M_{1i}, so $M_{1i} = M/A_{t-1}$. Similarly denote M_2 as the aggregate of M_{2i}, so $M_{2i} = M_2/\Delta A$ where $\Delta A \equiv A_t - A_{t-1}$. Because the ratio of the price of goods produced by M_{1i} to the price of goods produced by M_{2i} is β, and the demand elasticity is $1/(1-\beta)$, so the ratio of demand of M_{1i} to M_{2i} is $\beta^{1/(1-\beta)}$, we have

$$\frac{M_1}{A_{t-1}}\beta^{1/(1-\beta)} = \frac{M_2}{\Delta A} \tag{4.3}$$

Denote M_R as the aggregate amount of labor employed in the research sector. Given the assumption that the research sector will earn zero profit, the total research labor cost $w_m M_R$ will be equal to the total monopoly profit $w_m M_2(1/\beta - 1)/\alpha$, so we have

$$M_R = M_2(1/\beta - 1)/\alpha \tag{4.4}$$

So M_1,M_2, and M_R are of constant ratio to each other. To simplify the notation, we define constant $\phi_2 \equiv \beta^{1/(1-\beta)}$, and $\phi_R \equiv \phi_2(1/\beta - 1)/\alpha$, we have

$$M_1 : M_2 : M_R = A_{t-1} : \Delta A\phi_2 : \Delta A\phi_R \tag{4.5}$$

Further, M_1, M_2, and M_R add up to M:

$$M_1 + M_2 + M_R = M \tag{4.6}$$

From the above labor clearing condition and the constant ratio conditions, we can solve M_1, M_2, and M_R as a function of ΔA (A_{t-1} is known at time t). The expression for M_1 is

$$M_1 = M\frac{A_{t-1}}{A_{t-1} + \Delta A(\phi_2 + \phi_R)} \tag{4.7}$$

The expression for M_R is as follows:

$$M_R = M/[1 + \phi_2/\phi_R + \frac{A_{t-1}}{\Delta A\phi_R}] \tag{4.8}$$

In the above equation, we substitute ΔA with the production function of the research sector $\Delta A = \kappa M_R^{\epsilon}(B_t - A_{t-1})$ and we get:

$$M_R = M/[1 + \phi_2/\phi_R + \frac{A_{t-1}}{\kappa M_R^{\epsilon}(B_t - A_{t-1})\phi_R}] \tag{4.9}$$

Proposition 1. The above equation uniquely determines M_R (given B_t, and A_{t-1}), and M_R is increasing in B_t and decreasing in A_{t-1}.

Proof in Appendix.

This proposition states quite intuitively that immediately after trade liberalization, a larger technology gap (a jump in B_t) will raise the research/imitation effort (a higher M_R). But over time, the research effort will come down as the technology gap is reduced (as A_{t-1} increases). Keep in mind, the research effort will decrease under the assumption that M, the number of high-skill workers is fixed. However, with an endogenized M, the supply of M and hence M_R could increase a lot induced by a higher return to education, the research effort and speed of catch-up can actually go up.

From M_R we can uniquely solve M_1, M_2 and ΔA. Similarly, we can derive an equation for ΔA.

$$\Delta A^{1-\epsilon}[A_{t-1}/(\phi_R) + \Delta A(1+\phi_2/\phi_R)]^{\epsilon} M^{\epsilon} = \kappa[B_t - A_{t-1}] \tag{4.10}$$

Proposition 2. The above equation uniquely determines ΔA (given B_t, and A_{t-1}), and ΔA is increasing in B_t and decreasing in A_{t-1}.

Proof in Appendix.

This proposition states intuitively that the speed of technology catch-up will go up initially but will come down as the gap is closed.

Return to Education

Because L_1 and M_1 have constant cost share of production in this Cobb Douglas set-up, we have $w_l(L_1)/(1-\alpha) = w_m(M_1)/\alpha$, where L_1 and M_1 are the low-skill and high-skill labor respectively employed to produce variety from $[0, A_{t-1}]$. (Hereafter, we normalize $w_l = 1$.) Therefore, the return to education is:

$$w_m = \alpha/(1-\alpha)\frac{L_1}{M_1} \tag{4.11}$$

To go further, we will establish the ratios $L_1 : L_2 : L_L$, where L_L is the quantity of low-skill labor employed in the unskilled sector. Similarly to $M_1 : M_2$, we know that

$L_1 : L_2 == A_{t-1} : \Delta A\phi_2$. Further, we know $L_1 : L_L = A_{t-1} : A_L(w_m/\alpha)^{\beta/(1-\beta)}/(1-\alpha)$. This is because the demand elasticity is $1/(1-\beta)$, and the price for the $X(i)$ is w_m/α and the price for the low-tech good is 1, the low-skill labor demand for each unit of $X(i)$ is $(1-\alpha)w_m/\alpha$. So we have the following ratios for low-skill workers:

$$L_1 : L_2 : L_L = A_{t-1} : \Delta A\phi_2 : A_L(w_m/\alpha)^{\beta/(1-\beta)}/(1-\alpha) \tag{4.12}$$

Further, we have the market clearing condition, $L_1 + L_2 + L_L = L$. We re-write $w_m = \alpha/(1-\alpha)\frac{L}{M}\frac{L_1}{L}\frac{M}{M_1}$, and substitute in the ratios. We have:

$w_m = \alpha/(1-\alpha)\frac{L}{M}\frac{A_{t-1}}{A_{t-1}+\Delta A\phi_2+A_L(w_m/\alpha)^{\beta/(1-\beta)}/(1-\alpha)}\frac{A_{t-1}+\Delta A(\phi_2+\phi_R)}{A_{t-1}}$,

Cancel and simplify. We have

$$w_m = \alpha\frac{L}{M}\frac{A_{t-1}+\Delta A(\phi_2+\phi_R)}{(A_{t-1}+\Delta A\phi_2)(1-\alpha)+A_L(w_m/\alpha)^{\beta/(1-\beta)}} \tag{4.13}$$

Proposition 3. The above equation uniquely determines w_m, and w_m is increasing in B_t.

Proof in Appendix.

This proposition says quite intuitively, that when the opportunity to imitate increases after trade liberation (a higher B_t), the return to education will go up initially.

Solving w_h and w_l^*

Lastly with w_m, we can solve the wages in the rich country w_h and w_l^*. By the constant demand elasticity assumption, we have

$$\frac{w_h}{w_m} = [\frac{L_{1i}^{1-\alpha}M_{1i}^{\alpha}}{L*_i^{1-\alpha}H_i^{\alpha}}]^{1-\beta} \tag{4.14}$$

In the above equation, we substitute $H_i = H/(B_t - A_{t-1} - \Delta A)$, $L_{*i} = L_*/(B_t - A_{t-1} - \Delta A)$, $L_{1i} = L_1/A_{t-1} = L/(A_{t-1} + \Delta A\phi_2 + A_L(w_m/\alpha)^{\beta/(1-\beta)}/(1-\alpha))$, and $M_{1i} = M_1/A_{t-1} = M/(A_{t-1} + \Delta A(\phi_2 + \phi_R))$. We have the following expression w_h:

$$w_h = w_m[\frac{M^\alpha L^{1-\alpha}}{H^\alpha L_*^{1-\alpha}} \frac{B_t - \Delta A - A_{t-1}}{(A_{t-1} + \Delta A(\phi_2 + \phi_R))^\alpha (A_{t-1} + \Delta A \phi_2 + A_L (w_m/\alpha)^{\beta/(1-\beta)}/(1-\alpha))^{1-\alpha}}]^{1-\beta} \tag{4.15}$$

and by the constant cost share in the rich country, we have the following expression for w_l^*,

$$w_l^* = w_h(1-\alpha)/\alpha \frac{H}{L_*} \tag{4.16}$$

Now we have solved all the variables (i.e. M_R, ΔA, w_m, w_h, and w_l^*) in the model.

Let's discuss the how the model relates to the traditional trade model. If before trade liberalization, the two countries have identical technology ($B_0 = A_0 \equiv B$) and thus no catch-up ($\Delta A = 0$), then H and M are essentially the same, producing the same goods and will have the same wages ($w_m = w_h$). In this case, the equation for w_m will be:

$$w_m = \alpha(\frac{L + L_*}{M + H}) \frac{1}{(1-\alpha) + (w_m/\alpha)^{\beta/(1-\beta)} A_L/B_0} \tag{4.17}$$

From the above equation, we can see that w_m is increasing in $(L + L_*)/(M + H)$ which is ratio of low-skill workers relative to high-skill workers. Before trade liberalization the value is the ratio in the local country L/M. Given high-skill workers are relatively scarce in the local country ($L/M > L_*/H$), the ratio will be lowered after trade liberalization, so w_m will be lowered. Further, the low-tech sector will expand and the high-tech sector will shrink in the local country. This is the usual Heckscher-Ohlin type result of comparative advantage, i.e. when a low skill country trades with a high-skill country, the return to education will go down. But this is only because we have assumed that M and H have the same technology. In the general model, H can produce goods that M does not know how to produce yet, and in fact, M and H produce completely different sets of goods, so factor equalization does not occur, equation 4.13 applies instead of equation 4.17.

The key condition/assumption here is high-skill labor in the rich country cannot compete with the emerging country once the emerging country figures out how to produce a good. This is due to the assumption that w_h is much higher than w_m, i.e. the wage of high-skill labor is much higher in the rich country. This is a good approximation of the China/US trade. The reason for a much higher w_h could be that the rich country knows a much larger set of inventions. [4].

What if w_h and w_m were quite close before liberalization? This is also the case in the later period of catching up as the emerging country closes the gap. Then, the high-skill labor in the rich country will not completely specialize in producing high-tech goods. So there will be some goods produced by both countries, and factor prices equalize i.e., $w_m = w_h$, and equation 4.17 applies instead of equation 4.13.

4.2.3 The Steady State and Transition Dynamics

The Steady State

In the steady-state, if B_t is sitting still at B_0, then eventually A_t is going to converge to close enough to B_t, such that the rich country can not specialize and $w_m = w_h$. Notice A_t does not need fully catch up with B_t to have $w_m = w_h$. For example, if the emerging country's high-skill workforce is 4 times as large as the rich country, it needs only to imitate 80% of the inventions to have the same wages. When the gap is close enough, equation 4.13 will be reduced to the factor equalization case: the steady state w_m^s is:

$$w_m^s = \alpha(\frac{L+L_*}{M+H})\frac{1}{(1-\alpha)+(w_m^s/\alpha)^{\beta/(1-\beta)}A_L/B_0} \tag{4.18}$$

Before trade liberalization, w_m^0 at the local country is solved by

$$w_m^0 = \alpha(\frac{L}{M})\frac{1}{(1-\alpha)+A_L(w_m^0/\alpha)^{\beta/(1-\beta)}A_L/A_0} \tag{4.19}$$

Comparing w_m^0 and w_m^s, we know on the one hand $\frac{L+L*}{M+H} < \frac{L}{H}$ (the comparative advantage effect), which tends to make $w_m^s < w_m^0$; on the other hand, $B_0 > A_0$ (the

[4]The alternative explanation is that there is a high demand of high-skill workers in the non-tradable sector. We can add a non-tradable sector to the base model, and still get almost all the analytical results.

technology shift effect) which tends to make $w_m^s > w_m^0$. So the net effect could go both ways depending on the parameters, if the technology gap is very large, the second effect tends to dominate and $w_m^s > w_m^0$.

Transition Dynamics with a fixed M

We already know that w_m will go up initially as B_t goes up, but we cannot say for sure whether w_m will go up or down after the initial jump. On the one hand, a higher A_{t-1} reduces the opportunity to imitate which tends to lower w_m; On the other hand, a higher A_{t-1} shifts production to more skill-intensive goods which tends to raise w_m, so the net effect on w_m can be ambiguous. Intuitively, when the skill intensity of the new good is high (e.g. $\alpha = 1$), w_m will increase in A_{t-1}. In contrast, when there is no skill-biased technology change, w_m will decrease. We will analyze the dynamics of w_m in two special cases.

The Special Case of No Skill-Biased Technology Progress

The special case of $A_L = 0$ is where all the goods have the same skill intensity, in other words, there is no skill-biased technology progress. The equation 4.13 for w_m is reduced to:

$$w_m = \alpha/(1-\alpha)\frac{L}{M}[1 + \frac{\phi_R}{\frac{A_{t-1}}{\Delta A} + \phi_2}] \tag{4.20}$$

From the above equation, we have the following proposition:

Proposition 4. If $A_L = 0$, w_m is decreasing in A_{t-1}.

Proof in Appendix.

So after the initial jump, the return to education will go down, if the new technology has the same skill intensity ($A_L = 0$).

The Special Case of High Skill Intensity New Goods

The other extreme is new goods are very skill intensive. Let's solve the case when $\alpha = 1$, i.e. all the new goods use only high-skill labor. The equation for w_m is reduced to:

$$w_m = [\frac{L}{M} A_L^{-1} (A_{t-1} + \Delta A(\phi_2 + \phi_R))]^{1-\beta} \tag{4.21}$$

Similar as before, the initial increase of B_t after trade liberalization will increase M_R and ΔA, thus increasing w_m, but over time as the gap is closed, the effect is reversed. However, in contrast to the previous special case, there is a second effect. As A_{t-1} increases, w_m tends to go up. Intuitively, the demand of M for reverse-engineering will go down, but the new goods are skill-intensive which will raise the demand for M. To see the net effect, substituting $\Delta A \equiv A_t - A_{t-1}$, we have

$$w_m = [\frac{L}{M} A_L^{-1} ((1 - \phi_2 - \phi_R) A_{t-1} + A_t(\phi_2 + \phi_R))]^{1-\beta} \tag{4.22}$$

When $\alpha = 1$, $\phi_2 + \phi_R$ can be simplified to $\beta^{\beta/(1-\beta)} < 1$. So w_m is increasing in a convex combination of A_{t-1} and A_t, therefore, as A_t increases over time, w_m will increase, hence the following proposition:

Proposition 5. If $\alpha = 1$, then w_m will increase further over time after the initial jump.

So, when all the new goods require only high skill workers (or more generally, the new goods have same skill intensity as the research sector), the return to education will continue to go up after the initial jump, as long as it remains to be lower than w_h which will come down over time.

4.2.4 Balanced Growth Path

Now, we assume the rich nation is moving up the technology frontier, such that $B_t = B(1 + r)^t$ which is growing at constant rate r. In this case, the technology gap could persist in the long run. We still assume the technology gap is large enough such that $w_m < w_h \beta$, so the emerging country will have incentive to imitate. (otherwise, with a small technology gap, we will have wage equalization.)

We will guess a balanced growth solution, such that $A_t = kB_t$, i.e. A_t is a constant fraction of B_t, and A_t also grows at rate of r. With both A_t and B_t grow at a constant rate, we have $\Delta A = rA_{t-1}$. Substitute it in the expression $M_R = M \frac{\Delta A \phi_R}{A_{t-1} + \Delta A(\phi_2 + \phi_R)}$, we have M_R is a constant ratio of M, $M_R = M \frac{r\phi_R}{1 + r(\phi_2 + \phi_R)}$.

We also know $\Delta A = rkB_{t-1}$, and $B_t - A_{t-1} = (1 + r - k)B_{t-1}$. Substitute them in the production function for ΔA, and cancel out B_{t-1}. We have $rk = \kappa(1 + r - k)M^{\epsilon}(\frac{\phi_R}{1/r+\phi_2+\phi_R})^{\epsilon}$. Solving for k, we have:

$$k = \frac{1 + r}{1 + r[\kappa M^{\epsilon}(\frac{\phi_R}{1/r+\phi_2+\phi_R})^{\epsilon}]^{-1}} \tag{4.23}$$

If $k < 1$, k is the constant technology gap on the balanced growth path (also need $w_m < \beta w_h$ all the time). if $k > 1$, then catch-up is complete and we have technology convergence. (e.g. in the case of a very big κ or a very small r.)

Now, we will solve w_m by using equation 4.13. Subsituting $\Delta A/A_{t-1} = r$, we have

$$w_m = \alpha \frac{L}{M} \frac{1 + r(\phi_2 + \phi_R)}{(1 + r\phi_2)(1 - \alpha) + (w_m/\alpha)^{\beta/(1-\beta)} A_L/A_{t-1}} \tag{4.24}$$

Proposition 6. On the balanced growth path, w_m will increase over time if $A_L > 0$.

Proof in the Appendix.

Intuitively, with the imitation effort being constant, the return to education will go up if and only if the new goods are skill-biased (i.e. $A_L > 0$). Further, as A_{t-1} continues to grow, A_L/A_{t-1} will vanish, so w_m converge from below to w_m^*, where $w_m^* = \alpha \frac{L}{M} \frac{1+r(\phi_2+\phi_R)}{(1+r\phi_2)(1-\alpha)}$. (Of course, we still require $w_m^* < w_h\beta$ for the analysis to go through.)

4.3 Summary

In this model, the return to education could increase for many reasons:

- Initially, after trade liberation, there are more opportunities to imitate the rich country.
- Over time, when the newly acquired technologies are more skill-intensive.
- Over time, when the rich country is moving the technology frontier up, there are still more opportunities to imitate.

Thus far, we have assumed the supply of local skilled workers is fixed. A natural extension of the paper is to assume that the supply of M is a function of return to education. There are two obvious outcomes of an induced supply increase. First, an induced supply increase tends to slow down the increase of return to education. Second, if the induced supply increase is very large, or in other words, the education supply function is elastic, it can speed up the technology catch-up even as the technology gap is reduced. Both outcomes are supported by evidence in emerging countries like China and Korea.

4.4 Appendix: Proofs in this Chapter

Proposition 1. The following equation uniquely determines M_R (given B_t, and A_{t-1}), and M_R is increasing in B_t and decreasing in A_{t-1}.

$$M_R = M/[1 + \phi_2/\phi_R + \frac{A_{t-1}}{\kappa M_R^{\epsilon}(B_t - A_{t-1})\phi_R}] \tag{4.25}$$

Proof: Rearranging the above equation, we have

$$M_R^{1-\epsilon}((1 + \phi_2/\phi_R)M_R^{\epsilon} + \frac{A_{t-1}}{\kappa(B_t - A_{t-1})\phi_R} = M \tag{4.26}$$

Clearly, the left-hand side of the equation is increasing in M_R, the right-hand side is fixed (given $\epsilon < 1$), and the left-hand side goes from zero to infinity as M_R goes from zero to infinity, therefore the equation uniquely determines M_R. Also evident from the equation, the upward-sloping left-hand side is increasing in A_{t-1} and decreasing in B_t, therefore M_R is increasing in B_t and decreasing in A_{t-1}. Q.E.D.

Proposition 2. The following equation uniquely determines ΔA (given B_t, and A_{t-1}), and ΔA is increasing in B_t and decreasing in A_{t-1}.

$$\Delta A^{1-\epsilon}[A_{t-1}/(\phi_R) + \Delta A(1 + \phi_2/\phi_R)]^{\epsilon} M^{\epsilon} = \kappa[B_t - A_{t-1}] \tag{4.27}$$

Proof: Clearly, the left-hand side of the equation is increasing in ΔA, the right-hand side is fixed (given $\epsilon < 1$), and the left-hand side goes from zero to infinity as

ΔA goes from zero to infinity, therefore the equation uniquely determines M_R. Also evident from the equation, the right-hand side is decreasing in A_{t-1} and increasing in B_t and the left-handside is increasing in A_{t-1}, therefore ΔA is increasing in B_t and decreasing in A_{t-1}. Q.E.D.

Proposition 3. The following equation uniquely determines w_m, and w_m is increasing in B_t.

$$w_m = \alpha \frac{L}{M} \frac{A_{t-1} + \Delta A(\phi_2 + \phi_R)}{(A_{t-1} + \Delta A \phi_2)(1-\alpha) + A_L (w_m/\alpha)^{\beta/(1-\beta)}} \tag{4.28}$$

Proof: A higher ΔA shifts the downward sloping left-hand side up, therefore raises w_m. Also, by proposition 2, we know that ΔA will increase as B_t increases, therefore w_m is increasing in B_t (holding A_{t-1} fixed). Q.E.D.

Proposition 4. If $A_L = 0$, w_m is decreasing in A_{t-1}.

When $A_L = 0$, the equation for w_m is reduced to the following:

$$w_m = \alpha/(1-\alpha) \frac{L}{M} [1 + \frac{\phi_R}{\frac{A_{t-1}}{\Delta A} + \phi_2}] \tag{4.29}$$

In the equation, we already know ΔA is decreasing in A_{t-1} by proposition 2, so $\frac{A_{t-1}}{\Delta A}$ is increasing in A_{t-1}, therefore w_m decreasing in A_{t-1}. Q.E.D.

Proposition 6. On the balanced growth path, w_m will increase over time if $A_L > 0$. We have already shown that on the balanced growth path w_m is determined by the following equation.

$$w_m = \alpha \frac{L}{M} \frac{1 + r(\phi_2 + \phi_R)}{(1 + r\phi_2)(1-\alpha) + (w_m/\alpha)^{\beta/(1-\beta)} A_L / A_{t-1}} \tag{4.30}$$

Clearly, a higher A_{t-1} shifts the downward-sloping right-hand side up, therefore w_m will increase in A_{t-1}, so over time w_m will increase. Moreover, as A_{t-1} goes to infinity, w_m will converge to $\alpha \frac{L}{M} \frac{1+r(\phi_2+\phi_R)}{(1+r\phi_2)(1-\alpha)}$

Chapter 5

Conclusion

In this thesis, I developed three models on the topic of labor market and human capital development in developing countries. The three models are similar in that all of them predict an increase in return to education, after interacting with developed countries (either via trade or foreign direct investment). However, there are also important differences.

In the model in the first chapter, the cause for a higher return to education is foreign direct investment which increases the demand for high-skill experienced workers. FDI will raise the college wage premiums for the experienced high-skill workers in the short run and in the long run. However, the college wage premiums for young graduates may decrease in the long run. During the transition, both wage premiums for the young and old graduates will shoot up in the short run, but come down in the long run as the supply increases. Because the model does not deal with trade, it makes no prediction about the wages in the foreign country.

In the model in the third chapter, the cause for a higher return to education is cheaper foreign inputs(or trainers). The college wage premiums for the young and old graduates may go up in the short run and in the long run. During the transition, both premiums will shoot up in the short run, but come down in the long run. One difference from the previous model is that foreign high-skill wages will rise in the medium run when a large number of young graduates demand more foreign high-skill trainers.

Table 5.1: Comparing the Three Models

	Chapter 1	Chapter 3	Chapter 4
Cause for increase in return to education	FDI	Foreign Inputs	R & D, skill intensity
return to education dynamics	long run ↑ ↑ then ↓	long run ↑ ↑ then ↓	long run may ↑ ↑ then may ↑
wage premium for young dynamics	long run may ↓ ↑ then ↓	long run ↑ ↑ then ↓	No Prediction No Prediction
high-skill(foreign) wage dynamics	No Prediction No prediction	long run ↓ medium run ↑	long run ↓ short run ↓

In the model in the fourth chapter, the cause for a higher return to education is the technology catch-up process which increases R&D effort and the skill-intensity of the product mix. The return to education and wage premium will shoot up in the short run, and possibly in the long run. During the transition, if the skill-intensity increases very fast (or the frontier keeps moving up), the return to education can go up despite an induced supply increase. The foreign high-skill wages will come down all the time, as the foreign country loses market shares to the local country. The model does not distinguish young and old workers, so it makes no prediction about the wages of young graduates vs. old graduates.

Empirically, the first model is already tested and borne out using with a Chinese dataset in Chapter 2. Further, similar evidence was found in several other rapidly developing countries. Therefore, the key prediction of the model is quite relevant to many developing countries, i.e. an increase of return to skill will actually drive down the wages for young graduates given the supply is elastic. The first model is assuming an exogenous increase of return to skill due to foreign direct investment; whereas the second and third model analyze the mechanism of the rising return to skill.

To emipirically test the model of foreign inputs, we can examine the relationship between foreign inputs and skill intensity at industry or firm level. We expect to find that more use of foreign inputs and more interaction with foreign firms are associated with a more skilled workforce either at firm level or industry level. Further, we can test the predication that if foreign high-skill workers benefit in the medium run from exporting high-tech components.

To empirically test the model of technology catch-up, we can examine the change in product mix and skill intensitiy, as well as the related research and development expenditure in the local country. We expect to find, after trade liberalization, R&D expenditure in the local country will increase. Further, the skill-intensitiy of the exports will increase over time.

Bibliography

Acemoglu, D, “Technical change, Inequality, and the Labor Market.,” *Economic Literature*, 2002.

Amiti, Mary and Jozef Konings, “Trade Liberalization, Intermediate Inputs and Productivity.,” *American Economic Review*, 2007.

Antras, P, L Garicano, and E Rossi-Hansberg, “Offshoring in a Knowledge Economy.,” *Quarterly Journal of Economics*, 2006.

Baraka, Jessica, “Returns to education in Taiwan,” *Working Paper*, 1999.

Beyer, H, P Rojas, and R Vergara, “Trade Liberalisation and Wage Inequality,” *Journal of Development Economics*, 1999.

Bustos, C, “Rising Wage Inequality in the Argentinean Manufacturing Sector: The Impact of Trade and Foreign Investment on Technology and Skill Upgrading.,” *CREI memeo*, 2006.

Chase, “Markets for communist human capital: returns to education and experience in the Czech Republic and Slovakia,” *Discussion Paper*, 1997.

Choi, Kang-Shik and Jin-Ho Jeong, “The Rising Returns to Education and Skill-Biased Technological Change in Korea,” *Working Paper*, 2003.

Coughlin, Cletus C. and Eran Segev, “Foreign Direct Investment in China:A Spatial Econometric Study,” *World Economy*, 2002.

Dornbusch, R, S Fischer, and PA Samuelson, "Comparative advantage, trade, and payments in a Ricardian model with a continuum of goods.," *American Economic Review*, 1977.

Feenstra, R. and G. Hanson, "Foregin investement and relative wages: Evidence from Mexico's maquiladoras," *Journal of International Economics*, 1997.

Freeman, Richard and Lawrence Katz, *Differences and Changes in Wage Structures*, The University of Chicago Press, 1995.

Green, Francis, Andy Dickerson, and Jorge Arbache, "A Picture of Wage Inequality and the Allocation of Labor Through a Period of Trade Liberalization: The Case of Brazil," *World Development*, 2000.

Hanson, G and A Harrison, "Trade Liberalisation and Wage Inequality in Mexico," *Industrial and Labor Relations Review*, 1999.

Heckman, J., "Explaining Rising Wage Inequality: Explorations with a Dynamic General Equilibrium Model of Labor Earnings with Heterogeneous Agents," *Review of Economic Dynamics*, 1998.

Katz, L. and K.M. Murphy, "Changes in relative wages, 1963-1987: Supply and demand factors," *Quarterly Journal of Economics*, 1992.

Koopman, R, Z Wang, and SJ Wei, "How much of Chinese exports is really made in China? Assessing domestic value-added when processing trade is pervasive.," *NBER working paper*, 2008.

Kwark, Noh-Sun and Changyong Rhee, "Educational Wage Differentials in Korea," *Seoul Journal of Economics*, 1993.

Mehta, Aashish, Jesus Felipe, Pilipinas Quising, and Shiela Camingue, "Changing Patterns in Mincerian Returns to Education and Employment Structure in Three Asian Countries," *Center for Global Studies, Institute for Social, Behavioral, and Economic Research, UC Santa Barbara*, 2007.

Naughton, Barry, *The Chinese Economy*, The MIT Press, 2006.

Oostendorp, Remco H and Doan Hong Quang, "The Impact of Trade Liberalization on the Return to Education in Vietnam:Wage Versus Employment Effect," *Discussion Paper*, 2011.

Yeaple, SR, "A simple model of firm heterogeneity, international trade, and wages.," *Journal of International Economics*, 2005.

Zhang, Junsen, Yaohui Zhao, Albert Park, and Xiaoqing Song, "Economic returns to schooling in urban China, 1988 to 2001," *Journal of Comparative Economics*, 2005.

Zhao, Y., "Foreign direct investment and relative wages The case of China," *China Economic Review*, 2001.

Zhu, S and D Trefler, "Trade and inequality in developing countries: a general equilibrium analysis," *Journal of International Economics*, 2005.