Essays in Macro and Labor Economics

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I used the data from China Health and Nutrition Survey (CHNS) and China General Social Survey (CGSS), the OECD and IFS data base. Please see the relevant sections for information on the specific series.

Dedication

To my parents, Xiang Ma and Yuliang Wei

Abstract

This dissertation includes two chapters.

The first chapter studies the labor market effect of the college expansion policy in China. In 1999, the Chinese government embarked on a program to increase the entry class to tertiary education by 42% from the previous year; the college admission rate stayed at the higher level since then. The expansion of college education represents a large and exogenous increase in supply of the college graduates to the labor market. This paper identifies the key role of the relative college labor supply in driving the changes of college wage premium after the expansion program. Assuming imperfect substitutability of workers in different education and age groups, I propose an overlapping-generation model with endogenous educational choice to account for college premium trends in distinct demographic groups. The estimation results provide the basis for evaluating the welfare effects of the college expansion in different subgroups.

In the second chapter, which is co-authored with Huo Zhen, we try to understand the excess consumption volatility in the emerging countries. In emerging markets, business cycles are characterized by higher consumption volatility relative to output and strongly counter-cyclical current accounts. Meanwhile, agents in emerging countries face higher uncertainty in forecasting economic fundamentals. We build a general equilibrium business cycle model with heterogeneous income profiles and imperfect information. Agents observe their income to learn the growth rate of their individual human capital and the growth rate of the aggregate economy. Due to information frictions, a shock to the growth rate of the aggregate economy will be partly attributed to the growth rate of agents' own human capital, the latter of which has more persistent effects on agents' life-time income. As a result, the economy features higher consumption volatility than the output. Quantitatively, we find that the model can successfully explain the excessive volatility of consumption and generate a strongly negative correlation between the trade balance and output for a wide range of TFP and income processes.

Contents

List of Tables

List of Figures

Chapter 1

China's College Expansion Policy: Ability Selection and Labor Market Effects

1.1 Introduction

In June 1999, the State Council of China decided to increase the entry class to tertiary education by 42% from previous year mainly by expanding the class size at existing universities, and the admission rate stayed at this higher level since then. This paper assesses the role of supply, driven by the exogenous college expansion policy, in accounting for the large change in the returns to college education over different subgroups. The various trends of changing returns to college education in different age and residential groups motivates my assumption of imperfect substitutability between different age and education groups in production, and my estimation of the elasticities are comparable with the estimates by [1] and [2]. To further account for the differential dynamics of the college premium across age and residential groups, and to evaluate the welfare gain or loss of the college expansion policy, I propose an overlapping-generation model with endogenous college education choice. And in the end, I conduct counter-factual analysis and solve for the optimal college expansion size.

As documented by many literatures, the wage of college graduates compared to high school graduates increased dramatically after the opening up in 1978. However, a remarkable trend in the China's labor market in the recent years is the overall declining college premium, and this is especially phenomenal among the young college graduates. Using a longitudinal data set China Health and Nutrition Survey (CHNS) that include 26,000 individuals in eleven provinces of China, I documented the fact that the college premium for the young graduates (21-25 years old) begin to decrease immediately after the first cohorts of college students after the 1999 college expansion policy graduated in 2003, while the college premium for the older cohorts kept on growing until late 2000s. The panel data drawn from the China Health and Nutrition Survey (CHNS) also allow me to separately identify the extent to which the life-cycle earnings profile is determined by the curvature of the working-experience accumulation versus the changing efficiency of the labor input.

To account for the divergent college premium trends for different age groups, I build a heterogeneous-agent model with imperfect substitutability of workers in different education and age groups. The production technology in my model is based on the seminal analysis of [2], which explains the diverging trends of college premiums for old and young workers by a model of imperfect substitution between different age workers with same education. In particular, they segregate the labor inputs by five-year age groups and education groups. For each age group, they separately estimate the college premiums, and calculate the corresponding relative college labor supply by a ratio of weighted sum of hours worked by equivalent college and high school workers.[1] Adopting a similar strategy for measuring the effective supply of college labor and college premium, I could estimate the demand elasticity of substitution between workers with the same education in different age groups, and the elasticity of substitution between college and high school laborers. The estimated elasticity of substitution between college and high school labor is in the range of 1.1 to 1.9, comparable to the estimations by [1] and [2].[2] And my estimation of elasticity of substitution between different age groups are in the range of

[1] They divided workers into five educational groups: high school dropouts, high school graduates, workers with some college, college graduates, and workers with a postgraduate degree, then calculate the total supply of high-school and college equivalent labor by a weighted sum of different education groups' total annual hours, the weight being the regression coefficients of each group's average wage on the average wages of high school and college graduates.

[2] By comparison, [1] report an estimate of elasticity at 1.4 and the estimates from [2] is in the range of 1.1-1.6.

4.4 to 7.6, generally higher than the estimates from [2].

In order to analyse the effect of the college expansion policy on residential groups with different financial resources and ability distributions,[3] I further include the mechanism of college education choice with heterogeneity in abilities and initial assets. At high school graduation, individuals are endowed with abilities that will affect their labor earnings through effective labor inputs and the chance of access to higher education. They are also endowed with different initial assets. The ability threshold to college education is exogenously determined by the government policy, and the expansion of college entry class is equivalent to decreasing the college entry ability threshold if we assume a constant ability distribution over time.

The huge exogenous college expansion will induce two channels that affect the college wage premiums. Firstly, the increase in the relative college labor supply will decrease the relative college labor price. Secondly, the decrease in the ability threshold for college entry will affect both the average ability of college and high-school labor, and that will change the effective labor supply in both education groups. The endogenous college education choice could correspond to both of the above channels, where after the college expansion policy was announced, individuals perfectly expect the potential decrease in college premium out of the first supply force, and make their college education choice on their initial wealth and ability levels accordingly.

The dynamic model and numerical solutions could correspond to the evolution of the labor market over the recent years. The overall college premiums constantly increased initially; the college expansion exogenously increased the supply of young college graduates and drove down the wage for inexperienced graduates while the wage for prime age graduates continues to rise.

From a policy perspective, the model can be used to analyse the welfare effects of the college expansion policy on different subgroups. The counter-factual analysis on an alternative policy of limiting the growth of the higher education sector lay the foundation for a policy analysis of the development of higher education in China as well as other rapidly developing countries.

[3] See documented evidence in Section 1.2.2

Related Literature My paper is closely related to the literature of the labor supply effects on the wage structure, such as the cohort effects in [3], changes in college education by age groups and cohorts in [1] and [2], and changes in return to experiences in [4]. However, instead of a clear exogenous supply change, all of the above studies consider some endogenous response, such as the schooling and birth choice, to the underlying social-economic factors. This paper features a dramatic exogenous policy change, as a sharp identification strategy, to estimate the production demand elasticities on different categories of labor input. As a result, the estimated elasticities are generally comparable with the previous literature, with a slightly higher elasticities for different age groups.

The second strand of research is on the structural model of higher education choice with heterogeneous ability, such as [5] and [6], where students differ in ability and family income, and school enrolment decisions are made with perfect information. My model builds on the framework and combines it with heterogeneous income profiles (HIP) assumptions, as in [7], where workers with different abilities have various income growth rates, to study how ability selection affects measured college wage premiums.

Finally, the work is motivated by various empirical studies on the evolutionary policies on education sectors, such as [8] and [9], and [10] as well as empirical estimates of the education returns in China for recent years, as in [11], [12], and [13].

The rest of the paper is organized as follows. Section 1.2 describes the data and discusses the background of China's tertiary education evolution system as well as the college expansion policy, and explains why the policy might affect different residential subgroups differently. Section 1.3 sets up the two-sector economy and establishes the key variables of elasticities that need to be estimated from microlevel data. Section 1.4 illustrates the strong relationship between the relative supply of college labor with the college premium and reports the structural estimation results for the elasticities. Section 1.5 provides the calibration and quantitative results. Section 1.6 applies the calibrated results to study the counter-factual effects of policy measures of limiting the growth of the higher-education sector.

1.2 Data Sources and Institutional Background

This section provides a brief introduction of the two household survey data sets and a general description of the college education system in China. My main data sources are drawn from a longitudinal data set, the China Health and Nutrition Survey (CHNS),[4] including 9 survey waves from 1989 to 2011. I use another cross-sectional data set, the China General Social Survey (CGSS) for further information after 2003. I also present a brief history of evolution of college education as well as its private financing in China since the 1980s.

1.2.1 Data Sources

To quantify the effects of college expansion policy on both college enrolment for rural and urban students and increased human capital within subgroups requires micro-level data with detailed information about the income, residential status, education and employment of workers. To satisfy the requirements, two micro-level survey data sets are used in this chapter, a longitudinal data set CHNS, and a cross-sectional data set CGSS.

The CHNS data is an unbalanced panel household survey with refreshment that includes 26,000 individuals in nine[5] provinces of China, including Guangxi, Guizhou, Heilongjiang, Henan, Hubei, Hunan, Jiangsu, Liaoning, and Shandong, as shown in the Figure 1.1. The provinces sampled are broadly representative of China's regional variation. Of these provinces, two are dynamic high-growth ones in China's east coastal region (Jiangsu and Shandong); two are located in the northeast region (Liaoning and Heilongjiang), with one heavily industrialized (Liaoning); three are located in the middle region (Henan, Hubei, and Hunan); and two are in the southwest, where a large fraction of population consists of ethnic minorities (Guangxi and Guizhou). These surveys provide wage, education, employment and demographic information for the survey

[4] The CHNS is jointly conducted by the Carolina Population Center at the University of North Carolina at Chapel Hill and the National Institute of Nutrition and Food Safety at the Chinese Center for Disease Control and Prevention. More detailed information about the CHNS can be found at the CPC UNC website: http://www.cpc.unc.edu/projects/china

[5] The sample in 2011 was expanded by adding Shanghai, Beijing and Chongqing, the three mega municipalities in China.

years 1989, 1991, 1993, 1997, 2000, 2004, 2006, 2009 and 2011.

Figure 1.1: Map of Survey Regions

The main advantages of the CHNS relative to other publicly-available data sets are that it includes data on both rural and urban areas, and its survey waves cover all the relevant years of the college expansion policy, as well as the recent trends.[6] One potential concern is whether the unweighed panel is representative of the whole China on the key dimensions, including the college enrolment, labor supply and wage differentials between rural and urban residents. To allay the concern, in Table 1.1 I compare summary statistics from the nine waves of the CHNS (first panel) to data from four censuses as reported in the China Statistical Yearbooks (CSYs)[7] as in the bottom panel.

[6] Other publicly available data sets like the Chinese Household Income Project survey (CHIP) and China General Social Survey (CGSS) include only years before or after the college expansion, or only urban households like the Urban Household Income and Expenditure Survey (UHIES).

[7] The census occurs every five years, and the relevant series 1990, 1995, 2000, 2005 and 2010, available at http://www.stats.gov.cn/english/statisticaldata/CensusData/

Comparison of the two panels of Table 1.1 shows that the CHNS oversampled high-school graduates relative to college graduates, and in general oversampled males. Therefore, in each survey year, we separate the CHNS sample into cells by four education types and eight age groups, so that in each education-age cell, the proportion is comparable with the national survey. The share of workers with education levels of primary-school and below, middle-school graduates, high-school graduates and college/university graduates in the weighted sample remain roughly in line with census data in each of the 5-year age groups.

Table 1.1: Summary Statistics of CHNS Sample

	CHNS Survey Years								
	1988	1990	1992	1996	1999	2003	2005	2008	2010
Provinces	8	8	8	9	9	9	9	9	11
Full-time workers	3,670	3,128	2,792	2,790	2,842	3,613	3,806	4,197	5,556
Percentage of									
-Male workers	59.62	58.95	60.06	59.17	61.01	56.32	56.57	56.85	56.37
-Urban hukou	69.06	71.14	68.02	64.60	57.30	37.75	37.28	35.62	46.87
-High-school graduates	24.55	26.69	29.48	35.25	37.16	27.48	26.12	23.73	27.27
-College graduates	3.11	4.99	4.19	4.76	7.11	6.64	9.22	8.46	15.59
	National Census Survey Years								
	-	1990	-	1995	2000	-	2005	-	2010
Provinces	31	31	31	31	31	31	31	31	31
Percentage of									
-Male workers	-	55.04	-	54.26	54.66	-	54.58	-	55.46
-High-school graduates	-	15.12	-	12.01	14.60	-	14.02	-	16.24
-College graduates	-	2.92	-	3.23	5.11	-	7.68	-	12.52

The CGSS survey data sets focus on the post-policy change years. It includes only urban households in 2003 survey, but both urban and rural households are included in the survey waves afterwards. Around 6,000-10,000 households are included in each survey year. These surveys contain detailed information on individual education history, annual income and working experience as well as family background.

From these data sets, I create two samples: (1) a wage sample including weekly wages of workers by demographic groups and (2) a working hours count sample that I use to measure the amount of labor supplied by each group. I divide the sample into different labor groups, distinguished by sex, education (less than high-school, high-school diploma, college drop-outs, college/university diploma, and graduate school), and 8 age-groups (21-25, 26-30, 31-35, 36-40, 41-45, 46-50, 51-55, 56-60). And we construct a separate sequence of college application and enrolment ratios of rural versus all high-school graduates in each of the college entrance examination years from the precise information on individual education history from the CGSS survey data sets.

Both samples include all individuals aged 21-60 who worked at least 20 hours per week in the preceding year. The wage measure that I use throughout the paper is the average weekly wage, computed as total annual or monthly labor earnings divided by total weeks worked. To get the real wage, I adjust the nominal wage using last year's CPI (equal to 100 in 1988). I compute total working hours for each demographic group in each year by calculating the product of total annual hours (weeks worked times usual weekly hours) and the individual sample weight. Since the CHNS doesn't have the corresponding individual weight, I construct the sample weights using the population census data in the years 1990, 1995, 2000, 2005 and 2010.

1.2.2 Institutional Background

China's Higher Education. China has the largest higher education system in the world. According to the Ministry of Education,[8] there are 2,790 public higher education institutions enrolling 29.7 million students, including 1,867 regular higher education institutions with a total enrolment of 23.9 million, and 348 institutions for adults with a total enrolment of 5.8 million; and 707 other private institutions with a total enrolment of 5.3 million. With a centralized educational system, all the higher education institutions are under the control of the Ministry of Education through enrolment planning, funding, and evaluation.

Since 1977, The National College Entrance Examination (NCEE) is a prerequisite for entrance into almost all higher education institutions at the undergraduate level, and the unique criteria for college admission.[9] The examination was uniformly designed

[8] Most recent publicly available data in 2012 are at http://www.moe.edu.cn.

[9] Starting 2003, some top pilot schools were given autonomy of admission quota of no more than

by the Ministry of Education until the early 2000s.[10] Exams are held annually, and generally taken by high school students at the end of their third year, although there has been no age restriction since 2001.

The initial college admission rate[11] was astonishingly low, at only 4.7% in 1977. Since the opening up in 1978, China's economy has been growing at a stellar rate, and so has its physical capital accumulation. The high gross savings rate, together with the complementarity between physical capital and high-skill workers, increase the return to college education.[12] Up to the early 1990s, the admission rate to college education maintained a relatively constant growth of around 8.5% annually.

However, during the Asian financial crisis, in order to alleviate the unemployment, stimulate domestic consumption and meet the tremendous demand for higher education, the State Council decided to embark on a radical enrolment expansion plan.[13] It only took 4 months for the policy to be announced and take into effect; within just one year, the college admission rate was increased by more than 40%, from 33.8% in 1998 to 55.6% in 1999, as shown in the Figure 1.2. The admission rate has been kept around 60% since then. The initial target of increasing the gross enrolment ratio in tertiary education to 15% by 2010 was already surpassed in 2005, the actual gross enrolment rate increasing from less than 10% in 1998 to over 20% in 2005. After 2006, the government began to control the rapid growth of tertiary education, and the growth of college admission rate transformed to a steady and moderate trend.

The substantial increase in the college entry class would require a wider base of support for higher education. However, Between 1992 and 2003, the proportion of government expenditures in total education expenditures decreased from 84% to 62%.[14]

As a result, the burden of financing for tertiary education shifted from entirely government to the point where households have to finance a substantially increasing

5% of their total enrolments.

[10] The Ministry of Education allowed the College Enrolment Office of Shanghai and Guangdong to employ an independent exam in 1985. Starting from 2003, Beijing, Tianjin, Jiangsu, and Zhejiang were allowed to adopt independent propositions. Now there are 16 provinces and municipalities that have customized exams.

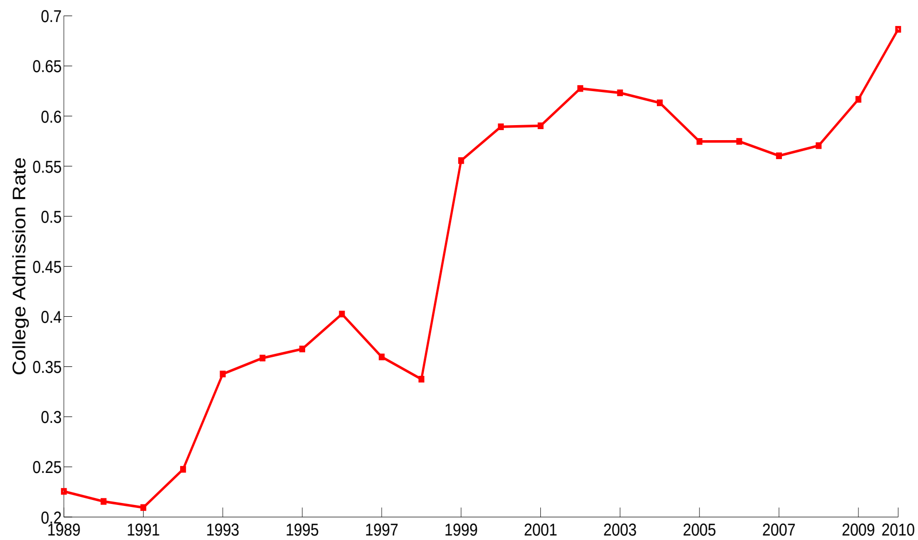
[11] Calculated as the ratio of college admitted population by the population taken the NCEE in the same year according to the Ministry of Education.

[12] [14] and [15]

[13] "Thirty years of evolution and development in education", http://theory.people.com.cn/GB/49157/49166/8143089.html.

[14] According to the China Statistical Yearbook 2005.

Figure 1.2: College Admission Rate



amount through tuition and fees. Indeed, the expenditure on education ranked the first in total household expenditure in the 10th 5-year-plan.[15]

Private Financing and Tuition Fees. Higher education was free of charge and heavily subsidized by the government until 1989, when the dual-track system of tuition was set up, wherein students who scored below a cut-off line on the NCEE could attend colleges at a higher tuition level. The tuition fee was only 200 RMB per student in 1989, it grew to 610 RMB in 1993 , when the State Council stated that higher education is non-compulsory, and students should pay tuition in principle.[16] The tuition system was unified in 1997, and tuition and fees vary by institutions, locations and programs. As shown in the Table 1.2, the average per capita tuition and fees grew at at an annual rate of 11.8% from 1996 to 2011, peaking at annual growth of around 30% from 1996 to 1999.

[15] According to the China Youth and Child Research Center (CYCRC) 2007, Report on the Development of the China Youth During the 10th and 11th 5-Year-Plan.

[16] According to the Guidelines for China's Education Reform and Development in 1993.

Table 1.2: Per Capita Tuition and Fees

	1996	1997	1998	1999	2000	2001	2002	2003
Tuition and Fees	1477	1824	2145	2956	3464	3928	4324	4562
Growth Rate (%)	34.3	23.5	17.6	37.8	17.2	13.4	10.1	5.5
	2004	2005	2006	2007	2008	2009	2010	2011
Tuition and Fees	4857	5071	4931	6489	7017	7182	7510	7850
Growth Rate (%)	6.5	4.4	-2.7	3.2	8.1	2.4	4.6	4.5

Reliance on household wealth to finance students' tertiary education, the lack of well-established credit markets, and substantial increases in tuition and fees might restrict the opportunities for students from poor families to attain a college education. Studies on China's household wealth universally report the huge and increasing income and wealth gap ever since the economic reforms in 1978, between rural and urban households. The Figure 1.3 displays the tuition burden by household residential status, calculated as the ratio of average per capita tuition and fees over the annual per capita disposable household income.[17] Tuition and fees have been well over the average per capita disposable incomes of rural households since 1999, while for urban households, it is around half of average per capita income. Thus China's geographic unbalance and segregation could potentially affect enrolment decisions through financial constraints faced by different residential groups.

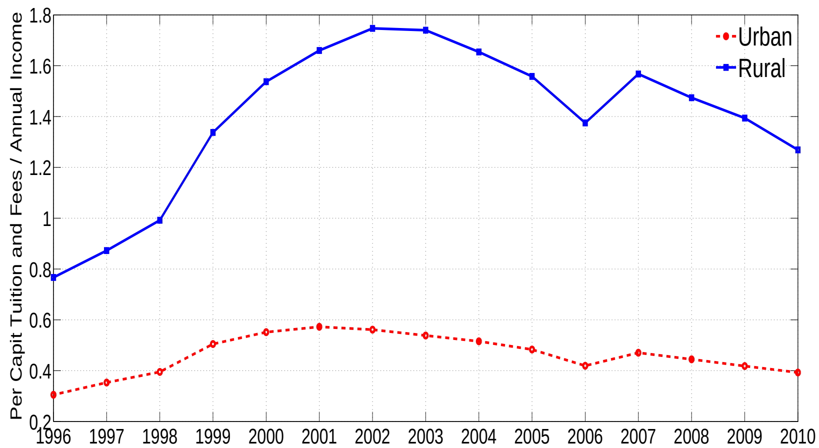
1.3 Baseline Model

In this section, I consider a heterogeneous-agent OLG model. The economy is populated with a continuum of individuals, each live for finite periods, with age indexed by $j = 1, \ldots, T$. Individuals start with high school graduation $(j = 1)$, survive from age j to $j + 1$ with probability ζ^j, and die after period T for sure. Time is discrete, at each period a new cohort of measure one enters the economy. Since cohort size and survival probabilities are time-invariant, the model age distribution is stationary.

We assume a risk-free asset market for simplicity, consumers could borrow at the

[17] Based on the tuition and income statistics from NBS, various years.

Figure 1.3: College Tuition Burden by Residential Status



risk-free interest rate up to a borrowing constraint $\underline{a}$. Workers in different education and age groups are imperfect substitutes in production.

1.3.1 Timing

At birth, individuals observe their initial wealth and ability level, and choose to attend college or not. If they choose to go to college, they will spend the first 4 periods in college, living on their initial wealth and a very small amount of stipends endowed by the government. If instead they choose non-college, they work from period 1 and will earn the high-school wage.

Lifetime is composed of working and retirement periods, $T = T_W + T_R$. The working periods are 1 through T_W for high school workers, and 5 through T_W for college labor. In period $T_W + 1$ through T, individuals earn retirement pension that is a function of their effective working wage.

1.3.2 Consumer's Problem

Value Function. Instead of working, college students get an annual stipend y_{col} in the first 4 periods: $j = 1, \ldots, 4$, after graduation, college workers work in periods

$j = 5, \ldots, T_w$. High school graduates work through the whole working period.

A worker's labor income is composed by a wage level on efficient units of work by the corresponding age and education group, and her efficient units of labor supplied, as an exponential function of her ability, age and education level. Consider a worker at age j, ability level b and education $e \in \{H, C\}$, denoting high school and college education respectively. Age efficiency schedule $N(j, b, e)$ is assumed to follow an exponential function of a second-degree polynomial with coefficients depending on worker's ability and education.

$$V(j, e, b, a) = \max_{c,a'} \{U(c) + \beta\zeta^j V(j+1, e, b, a')\}$$

subject to

$$\begin{aligned} c + \zeta^j a' &= (1+r)a + y \\ y &= \begin{cases} w_j^e N(j, b, e)(1-\tau) & \text{if working} \\ y_{col} & \text{if j=1,\ldots, 4 and e=C} \end{cases} \\ a' &\geq \underline{a} \end{aligned}$$

Consumers are subject to borrowing constraint $\underline{a}$ each period, and make their consumption as well as saving choice for next period a'. One unit of savings delivers $1/\zeta^j$ units of assets next period, reflecting the annuity-market survivors' premium.

After retiring at the end of period T_w, individuals earn a retirement pension $\phi(e, b)$ as a function of their effective working wage determined by education and ability levels, for periods $j = T_w + 1, \ldots, T = T_w + T_R$

$$\begin{aligned} V(j, e, b, a) &= \max_{c,a'} \{U(c) + \beta\zeta^j V(j+1, e, b, a')\} \\ c + \zeta^j a' &= (1+r)a + \phi(e, b) \\ a' &\geq \underline{a} \end{aligned}$$

Education Choice. In the beginning of their life-time, individuals make college enrolment decisions with full knowledge of their initial ability and asset endowments. The government controls the total college admission by choosing the ability threshold $\underline{B}$, where in equilibrium the desired college admission E_t^C satisfies:

$$E_t^C = \iint\limits_{\underline{B^t}} \eta(b,a) dF(b) dF(a) \tag{1.1}$$

With both types of workers' value function defined above, individual's education choice is belowing:

$$\mathbb{V}(b,a) = \begin{cases} \max\{V(1,C,b,a), V(1,H,s,a)\} & \text{if } b \geq \underline{B^t} \\ V(1,H,b,a) & \text{if } b < \underline{B^t} \end{cases} \tag{1.2}$$

$$\eta(b,a) = \begin{cases} 1 & \text{if } \mathbb{V}(b,a) = V(1,C,b,a) \\ 0 & \text{if } \mathbb{V}(b,a) = V(1,H,b,a) \end{cases} \tag{1.3}$$

The first order condition can be written as the following equation if a is not binding, where c is the current period consumption and c' is consumption in the next period:

$$u'(c) = \beta(1+r)u'(c') \tag{1.4}$$

1.3.3 Firm's Problem

There is a large number of competitive firms, with the following production technology, where H_t and C_t denote the aggregate high-school and college educated labor.

$$F(H_t, C_t, K_t) = AK_t^{1-\alpha}(\theta_{ct}C_t^\rho + \theta_{ht}H_t^\rho)^{\frac{\alpha}{\rho}}$$

$$H_t = \left(\sum_{j=1}^{T_w} \alpha_j H_{jt}^\eta\right)^{\frac{1}{\eta}}, \quad C_t = \left(\sum_{j=1}^{T_w} \beta_j C_{jt}^\eta\right)^{\frac{1}{\eta}}$$

I assume imperfect substitution between different age and education groups, following the assumption in [2]. $-\infty < \rho \leq 1$ is a function of elasticity of substitution σ_E between the two education groups, where $\rho = 1 - 1/\sigma_E$. Similarly, $-\infty < \eta \leq 1$ is a function of the partial elasticity of substitution σ_A between different age groups and same education level, $\eta = 1 - 1/\sigma_A$. α_j, β_j and $\{\theta_{ct}, \theta_{ht}\}$ sequences are the relative effective parameters between age and education groups. When $\alpha_j = 1$, $\beta_j = 1$ and $\eta = 1$, labor inputs are perfect substitutable with same education and different age.

In each period, the representative firm takes both wages and interest rate as given, and choose its optimal college and high-school labor c_j, h_j and investment demand i:

$$\Omega(k) = \max_{c_j,h_j,i} F(H,C,k) - \sum_j w_j^c c_j - \sum_j w_j^h h_j - i + \frac{1}{1+r}\Omega(k') \tag{1.5}$$

subject to: $k' = (1-\delta)k + i - \frac{\epsilon}{2}(\frac{i}{k} - \delta)^2 k$, δ denotes the steady-state depreciation rate, and ϵ is the investment cost parameter.

The first order conditions are:

$$\begin{aligned}
\frac{1+r_t}{1-\epsilon(\frac{i_t}{k_t}-\delta)} &= \alpha A k_{t+1}^{\alpha-1}\left(\theta_{ct+1}C_{t+1}^{\rho} + \theta_{ht+1}H_{t+1}^{\rho}\right)^{\frac{1-\alpha}{\rho}} + \frac{1-\delta+\frac{\epsilon}{2}(\frac{i_{t+1}^2}{k_{t+1}^2}-\delta^2)}{1-\epsilon(\frac{i_{t+1}}{k_{t+1}}-\delta)} \\
w_{jt}^C &= \alpha\beta_j\theta_{ct}Ak^{1-\alpha}C_t^{\rho-\eta}(\theta_{ct}C_t^{\rho}+\theta_{ht}H_t^{\rho})^{\frac{\alpha}{\rho}-1}C_{jt}^{\eta-1} \\
w_{jt}^H &= \alpha\alpha_j\theta_{ht}Ak^{1-\alpha}H_t^{\rho-\eta}(\theta_{ct}C_t^{\rho}+\theta_{ht}H_t^{\rho})^{\frac{\alpha}{\rho}-1}H_{jt}^{\eta-1}
\end{aligned}$$

In the steady state, the first equation reduces to:

$$r+\delta = \alpha A k^{\alpha-1}\left(\theta_{ct}C_t^{\rho}+\theta_{ht}H_t^{\rho}\right)^{\frac{1-\alpha}{\rho}}$$

1.3.4 Equilibrium Definition

A stationary equilibrium in this economy is a set of value functions and decision rules for the households: $\{c_t(j,e,b,a),\ a_{t+1}(j,e,b,a),\ \eta_t(b,a), V_t(j,e,b,a)\}$, firms' optimal decision C_t, H_t, K_t, the capital rental rate r, and the wage rate for college and non-college labor, w_{jt}^C, w_{jt}^H, such that

1. Given the labor income tax τ, and initial endowments, individuals' decision rules and value functions solve problems (1.1).

2. Firms' decisions solve the corresponding problem (1.5).

3. Asset market clears

$$K = \sum_{j=1}^{T}\mu_j \int a(j,e,b,a^{-1})dF(b,s,a^{-1}), \tag{1.6}$$

4. College labor market for each cohort clears, $j = 1,\ldots,T_w$:

$$C_j = \mu_j \int \eta(b,a)dF(b,a) \tag{1.7}$$

5. High-school labor market for each cohort clears, $j = 1, \ldots, T_w$:

$$H_j = \mu_j \int (1 - \eta(b, a)) dF(b, a) \tag{1.8}$$

6. The government chooses college entry threshold $\underline{B^t}$ and the budget constraint satisfies

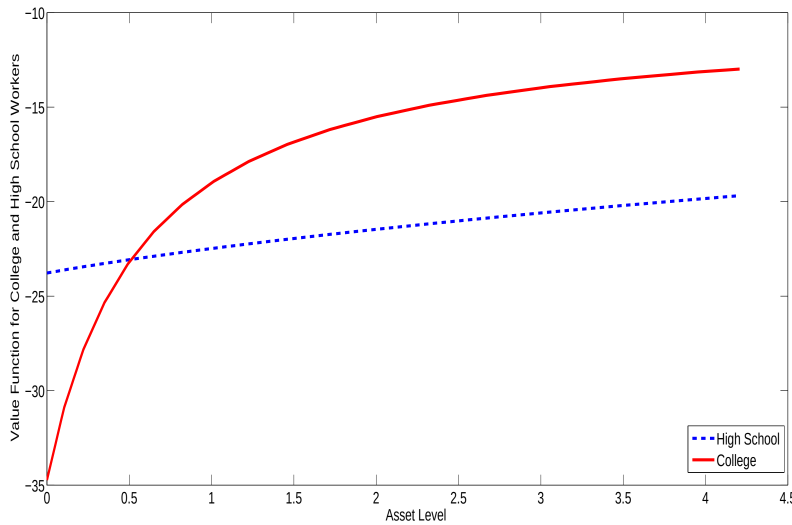
$$\begin{aligned} \sum_{e=C,H} \sum_{j=T_w+1}^{T} \mu_j \int f^r w^e_{T_w} \phi(e, b) dF(b) + \sum_{j=1}^{4} \mu_j \int_{\underline{B^t}} y_{col} dF(b) \\ = \tau \mu_j \sum_{j=5}^{T_w} \int w^C_{jt} N(j, b, C) \eta(b, a) dF(b, a) \\ + \tau \mu_j \sum_{j=1}^{T_w} \int w^H_{jt} N(j, b, H)(1 - \eta(b, a)) dF(b, a) \end{aligned} \tag{1.9}$$

1.3.5 Model Mechanism

In this section I will discuss the general equilibrium effects of an expansion in the college entry class. In the initial steady state, individual college enrolment decision depends on the comparison of life-time value out of college and high school education. As shown in Figure 1.4, individuals with little initial assets would prefer to go to work early to consume more early on, and wealthy agents would prefer to go to college and earn a positive college wage premium in their life-time. There is also a positive correlation between individual ability level and the probability to go to college, since smarter workers could generally reap more benefits from the college education, as shown by Figure 1.5.

We could further graph the education choice outcome of an individual characterized by both ability and initial wealth level as in Figure 1.6. The college admission was determined by both individual preferences and the college entrance ability threshold set by the government. As college expands by a substantial magnitude, the increased college labor supply will drive down the college wage premium where less workers would choose to enrol. Thus, for the same amount of assets, individuals need to be endowed with more ability to be willing to go to college, and for the same level of ability, they should be wealthier to attend. The indifference curve of college education choice is driven to the right in the mid-panel of Figure 1.6.

Figure 1.4: Value Functions over Initial Asset Levels for College and High School Education



1.4 Empirical Analysis

This section presents (1) the time series of college wage premiums and the effective college over high-school labor supplies, for different age and residential status groups, (2) strong negative correlations between the change in college wage premiums and the labor supply in the periods immediately after the college expansion in 1999, and (3) a second-stage estimation of elasticities of substitution between age and education groups.

1.4.1 College Wage Premiums

College Wage Premiums by Age Groups. Table 1.3 presents the estimated college wage premiums for five-year age groups, taken at each survey year in CHNS from 1993 onwards. The college wage premiums are estimated in separate regression models for each age group in each survey year, using samples of full-time workers with exactly a high school or exactly a college degree. Each regression includes a dummy for college graduates, a linear age term, and dummies for other demographic properties, gender and residential status.

An important feature of the college wage premium in Table 1.3 is that they are based on differences in earnings between individuals of the same age with a college degree or a high school diploma. This measure compares individuals who attended elementary and secondary schooling together, and faced the identical scenarios when they made decisions to attend college or not. Depending on our interest in explaining the effects of college expansion policy on college entrance choices and the systematic age effects in our econometric models, this measure will outweigh the potential disadvantage of ignoring different labor market experience in the same age groups who have different level of schooling.

Table 1.3: College-High School Wage Differentials by Age and Year

	Age Range							
	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60
1992	-0.149	-0.347	-0.004	-0.108	0.149	-0.244	0.674	0.045
	(0.054)	(0.028)	(0.028)	(0.016)	(0.016)	(0.040)	(0.039)	(0.018)
1996	-0.096	-0.059	0.186	0.089	0.281	0.292	-0.096	0.195
	(0.023)	(0.011)	(0.027)	(0.016)	(0.014)	(0.019)	(0.019)	(0.051)
1999	0.158	0.096	-0.066	0.110	0.146	0.138	0.089	0.361
	(0.013)	(0.016)	(0.016)	(0.009)	(0.010)	(0.008)	(0.032)	(0.014)
2003	0.215	0.172	0.309	0.156	0.250	0.388	0.194	0.315
	(0.012)	(0.013)	(0.017)	(0.013)	(0.009)	(0.012)	(0.014)	(0.048)
2005	0.197	0.295	0.315	0.224	0.493	0.489	0.359	0.324
	(0.027)	(0.008)	(0.009)	(0.008)	(0.008)	(0.009)	(0.021)	(0.026)
2008	0.075	0.208	0.263	0.161	0.240	0.531	0.570	0.441
	(0.024)	(0.012)	(0.017)	(0.014)	(0.014)	(0.016)	(0.014)	(0.026)
2010	0.047	0.272	0.267	0.296	0.411	0.383	0.395	0.487
	(0.010)	(0.005)	(0.005)	(0.006)	(0.004)	(0.005)	(0.008)	(0.010)

The entries in Table 1.3 provide a variety of information on the evolution of college-high school wage differentials Comparisons across the rows of Table 1.3 reveal the age profile of the college-high school wage differentials in the particular survey year. Across the years, the age profiles generally show a hump-shape with the maximum obtained around age 41-50. And comparing down a column of the table shows the changing college premium for a particular age group.

Panel A of Figure 1.7 graphs the time series of college wage premium across three representative age groups. Among the youngest group, 21-25 years olds, the college wage premium increases until 2003, when the first cohort of college students who is impacted by the college expansion policy in 1999 graduates, and immediately decreases from that year onwards. For older groups, their college wage premium generally rose until later than 2008 then slowly levelled off. The college wage premium trends across different age groups in Figure 1.7 show that the college wage premiums for specific age groups can rise or fall independently of other groups, suggesting the potential importance of the age effects on the college wage premium.

College Wage Premium by Household Registration Status. Using the detailed household registration information from CHNS,[18] Table 1.4 documents the college premium by individual's household residential status across survey years. Rural workers have lower college wage premiums until 1996, it grew sharply and overtook the college wage premium of the corresponding urban workers from 1996 to 1999 when tuition fees increased. After 2003, the college wage premium generally levelled off. While for urban workers, the college wage premiums stay below the corresponding rural premiums since 1999, and it began to decrease after 2005, as shown in the panel A of Figure 1.8.

Table 1.4: College-High School Wage Differentials by Residential Status

	Survey Years								
	1988	1990	1992	1996	1999	2003	2005	2008	2010
Rural	0.092	0.049	-0.229	0.054	0.189	0.554	0.503	0.523	0.478
	(0.006)	(0.004)	(0.017)	(0.007)	(0.006)	(0.008)	(0.006)	(0.006)	(0.004)
Urban	0.038	0.022	0.105	0.100	0.165	0.247	0.377	0.315	0.354
	(0.001)	(0.001)	(0.005)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)

[18] When individuals surveyed multiple times throughout the survey series, the earliest available household registration status information is taken.

1.4.2 Relative Supply

We turn next to an overview of the relative supplies of college-educated labor by age and residential status. Following [1], I measure efficient supply of labor by each demographic group as weighted total hours worked in that group, where the weighting being the average relative wage across all the survey years. I then take the log ratio of the effective college over high school hours as the relative supply of college versus high-school labor.

Panel B of Figure 1.7 shows the evolution of the relative college labor in three representative age groups: 21-25 years olds, 26-30 years olds and 46-50 years olds. For the 21-24 years-old group, relative college labor supplies grow most sharply from 1999 to 2003, while for older groups, the relative supplies trended upwards fairly steadily after 1999.

The relative college labor supply by household registration status is shown in Figure 1.8. The general college labor supply is higher across the years for urban hukou-holders. To compare the growth rate of relative college labor supply, I use the y-axis on the left to show the relative college labor supply for rural workers, the corresponding urban labor supply is presented using the y-axis on the right. The relative college labor supply grows at around the same rate for both residential groups from 1996 to 2003, when the college tuition grows fast. After 2003, the rural college labor grows strictly faster.

Using the detailed individual education history from CGSS surveys, we construct the rural student's ratio over all the college applicants (those who took college entrance examination in their senior years of high school) , and the rural students' proportion over all the actual college enrolment population, by the years when they took the National College Entrance Exams, as in Figure 1.9. For both the application and enrolment trends, the relative ratio of rural students didn't grow until after 1999, this confirms the change of relative college labor supply among different residential groups. And one possible reason might be that rural residents are restricted by their available family resources to finance the substantial increase in college tuition and fees. From 1997 to 1999, the rural students' college enrolment ratio dropped even more than their corresponding application ratio.

1.4.3 Elasticity Estimation

Figure 1.10 graphs the times series of college wage premium and the corresponding relative labor supply. The overall series for the college labor supply is upward sloping, the supply grows faster than average after 1996, especially after 2003 when the first cohort of college labor graduates out of the college expansion in 1999. In the meantime, the college wage premium began to fall after 2005, it appears that fluctuations in supply growth has the potential to explain observed college wage premium changes, especially after 2005. To further examine the negative correlation between the college wage premiums and the relative college labor supplies, we present the changes in these two variables from 2003 to 2008, in 64 distinct age, gender and education groups in Figure 1.11.

Thus, using the first order conditions from the firm's problem, as in [2], and applying a linear time trend to proxy the technology shock ($\log(\theta_{ct}/\theta_{ht})$) and the aggregate supply effect ($(\frac{1}{\sigma_E} - \frac{1}{\sigma_A}) \log(\frac{C_t}{H_t})$), we get the first stage estimates (REG1) for the elasticity for age-group specific college labor supply. The estimated year effect, as shown in the first column of Table 1.5 is positive and significant.

$$\log\left(\frac{w_{jt}^C}{w_{jt}^H}\right) = \log\left(\frac{\beta_j}{\alpha_j}\right) + \log\left(\frac{\theta_{ct}}{\theta_{ht}}\right) - \left(\frac{1}{\sigma_E} - \frac{1}{\sigma_A}\right)\log\left(\frac{C_t}{H_t}\right) - \frac{1}{\sigma_A}\log\left(\frac{C_{jt}}{H_{jt}}\right) + e_{jt}$$

$$\text{REG1}: \quad \log\left(\frac{w_{jt}^C}{w_{jt}^H}\right) = b_j + dt - \frac{1}{\sigma_A}\log\left(\frac{C_{jt}}{H_{jt}}\right) + e_{jt}$$

The second and third column of Table 1.5 presents the estimates of the second-stage models that include both age-group specific relative college labor supplies and the aggregate labor supply. Where the relative productivity efficiency effect ($\log(\beta_j/\alpha_j)$) is estimated on the first stage age-group elasticity, and the aggregate supplies of college and high school labor time series is constructed assuming perfect (as in REG2) and imperfect (as in REG3) substitution across age groups with same education. The estimated elasticity of substitution between college and high school labor is in the range of 1.1 to 1.9, comparable to the estimates in [1] and [2].[19] And my estimation of elasticity of substitution between different age groups are in the range of 4.4 to 7.6, generally higher than the estimates range of 4 to 6 from [2]. The estimates of age-group

[19] I compare my estimation results with the elasticity estimates from United States of [1] and [2] in Table 1.6.

Table 1.5: Estimated Models for the College-High School Wage Gap

	REG1	REG2	REG3
Age-group specific relative supply	-0.138*	-0.134*	-0.130*
	(0.054)	(0.060)	(0.060)
Time Trend	0.024***	0.027**	0.026***
	(0.004)	(0.009)	(0.005)
Katz-Murphy aggr. supply index		-0.193	
		(0.158)	
Aggr. supply index with imperfect substitution			-0.173*
			(0.069)
R^2	0.745	0.746	0.748
pvalue	0.001	0.001	0.001

Table 1.6: Elasticity Estimates Comparison

Elasticities	China(CHNS,CGSS)	U.S.(Katz& Murphy)	U.S.(Card& Lemieux)
Age-group (σ_A)	4.4-7.6		4-6
Col-High (σ_E)	1.1-1.9	1.4	1.1-1.6

elasticities from the second-stage are close to the first-stage results, and the year effects across different specification show a steeply rising returns.

1.5 Calibration

Given the elasticities estimation in Section 1.4, I calibrate the parameters by choosing an initial steady state which is consistent with the pre-expansion policy data. Assuming that after the college expansion, only the ability threshold for college entry changes, I present the implications of the calibrated model for college wage premiums and relative college labor supply for different subgroups, both in comparative statics and the simulated transition path.

1.5.1 Parameter Choices

Exogenously Determined Parameters A model period corresponds to one year of calendar time. Individuals enter the economy at age 21 and retire at age 55 (working periods $T_w = 35$). Retirement lasts for 15 years, and everyone dies at age 70. The net interest rate, r, is set equal to 2%. Since there is no leisure decision involved, I use the conventional power utility specification of preferences, and the risk aversion for utility function is set equal to 2.0. The labor share of the Cobb-Douglas production technology is set at 0.50, broadly consistent with the existing empirical evidence.[20] Table 1.7 shows all the exogenously determined parameters.

Table 1.7: Exogenously Determined Parameters of the Baseline Economy

Description	Parameter	Value	Remark
Risk aversion	σ	2.0	
Interest rate	r	0.02	
Discount rate	β	$1/(1+r)$	
Labor Share	α	0.5	
Survival Rate from j to $j+1$	ζ^j	—	WHO(2000)
Els of substitution btw age groups	σ_A	7.60	Estimation from data
Els of substitution btw edu groups	σ_E	1.40	Estimation from data
Working periods	T_w	35	years: 21-55
Retirement periods	T_r	15	years: 56-70

Distributions: Ability, Initial Wealth for Rural and Urban Groups Agents enter the economy with perfect knowledge of two individual-specific attributes: ability and initial assets endowment. Accounting for the sizeable gap between the rural and urban household, not only in income and wealth level, but also in the education

[20] As in [16] and [17].

resources,[21] , I assume different distribution parameters for rural and urban groups.

The initial asset is assumed to follow log-normal distributions for both groups, and the ability is assumed to be uniformly distributed. Thus the distribution of ability and initial assets yield six parameters to be calibrated: (i) the standard deviation of ability for both groups, (ii) the mean ability level for the rural group, and (iii) the mean and standard deviation of initial wealth level for both groups (the average rural ability and rural wealth level are simply set to a computationally convenient level).

Data Targets I use the wage series from micro-econometric evidence of the panel data to pin down the ability distributions for both age groups. For initial wealth distribution for rural and urban individuals, I use the target of aggregate household disposable income as well as the corresponding Gini coefficients.[22] The detailed list of steady state targets are listed in Table 1.8.

Table 1.8: Steady-State Targets and Associated Parameters

	Parameter	Value	Target	Data
Threshold (Initial)	$\underline{A_1}$	0.60	College admission rate before the expansion	0.33
Threshold (After Expansion)	$\underline{A_2}$	0.35	College admission rate after the expansion	0.56
SD of ability (Rural)	σ_b^R	0.29	SD of log wage for rural workers	1.09
Average Ability (Rural)	$E[b]^R$	0.5	Mean log wage for rural workers	5.13
SD of ability (Urban)	σ_b^U	0.29	SD of log wage for urban workers	0.95
Average Ability (Urban)	$E[b]^U$	0.65	Mean log wage for urban workers	5.23
SD of initial asset distr. (Rural)	σ_a^R	0.7	Rural Gini-Coefficient	0.35
Mean of initial asset distr. (Rural)	$E[a]^R$	1.0	Rural Household Disposable Income	2210
SD of initial asset distr. (Urban)	σ_a^U	2.0	Urban Gini-Coefficient	0.25
Mean of initial asset distr. (Urban)	$E[a]^U$	2.65	Urban Household Disposable Income	5854

Age Efficiency Schedule and the Pension Scheme. To make sure labor income sequences generated by the model be consistent with the empirical evidence on the dynamics of wages found in the panel data, we need to select the functional forms for the age efficiency schedules and the retired pension scheme. Specifically, I assume the

[21] As documented by [18] and [19] there are huge gaps in educational funding, teacher qualifications, and school conditions between rural and urban schools.

[22] Income statistics from NBS, various years.

age efficiency follows an exponential function of a quadratic polynomial on individual age $f(j)$, and an individual component that follows a linear function of age, with the coefficient determined by individual ability and intercept by education level.[23]

$$N(j, b, e) = \exp\Big[f(j) + bj + g(e)\Big]$$

We model the pension system in China as a defined benefits plan, as in [20], the replacement ratio is assumed to be 60%. And this is also general in line with the retirement labor income in the survey data, so we approximate the pension scheme to be 60% of the average life-time labor income. The subsidy for college education y_{col} is assumed to be 30% of the current average wage, which closely assembles the average living expenses for a college students.

1.5.2 Quantitative Results

In this section, I begin by presenting the comparison of two steady states, before and after the college expansion policies. I then proceed to give out the simulation results on the transitional path of the key variables of interest.

The Long-term Impacts of a College Expansion: Steady State Comparison. As shown in Table 1.9, as the ability threshold is lowered by the government, college wage premiums are decreased for both groups by similar magnitudes, where the college labor supply increased much more in rural than urban groups. This is also shown by a 35% increase in the admission rate for rural students, where only less than 20% increase for the corresponding urban groups in the long run.[24] It seems in the long run, the ability effects dominate. Rural students are concentrated around the a relatively lower level of ability, with less initial wealth. As the ability threshold decreases, more rural students could access the college education with an ability level below the initial threshold and above the later one. On the other hand, urban students' ability are generally higher, so they are not affected as much by the expansion.

[23] As in [7], the regression residual of a raw wage on a polynomial in age is assumed to follow a linear trend in age, with coefficients and intercepts determined by a pair of perfectly correlated learning abilities.

[24] This is in line with our estimation of rural college enrolment ratio using CGSS data in Figure 1.9 and as documented by [18].

Table 1.9: Steady State Comparison

	Average College Wage Premium	Log Relative College Labor Supply	Admission Rate
Baseline(Rural, Before)	1.09	-1.19	0.21
Baseline(Urban, Before)	1.10	0.14	0.50
Baseline(Rural, After)	0.28	-0.33	0.47
Baseline(Urban, After)	0.29	0.65	0.70

Transitional Dynamics. Figure 1.12 displays the transition path of the college enrolment rates for urban and rural students in Panel A. There is a clear overshooting trend that the initial admission rates increase by over 40%, then gradually decrease over time as more college labor supplied and college wage premium driven down. Panel B shows the relative college labor supplied, it doesn't increase much in the first four periods before the first cohorts of students affected by the expansion policy graduates, then it also overshoots to a higher level than the new steady state college labor supply, and gradually decreases afterwards. Rural college labor increases much more than the corresponding urban labor. Panel C presents the percentage decrease in college wage premium, the premium decreases most in the first four years after the expansion, and increases gradually after that. The general patten of transitional dynamics are in line with our empirical trends in Section 1.4.

1.6 Counterfactual Experiments

In Nov 1998, the chief economist Dr. Min Tang, at the Beijing representative office of the Asian development bank, wrote a proposal to the Premier Minister Rongji Zhu on expanding the college admission by one fold in three years.[25] The initial proposal was to increase the college entry class by 25% annually until it expand the college admission population by one fold in three to four years. The suggestion was quickly taken into consideration by the Ministry of Education, and the initial target in early 1999 was set

[25] Published in the Economic News on Feb. 19th, 1999 under title of "Education to Promote Consumption", http://finance.sina.com.cn/review/20041023/15201102716.shtml.

to increase the college entry class by 21% from the previous year. However, in June of 1999, the official policy by the State Council increased the college admission quota by 47.4%,[26] which largely exceeded the initial expansion plan.

In this section, I conduct counterfactual analysis using the calibrated model in Section 1.5. The policy experiment is on an alternative conservative expansion policy, closely resembles the initial proposal by Dr. Min Tang, and the plan of the Ministry of Education in the early 1999. Comparisons are made between the actual policy expansion and the alternative policy experiments with welfare analysis on different residential groups.

Mild College Expansion Policy In view of the recent decreasing in the college wage premium, and especially in the young college graduates, as shown in Figure 1.7, there are heated debate on the possible oversupply of college graduates in China. In the first counterfactual experiment, I examine the alternative effects on enrolment decisions and the corresponding relative college labor supply and college wage premiums, for different residential groups. I increase the college entry class by 20% each year for 3 consecutive years, which will generate an increase of total enrolment population by only one fold, and I keep the admission rate constant after the expansion. Comparing to the actual college expansion starting from 1999 in China, which increase the total enrolment population by five folds in just 6 years, the policy experiment is a conservative and mild expansion policy.

Panel A of Table 1.10 presents the college enrolment results, with just a mild expansion, the overall admission rate is increased by only 30%, and although rural enrolment rate grows faster than the urban groups, the overall relative college labor supply increases by only 57 log points, comparing to an increase of 86 log point in the college expansion in 1999. As for the urban groups, the relative college labor supply increases by 9 log points less than the expansion in 1999. Thus a mild college expansion would generate less college labor supply, especially for the rural groups. A long-term welfare comparison from the Panel C shows that the overall welfare will increase by less than the actual college expansion, and this is specially phenomenal for the rural group, with

[26] According to "What's the decision process for the College Expansion?" at http://learning.sohu.com/20140619/n401049674.shtml.

a slightly increase of 6.87% comparing to an original 22.70% of increase in their welfare. Since the overall growth in college labor supply in urban groups is less than rural students, a mild college expansion will increase their welfare by curbing the decrease of the college wage premium.

Table 1.10: Experiment I: Mild College Expansion

Panel A: Admission Rates

	All	Urban	Rural
Before Expansion	0.33	0.50	0.21
Base Expansion	0.56	0.70	0.47
Mild Expansion	0.43	0.61	0.32

Panel B: Relative College Labor Supply

Change (log points)	All	Urban	Rural
Base Expansion	66	51	86
Mild Expansion	46	45	57

Panel C:Long-term Welfare Comparison

Change (%)	All	Urban	Rural
Base Expansion	19.10	12.08	22.70
Mild Expansion	11.46	13.81	6.87

1.7 Conclusion

In this paper, I developed an empirically grounded dynamic overlapping-generation general equilibrium model with endogenous college education choice. It provides a better understanding of the college labor market by jointly considering an exogenous policy threshold and an endogenous ability selection conditional on the initial wealth. I allow for heterogeneity in ability and initial wealth, and produce a model that is consistent with the main features of life-cycle wage growth and the discrepancies between rural and urban workers that are the central features of the recent China labor market.

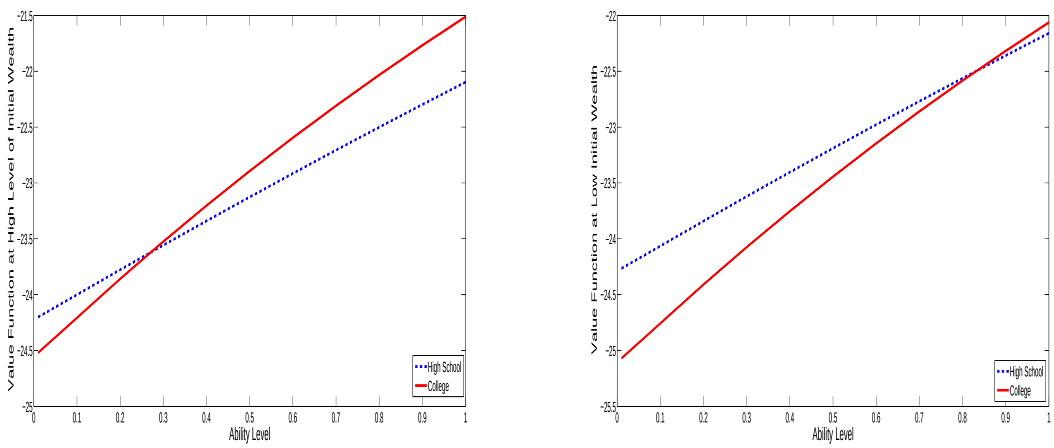
My empirical analyses suggest that there is significant heterogeneity in workers' response to the substantial college expansion in 1999. The urban students respond immediately to the college expansion with an overall higher initial asset level. However, as the college wage premium driven down by the increasing supply of young college graduates, intention for college enrolment decreased. On the other hand, rural students are constrained by their average low level of household income, the college labor supply increased gradually, and the overall growth in rural college labor exceeds the urban college labor supply. Also, the college-high school wage gaps of different age groups have not moved together. In particular, the college premium for young graduates fall immediately after the first cohort affected by the college expansion policy graduated in 2003, while the premium for older workers didn't level off until five to ten years later.

Following a model that incorporates imperfect substitution between different age and education groups, I found that the evolution of the college wage premiums accounts well for the patterns in data. The dramatic exogenous policy change in 1999 serves as a sharp identification strategy, to estimate the production demand elasticities on different categories of labor input. As a result, the estimated elasticities are generally comparable with the previous literature, with a slightly higher elasticities for different age groups.

Finally, I apply the calibrated model to a set of alternative government policies on college admission. This lays the foundation for the welfare analysis on different residential subgroups and generations. And the huge college expansion policy, as well as its effects on different subgroups, constitutes a good case study on acceleration in the supply of college educated workers across the developing countries.[27]

[27] [21] documented the age-profile of college wage premiums in India, Philippines and Thailand, and [22] docoumented the case in Vietnam.

Figure 1.5: Value Functions over Ability Levels



Value Function for High Initial Wealth

Value Function for Low Initial Wealth

Figure 1.6: College Enrolment with Ability Thresholds

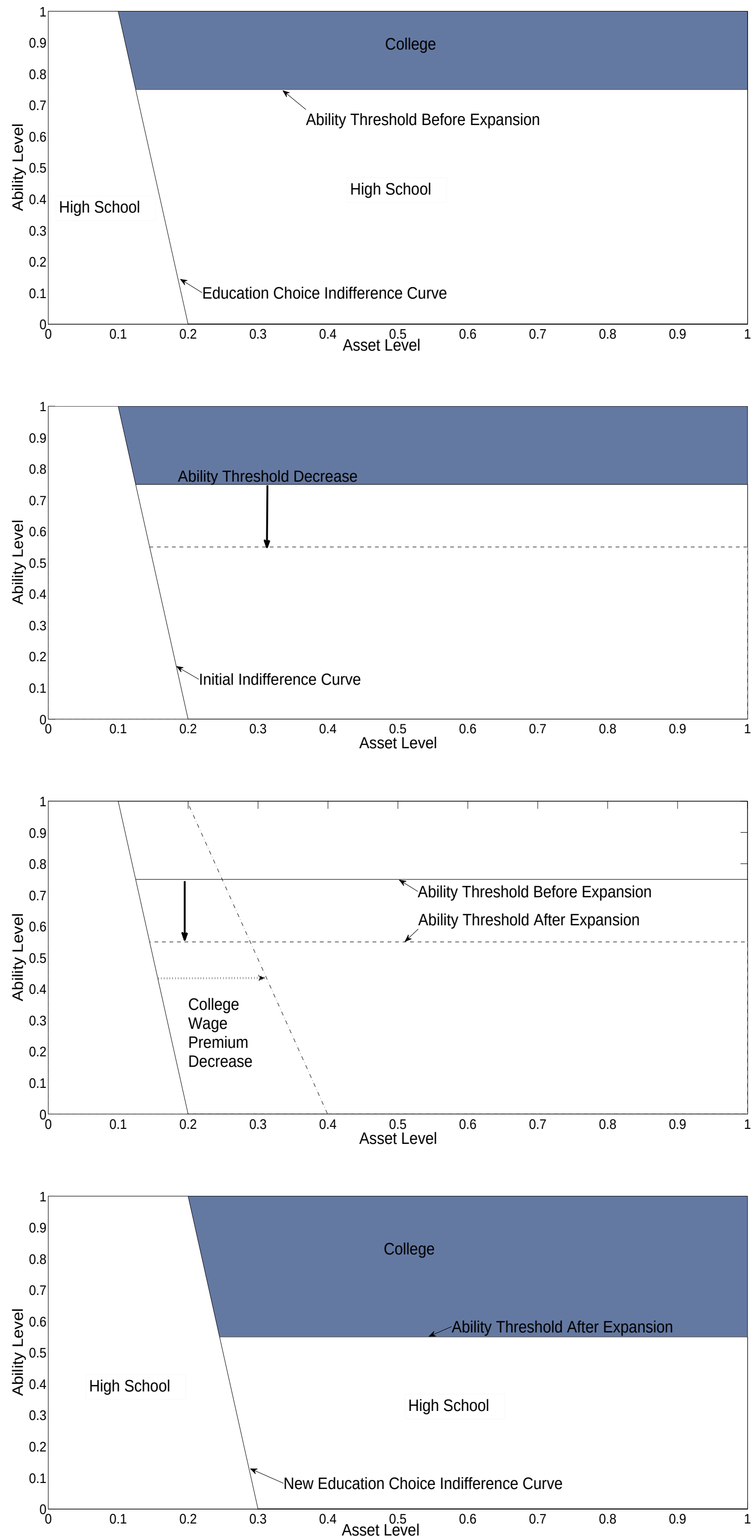
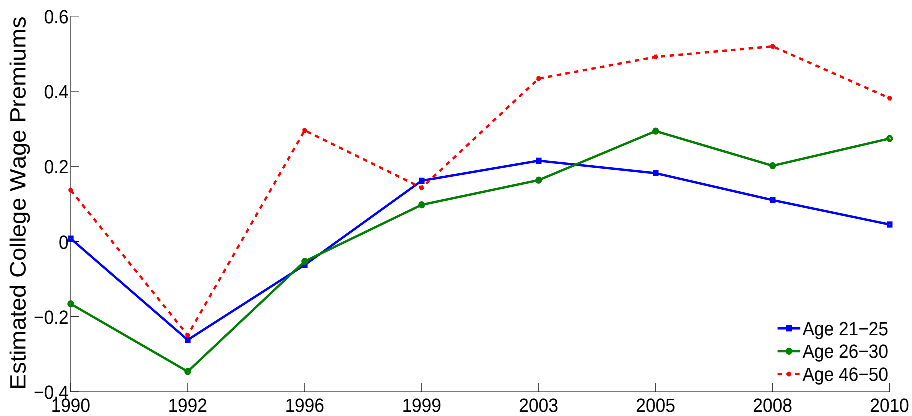
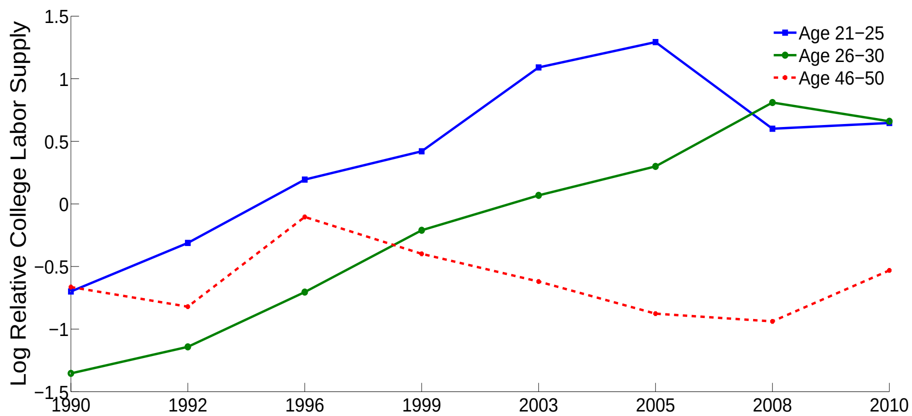


Figure 1.7: College Wage Premium and Relative Efficient College Labor Supply by Age Groups

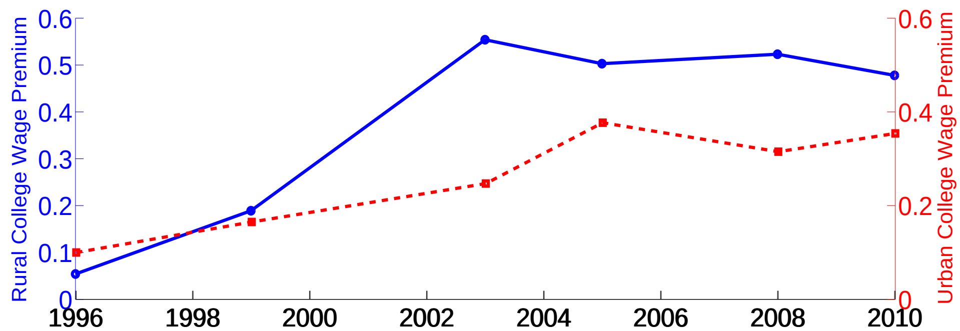


Panel A: Estimated Collge Wage Premium

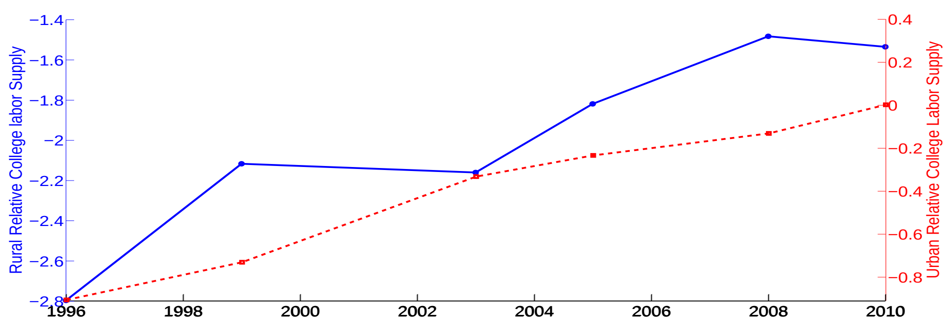


Panel B: Efficient College over High School Labor Supply

Figure 1.8: College Wage Premium and Relative Efficient College Labor by Residential Status



Panel A: Estimated Collge Wage Premium: Rural ——— Urban – – –



Panel B: Efficient College over High School Labor Supply: Rural ——— Urban – – –

Figure 1.9: Rural Students' Share for College Enrolment and Application

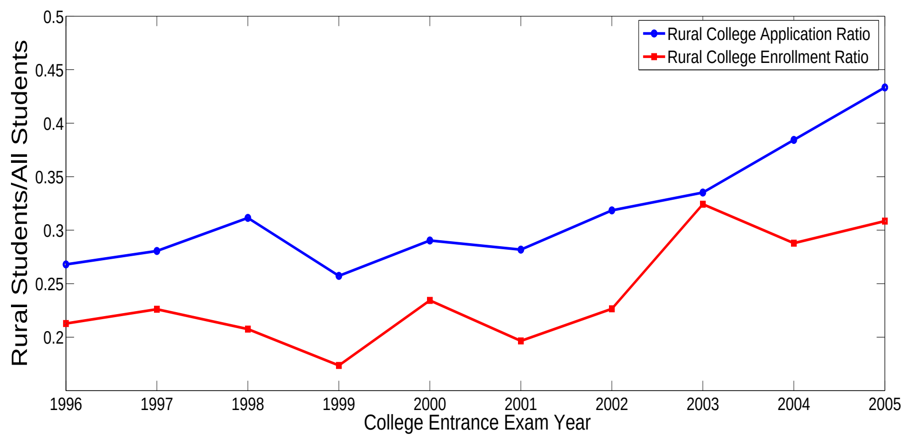


Figure 1.10: College Wage Premium and Relative College Labor Supply

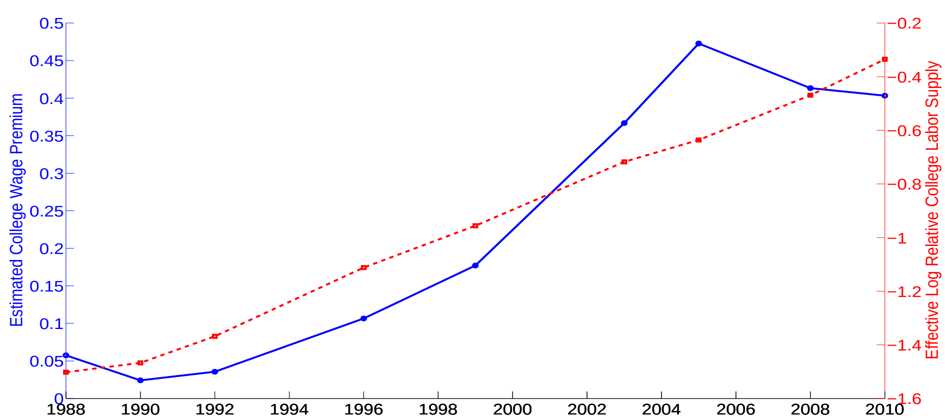


Figure 1.11: Price and Quantity Changes for 64 Groups, 2003-2008

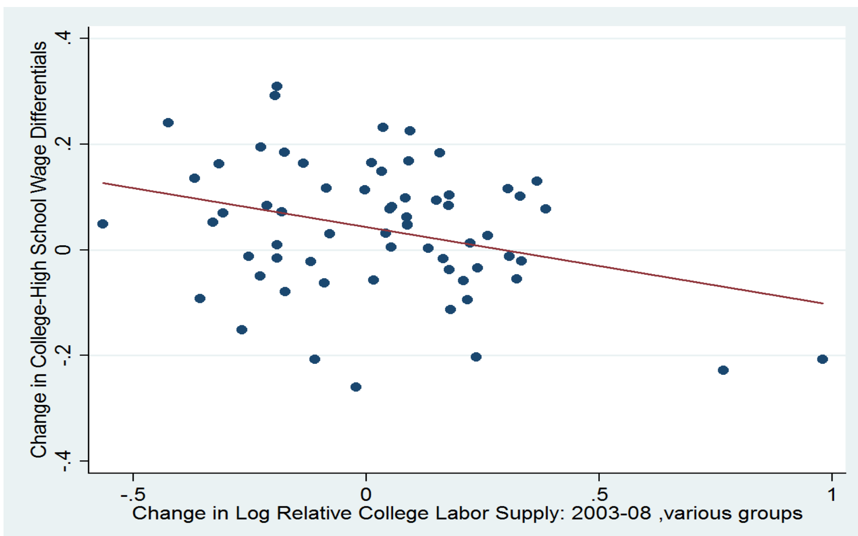
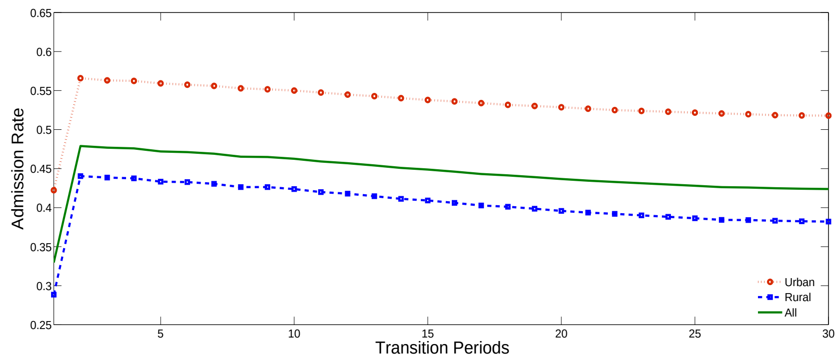
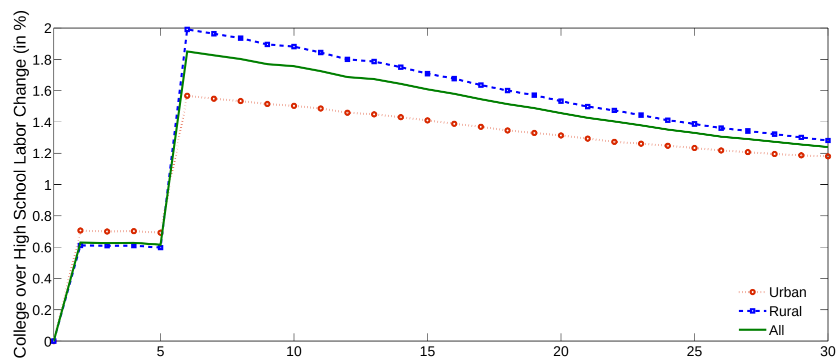


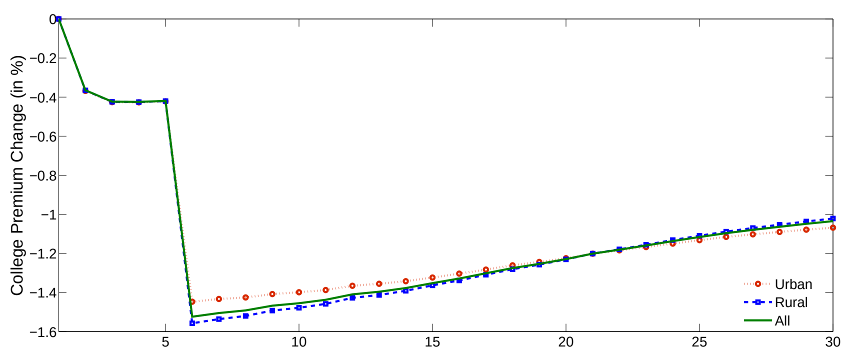
Figure 1.12: Transition Path by residential groups



Panel A: College Enrolment Rate



Panel B: Effective College over High School Labor Supply



Panel C: College Wage Premium

Chapter 2

Learning Your Earning over Business Cycles: Excess Consumption Volatility in Emerging Countries

2.1 Introduction

This paper emphasizes the individual learning about the heterogeneous income profiles (HIP)in explaining salient features of emerging market economies (EMEs) business cycles-large swings in consumption relative to output and countercyclical current account dynamics. To do so, we build a general equilibrium business cycle model with heterogeneous income profiles (HIP) and imperfect information. Agents observe the history of their own labor income and of a noisy public signal on aggregate total factor productivity (TFP) shock. They know the distributions of each components of their labor income process, but are faced with imperfect information that they cannot separate the aggregate and the idiosyncratic shocks. Using the available information, they form their own expectations about the aggregate TFP, the idiosyncratic shocks, and their own income growth rate in an optimal (Bayesian) fashion.

In our model, individual hourly wage income is composed of aggregate and idiosyncratic stochastic components, as well as an individual-specific income growth rate, which is multiplied by age. Agents observe their income to learn the growth rate of their individual human capital and the growth rate of the aggregate economy. Due to information frictions, a shock to the growth rate of the aggregate economy will be partly attributed to the growth rate of agents' own human capital, the latter of which has more persistent effects on agents' life-time income. As a result, the economy with more information friction will feature more volatile consumption dynamics relative to output.

To reconcile the key differences between emerging and developed economy business cycles, we introduce a noisy public signal on aggregate TFP. This allows us to vary the degree of information imperfection while keeping all the other structural parameters unchanged. Feeding in the parameters from [23] and calibrating to some key features on real interest rate and aggregate TFP, the imperfect information model can generate a higher variability of consumption relative to output. Starting from this baseline imperfect information model and reducing the noisiness (variance) of the signal, the model moments resemble more the developed economies (DCs) regarding variability of consumption and cyclical behaviour. This experiment shows that the degree of uncertainty that agents face while formulating expectations can potentially explain key differences of EME business cycles compared to DCs.

Why are information frictions important in accounting for EMEs' business cycles? Individuals in EMEs are likely to face more uncertainty because of lack of transparency, weaker quality of economic statistics, and greater policy uncertainty compared to DCs. These information frictions would make it harder for individuals in EMEs to predict the aggregate performance of the economy, which makes it difficult to differentiate a lower individual income profile from an aggregate TFP shock.

To compare the severity of information frictions in EMEs with DCs, we compare and analyze the behaviour of GDP growth forecasting in these regions. We first examine the forecasting errors for EMEs and DCs, and we find that the root mean squared error (RMSE) of the forecast errors in EMEs is three times that of the DCs, even after controlling for variability of GDP growth, we observe substantially higher unpredictability in EMEs. We also find a systematically non-zero means of errors in EMEs comparing to DCs, and the dispersion of analysts' forecasts for GDP growth is more than three times as much for EMEs compared to DCs. This motivates us to study efficiency of individual forecasts. As documented by [24], the magnitude of information rigidity for EMEs is twice as high as in advanced economies. And the distribution of the forecast revisions are more dispersed in EMEs compared to advanced economies, which implies that individual beliefs on GDP growth among EMEs are more at odds to each other comparing to advanced economies. These suggestive findings motivate us to build a structural model where agents have difficulty differentiating the growth rate of the aggregate economy from the growth rate of their own income profiles.

Related Literature. Our paper connects two strands of literature-the emerging market business cycles literature and the heterogeneous income profiles (HIP) literature. In the emerging market business cycles literature, [25] and [26], among others, provide the early contributions. More recently, [27] and [28] study the role of countercyclical interest rate shocks in EMEs that are amplified through the working capital constraints. [29] examines the role of trend growth shocks and argue that these shocks can explain the high variability of consumption relative to output and the countercyclical current account. [30] argues that imperfect information on trend versus cycle shocks generates a more realistic response of labor with highly persistent trend growth shocks. These papers, however, are largely silent about the underlying individual income structure and our paper complements these studies by explicitly modeling a friction that previous literature has largely been overlooked.

In the heterogeneous income profiles literature, [31] among others first introduce an individual-specific life cycle earning process. [32] and [33] reassess the evidence on labor income dynamics, and develops a hybrid model, where there is an individual specific age profile and stochastic shocks to income. We introduce this framework in the standard small open economy (SOE) business cycle models, and extend it to include heterogeneous income profiles and imperfect information. Our model also contributes to the news shock literature, [34] and [35] among others, shows the standard RBC model with Cobb-Douglas preferences failed to deliver empirically-plausible labor dynamics. Our paper introduces another channel of gradual learning with heterogeneous income profiles that potentially leads to realistic dynamics of labor supply.

The rest of the paper is structured as follows. Section 2.2 presents our empirical evidence on information frictions. Section 2.3 introduces the model as well as the information structures and the consequent learning process. Section 2.4 presents a simple linear-quadratic version of the full model that permits an analytical solution, thereby allowing us theoretically analyse the model mechanism, we also shows a numerical example in this section. Section 2.5 concludes and discusses extensions for further research.

2.2 Empirical Evidence: Forecast Error and Revision

To analyse whether there are substantial differences in the uncertainty faced by individuals in EMEs compared with DCs, we compare the forecasting of real GDP growth for countries belong to each group. We start by calculating the forecast errors, after which we examine the RMSE of the forecast errors and compare the forecast error's autocorrelation structure. Then we test the efficiency of the forecasts by studying the forecast revisions from individual and consensus forecast data, and compare the evidence from EMEs and DCs.

Forecast Error. Let the forecast for period $t+1$ GDP growth based on information available at period t be defined as $\hat{y}_{t+1,t}$, and actual GDP growth for period $t+1$ be y_{t+1}, the the one-step-ahead forecast error is defined as:

$$e_{t+1,t} = y_{t+1} - \hat{y}_{t+1,t} \tag{2.1}$$

Using the data from Consensus Forecasts, IMF's World Economic Outlook forecasts,[1] we summarize the RMSE of Consensus Forecasts' forecast errors ($e_{t+1,t}$) for a set of developed and emerging market countries from 1998 to 2007 in Table 2.3.

As suggested in Table 2.3, if we compare across countries, the RMSE of forecast errors on GDP growth are systematically higher in EMEs than in DCs. This is also shown by average and median of the RMSE of forecast errors, the average RMSE for DCs is 0.27 percentage points, less than one third of that corresponding measure of the EMEs of 0.95 percentage points. The EMEs median value is 0.82 percentage points, comparing to only 0.30 percentage points for DCs. A systematically higher RMSE on forecast errors shows that forecasts on future GDP growth are subject to more

[1] The GDP growth data are from Bloomberg and refer to quarterly year-on-year growth rates. We include only the countries with at least 12 quarters of forecasts available.

uncertainty and information friction in EMEs. [30] and [36] documented similar results using the IMF's World Economic Outlook forecasts. [24] uses survey data obtained from Consensus Economics, and reported RMSEs for EMEs are on average, more than twice as the corresponding figures for advanced economies, and still 75% higher even one month before the target year.

In the third column of Table 2.3, we document the first order autocorrelations of forecast erros across countries. There is no significant autocorrelation across developed countries. While in EMEs, both Argentina and Mexico shows a positive and significant autocorrelation. This type of errors could occur if a trend shock hits the economy and individuals are uncertain about it. In the case of a positive (negative) aggregate shock, agents might overestimate (underestimate) the individual income growth rate, which transfers to the expected life-time income and affects the excess consumption volatility.

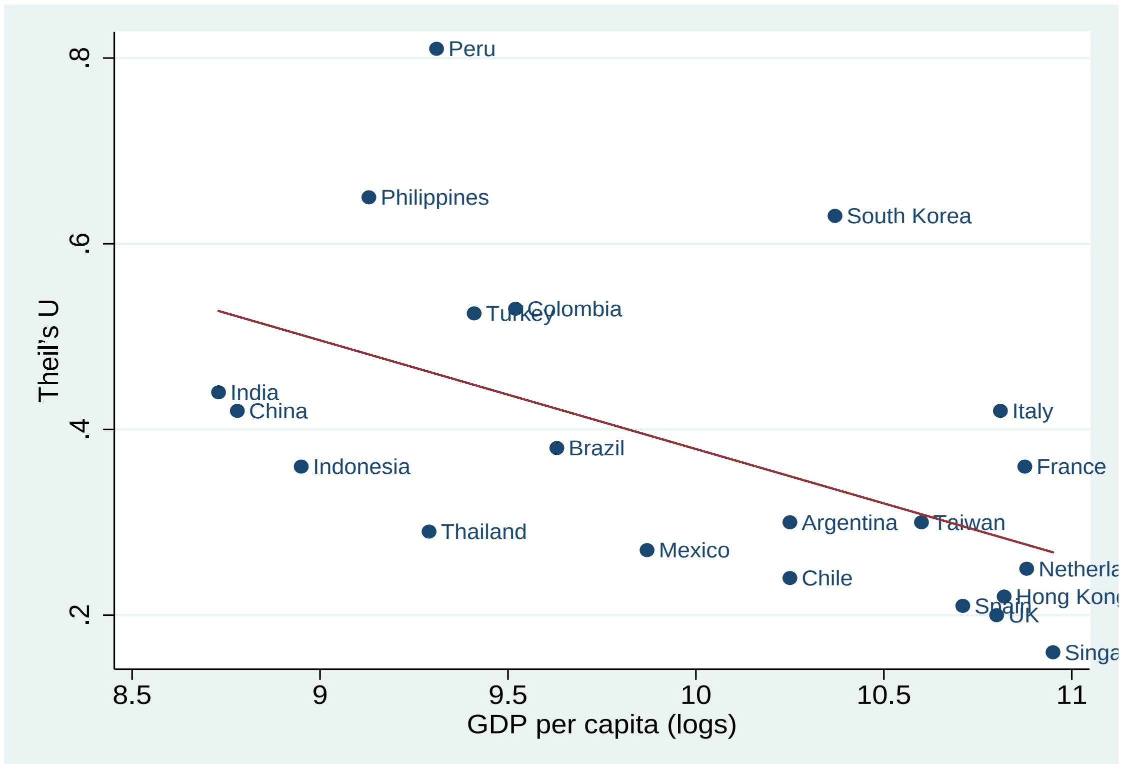
As in [30], we document the median of the standard deviations (SDs) of the forecasts across analysts over the sample periods for each country, and similarly, we get a systematically higher dispersion across EMEs, which shows that there exists more policy and information uncertainty and less transparency in EMEs compared to DCs.

To control for the effect that the GDP growth is more volatile in EMEs than DCs, we apply the measure of Theil's U as in [37] to compare the relative predictability of forecasts with different variability. The statistic of Theil's U for country i with period t is defined as:

$$U_i = \sqrt{\frac{\frac{1}{N}\sum_{t=1}^{N} e_{i,t}^2}{\frac{1}{N}\sum_{t=1}^{N} y_{i,t}^2}} \tag{2.2}$$

When the statistics equals to 0, it means perfect forecast, and larger values means less forecasting accuracy. We document the statistics as in the last column of Table 2.3. After controlling for the variability of GDP growth, the forecast errors are still larger for EMEs, with an average of 0.41, than for DCs, with an average of 0.29. More prominently, we graph the Theil's U statistics over log values of GDP per capita across countries. In Figure 2.1, there is significantly negative correlation between both variables. Generally, the forecasts are less accurate in less developed countries.

Figure 2.1: Relative Predictability of Real GDP Growth



Forecast Revision. Let the forecast for GDP growth at period T based on information available at period t ($t < T$) be $\hat{y}_{T,t}$, the forecast revision from period $t-1$ to period t is defined as:

$$r_{T,t} = \hat{y}_{T,t} - \hat{y}_{T,t-1} \tag{2.3}$$

[38] proposed a test of regressing the contemporaneous revision on the lagged forecast revisions:

$$r_{T,t} = \beta + \lambda r_{T,t-1} + u_{T,t} \tag{2.4}$$

If $\lambda = 0$, forecasts are (weakly) efficient, otherwise, forecast revisions are correlated, and the null hypothesis of forecast efficiency is rejected. Using the individual and consensus forecasts on annul GDP growth from a cross-country survey data compiled by *Consensus*

Economics,[2] [24] examines the forecast efficiency for 36 EMEs and advanced economies from 1989 to 2011 at a quarterly frequency. Their regression analysis shows strong evidence of forecast smoothing (information rigidities). More interestingly, they find substantial differences in the magnitude of information rigidities in forecasts for EMEs and advanced economies. The coefficients on lagged revisions for EMEs is significantly higher at 0.23, comparing to 0.12 for advanced economies. And the distribution of the forecast revisions are more dispersed in EMEs compared to advanced economies, which implies that individual beliefs on the GDP growth among EMEs are more at odds to each other compared to advanced economies.

The evidence we documented above that agents in EMEs are subject to a greater amount of uncertainty possibly comes from the lack of transparency, weaker quality of economic statistics, and greater policy uncertainty compared to DCs. These differences could also transfer to the uncertainty as to how individuals might react to an aggregate shock. A shock to the growth rate of the aggregate economy will be partly attributed to the growth rate of agents' own human capital, and the latter of which has more persistent effects on agents' life-time income.

2.3 Baseline Model

Motivated by the above observations, we consider a heterogeneous-agent OLG model as in chapter 1. The economy is populated with a continuum of individuals, each live for finite periods, with age indexed by $j = 1, \ldots, T$. Individuals survive from age j to $j+1$ with probability ζ^j, and die after period T for sure. Time is discrete, at each period a new cohort of measure one enters the economy. Since cohort size and survival probabilities are time-invariant, the model age distribution is stationary.

Individuals have heterogeneous income profiles and are subject to imperfect information so that they cannot separate the aggregate from the idiosyncratic shocks. Therefore, they solve the extraction problem and learn the aggregate TFP and their own income profiles in an optimal (Bayesian) fashion.

[2] The data set contains a macroeconomic forecasts made by both public and private economic institutions in a large number of countries covering the G-7 industrialised nations, Asia Pacific, Eastern Europe and Latin America. The survey has been conducted monthly since October 1989. For each target year, the data set contains a sequence of 24 forecasts of each institution made between January of the year before the target year and December of the target year.

The baseline model features linear production technology with endogenous labor. Financial markets are incomplete: agents could borrow or lend in international capital markets with only one asset being the one-period non-contingent bond, subject to a borrowing constraint $\underline{a}$. The interest rate on the bonds is set internationally and assumed to be constant and equal to r. Every period, agents observe both their own labor income and a noisy public signal on the aggregate TFP, and update their knowledge on their own income growth rate and TFP shocks, makes decisions on consumption, saving and labor supply.

2.3.1 Consumer's Problem

Individuals start working at birth from age $j = 1$ to T. An individual's labor income depends on her hourly wage $w^i_{t,j}$ and total working hours $n^i_{t,j}$. Following [7], we assume that the hourly wage for an individual i of age j at time t is:

$$\ln(w^i_{t,j}) \equiv I^i_{t,j} = \ln(A_t) + \underbrace{\beta^i j + f(j) + z^i_t + \epsilon^i_t}_{e^i_{t,j}} \tag{2.5}$$

where A_t is the aggregate TFP, and $\ln(A_t)$ follows an AR(1) process. $e^i_{t,j}$ is the individual efficiency units, which is determined by individual age and the history of idiosyncratic labor productivity shocks. $f(j)$ is a polynomial of individual age, and z^i_t is the persistent idiosyncratic shock that follows an AR(1) process

$$z^i_t = \rho_z z^i_{t-1} + \eta^i_t$$

with $|\rho_z| < 1$, and η^i_t is *i.i.d.* draws from a normal distribution, $\eta^i_t \sim N(0, \sigma^2_\eta)$. ϵ^i_t is the *iid* transitory idiosyncratic shock, $\epsilon^i_t \sim N(0, \sigma^2_\epsilon)$.

Individuals also observe a noisy public signal on aggregate TFP as

$$x_t = \ln(A_t) + \theta_t$$

where $\theta_t \sim N(0, \sigma^2_\theta)$, when $\sigma_\theta \to \infty$ is identical to no signal for aggregate TFP, and $\sigma_\theta = 0$ represents perfect information on aggregate TFP. Agents observe both their hourly wage $I^i_{t,j}$ and the public signal on aggregate TFP x_t to infer the true A_t and their own type β^i using the Kalman filter.

The Kalman Filtering Problem In order to express the learning process as a Kalman filtering problem, we use the state-space representation as in [39]. This form is composed of a state equation and an observation equation. The state equation describes the evolution of the vector of state variables that is unobserved:

$$\underbrace{\begin{bmatrix} \beta^i \\ z^i_{t+1} \\ \ln(A_{t+1}) \end{bmatrix}}_{S^i_{t+1,j+1}} = \underbrace{\begin{bmatrix} 1 & 0 & 0 \\ 0 & \rho_z & 0 \\ 0 & 0 & \rho_A \end{bmatrix}}_{F} \underbrace{\begin{bmatrix} \beta^i \\ z^i_t \\ \ln(A_t) \end{bmatrix}}_{S^i_{t,j}} + \underbrace{\begin{bmatrix} 0 \\ \eta^i_t \\ \nu_t \end{bmatrix}}_{\xi^i_{t+1}} \tag{2.6}$$

The observation equation describes observed variables as a linear function of the underlying hidden state and a transitory shock. [3]

$$\underbrace{\begin{bmatrix} I^i_{t,j} \\ x_t \end{bmatrix}}_{y^i_{t,j}} = \underbrace{\begin{bmatrix} j & 1 & 1 \\ 0 & 0 & 1 \end{bmatrix}}_{H'} \underbrace{\begin{bmatrix} \beta^i \\ z^i_t \\ \ln(A_t) \end{bmatrix}}_{S^i_{t,j}} + \underbrace{\begin{bmatrix} \epsilon^i_t \\ \theta_t \end{bmatrix}}_{\varepsilon^i_t} \tag{2.7}$$

We assume that both shocks ξ^i_{t+1} and ε^i_t have *i.i.d.* normal distributions and are independent of each other, with Q and R denoting their covariance matrix respectively. Let the prior belief over $S^i_{t,j}$ be a multivariate normal distribution, with one-period-ahead forecasts of the mean vector being $S^i_{t+1,j+1|t,j}$ and covariance matrix $P_{j+1|j}$. After observing the information on public signal and individual wage rate at period $t+1$, an agent updates her belief about $S^i_{t+1,j+1}$, and forms a posterior distribution with mean vector $S^i_{t+1,j+1|t+1,j+1}$ and covariance matrix $P_{j+1|j+1}$

$$S^i_{t+1,j+1|t,j} = FS^i_{t,j|t,j} \tag{2.8}$$

$$P_{j+1|j} = FP_{j|j}F' + Q \tag{2.9}$$

$$\phi^i_{t+1,j+1|t,j} = y^i_{t+1,j+1} - y^i_{t+1,j+1|t,j} = y^i_{t+1,j+1} - H'S^i_{t+1,j+1|t,j} \tag{2.10}$$

$$f^i_{t+1,j+1|t,j} = E^i_{t,j}[\phi^i_{t+1,j+1|t,j}(\phi^i_{t+1,j+1|t,t})'] = H'P_{j+1|j}H + R \tag{2.11}$$

Updating:

$$S^i_{t+1,j+1|t+1,j+1} = S^i_{t+1,j+1|t,j} + K_{j+1}\phi^i_{t+1,j+1|t,j} \tag{2.12}$$

$$P_{j+1|j+1} = P_{j+1|j} - K_{j+1}H'P_{j+1|j} \tag{2.13}$$

[3] To simplify for the analysis, we set $f(j) \equiv 0$ for the rest of the paper.

where $K_{j+1} = P_{j+1|j} H f_{j+1|j}^{-1}$ is the Kalman gain matrix. Notice that the covariance matrix evolves independently of the realization of $y_{t,j}^i$, and is also deterministic in this environment since H' is deterministic.

Consumers are subject to borrowing constraint $\underline{a}$ in each period, and one unit of savings delivers $1/\zeta^j$ units of assets next period, reflecting the annuity-market survivors' premium. To write down the value function for individual i, the relevant state variables are the asset level a_j^i, the log hourly wage I_j^i, and last period's forecast of the true state in the current period $\hat{S}_{j|j-1}^i$:

$$V_j^i(a_j^i, I_j^i, \hat{S}_{j|j-1}^i) = \max_{c_j^i, a_{j+1}^i, n_j^i} \{u(c_j^i, n_j^i) + \delta\zeta^j\, \mathbb{E}[\mathbb{V}_{j+1}^i(a_{j+1}^i, I_{j+1}^i, \hat{S}_{j+1|j}^i)]\} \tag{2.14}$$

subject to

$$\begin{aligned} c_j^i + \zeta^j a_{j+1}^i &= (1+r)a_j^i + \exp(I_j^i) n_j^i \\ a_{j+1}^i &\geq \underline{a} \\ a_{T+1}^i &= 0; \quad c_j^i \geq 0; \quad n_j^i \in (0,1) \\ &\text{Kalman filter} \end{aligned}$$

2.3.2 Equilibrium Definition

A recursive equilibrium in this economy is a set of decision rules for the consumers: $\{c_j^i(a_j^i, I_j^i, \hat{S}_{j|j-1}^i),\ a_j^i(a_j^i, I_j^i, \hat{S}_{j|j-1}^i),\ n_j^i(a_j^i, I_j^i, \hat{S}_{j|j-1}^i\}$, aggregate efficient units of labor N, and the wage rate w on efficient units, such that

1. Given the real interest rate r, and hourly wage, individuals' decision rules $\{c_j^i(a_j^i, I_j^i, \hat{S}_{j|j-1}^i)$, $a_j^i(a_j^i, I_j^i, \hat{S}_{j|j-1}^i)$, $n_j^i(a_j^i, I_j^i, \hat{S}_{j|j-1}^i\}$ solve problem (2.14).

2. Given the wage rate w for an efficiency unit, competitive firms solve the problem by hiring efficient units of labor n in each period

$$\max_n \pi = y - wn \tag{2.15}$$

where

$$y = \int A \exp(e_j^i) n_j^i di$$

and

$$n = \int \exp(I_j^i) n_j^i di$$

3. The domestic labor market clears with $w = 1$, where aggregate labor demand N equals the total labor supply from individuals

$$N = \int \exp(I_j^i) n_j^i di \tag{2.16}$$

2.4 Model Mechanism: A Stylized Linear Quadratic Framework

In this section, we use a simple quadratic utility function to illustrate the key mechanism of the baseline model. For simplicity, we abstract from the borrowing constraint and assume that labor supply is inelastic, we further assume that the time discount rate δ is the reciprocal of the international gross interest rate $1 + r$. Under these assumptions, the consumer's problem can be written as:

$$V_j^i(a_j^i, I_j^i, \hat{S}_{j|j-1}^i) = \max_{c_j^i, a_{j+1}} -(c_j^i - c^*)^2 + \delta\, \mathbb{E}\left[V_{j+1}^i(a_{j+1}^i, I_{j+1}^i, \hat{S}_{j+1|j}^i)\right]$$

subject to

$$\begin{aligned} c_j^i + a_{j+1}^i &= (1 + r)a_j^i + \exp(I_j^i) \\ a_{T+1}^i &= 0 \\ &\text{Kalman filter} \end{aligned}$$

This framework is a much simplified version of the full model. However, it highlights the consumption response to an aggregate TFP shock with Bayesian learning about the heterogeneous income profiles. With a quadratic utility function and inelastic labor supply, individuals' consumption will simply reduce to a fraction of their expected lifetime income:

$$c_j^i = \frac{1 - \delta}{1 - \delta^{T-j+1}} \left[(1 + r)a_j^i + \mathbb{E} \sum_{s=0}^{T} \frac{\exp(I_{j+s}^i)}{(1 + r)^s}\right] \tag{2.17}$$

where $I_{t,j}^i = \ln(A_t) + \beta^i j + z_t^i + \epsilon_t^i$ is the individual income (we assume inelastic labor supply here). The present value of expected lifetime income $\mathbb{E} \sum_{s=0}^{T} \frac{\exp(I_{j+s}^i)}{(1+r)^s}$ is affected by three factors, the aggregate TFP $\ln(A_t)$, individual income growth β^i, and a persistent idiosyncratic shock z_t^i. Of these three factors, individual income growth has the most persistent effects on the lifetime income, since it accumulates over the life cycle and is amplified by the age. How persistent the TFP shock comparing to the idiosyncratic shock z_t^i will depend on their corresponding parameters.

Numerical Example. Assuming the model period is one year, we feed in the parameters from [23] and calibrate to some key features on real interest rate and aggregate TFP, as in Table 2.1. To gain some insight into how the imperfect information and heterogeneous income profiles might affect consumption volatility, we first study the impulse response function to a one percent negative TFP shock in Figure 2.2.

Table 2.1: Parameter Values

Description	Parameter	Value	Remark
Discount factor	δ	0.96	Real interest rate 4%
Persistence of TFP	ρ_A	0.87	Quarterly autocorr 0.95
Std of TFP	σ_ν	0.0107	Quarterly std 0.007
Std of β	σ_β	0.02	Guvenen and Smith (2010)
Std of η	σ_η	0.19	Guvenen and Smith (2010)
Std of ϵ	σ_ϵ	0.004	Guvenen and Smith (2010)
Persistence of z	ρ_z	0.75	Guvenen and Smith (2010)

Figure 2.2 contrasts the aggregate consumption dynamics in perfect signal case with the case of no signal on aggregate TFP shock, we also graph the corresponding aggregate output ($y = \int A_t \exp(e_{j,t}^i)di$) for comparison. The red square line plots the consumption with no signal of aggregate TFP, the blue dashed line plots the perfect information case, and the green line shows the corresponding aggregate output. Panel A depicts the baseline scenario when there are both heterogeneous income profiles ($\sigma_\beta > 0$) and idiosyncratic persistent shock ($\sigma_\eta > 0$). In response to an aggregate TFP shock, individuals with perfect information will decrease their consumption, but less than the output and generally less volatile than the aggregate output out of consumption smoothing motive. On the other hand, individuals lack of information on TFP growth would attribute part of their income decrease to a lower heterogeneous growth profile, thus

decreasing their consumption even more. This is because the income growth has a very persistent effect on their lifetime income. As time goes on, they will update their belief on individual growth β_i, as shown in Figure 2.3. The posterior belief on individual income growth first decreases on the observation that the income falls below the trend, and gradually increases as more information is revealed.

Which factor drives the differences in the consumption volatility we see in panel A of Figure 2.2? Is it because of the heterogeneous income profile or does it come mainly from a confusion between idiosyncratic income shock and the aggregate TFP shock? We shut down one of these channels separately in panels B and C. When there is no substantial differences between individual income growth ($\sigma_\beta = 0$), we notice that there is little difference between the volatility of consumption in perfect signal and no signal cases. Actually, since individuals assign positive possibility to a less persistent individual income shock (we assume $\rho_z < \rho_A$ here), individuals with information friction will decrease their consumption even less than the perfect information case initially. This insight confirms the crucial role that heterogeneous income profile plays in explaining the excess consumption volatility with imperfect information.

Panel C of Figure 2.2 graphs the situation when there is no individual persistent shock ($\sigma_\eta = 0$), here the excess volatility on consumption is amplified comparing to Panel A. Initially, consumers with information friction will assign positive possibility on each of the three factors, heterogeneous income growth β, TFP shock $\ln(A_t)$, and the idiosyncratic shock z_t^i, with decreasing level of persistence. Shutting down the least persistent effect of z_t^i will bump up the possibility of a low income growth rate, thus consumption falls more significantly initially. As the learning process goes on, there is also an obvious overshooting on aggregate consumption when individuals realize that they save too much earlier, thus the consumption with no signal on aggregate TFP will generate even higher volatility comparing to Panel A.

Table 2.2: Simulation Statistics on Relative Consumption Volatility

	$\frac{\sigma(C)}{\sigma(Y)}$	$\frac{\sigma(C)}{\sigma(Y)}$ HP-filter
Perfect signal	0.85	0.53
No signal	1.03	0.68

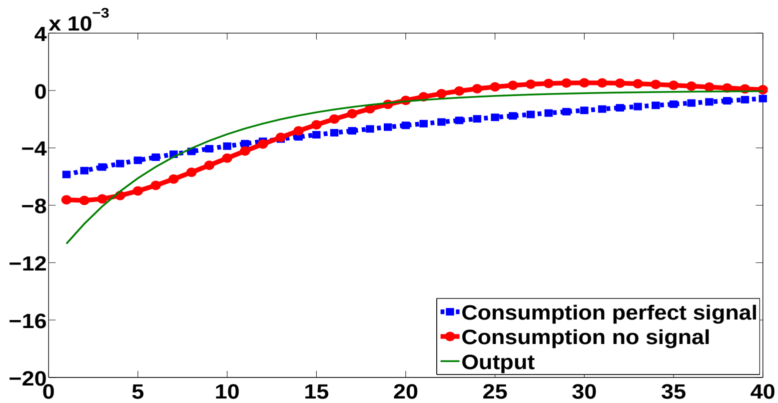
Our simulated results show that the information structure could potentially generate an excess volatility in consumption, as shown in Figure 2.4. In Table 2.2, the HP-filtered value of $\frac{\sigma(C)}{\sigma(Y)}$ increases by 32% from perfect information on aggregate TFP to no signal at all.

2.5 Conclusion

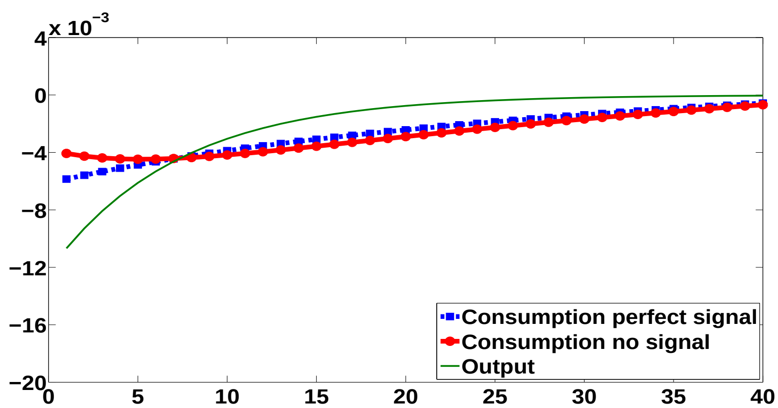
In this paper, we provided a framework to explain the key business cycle characteristics of emerging market economies. We showed that when agents are imperfectly informed about the aggregate TFP shocks, and they have heterogeneous income growth rates, they will solve a learning problem using the Kalman filter to estimate the growth rate of their individual human capital and the growth rate of the aggregate economy. Due to information frictions, a shock to the growth rate of the aggregate economy will be partly attributed to the growth rate of agents' own human capital, the latter of which has more persistent effects on agents' life-time income. As a result, the economy features higher consumption volatility than the output. The key ingredients for these results include the existence of heterogeneous income growth rates and uncertainty regarding the aggregate versus individual income growth rates.

Our analysis contributes to the emerging market business cycle literature, which has largely emphasized the role of financial frictions, terms of trade shocks, and trend versus growth shocks, but has overlooked the role of information frictions and the underlying heterogeneous income structures. We fill the gap by introducing another channel of gradual learning with heterogeneous income profiles that potentially leads to realistic dynamics of labor supply. Quantitatively, we find that the model can successfully explain the excessive volatility of consumption and generate a strongly negative correlation between the trade balance and output for a wide range of TFP and income processes.

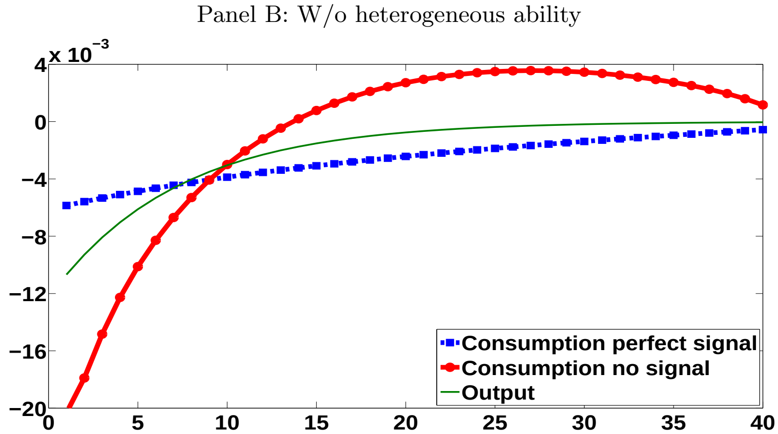
Figure 2.2: IRF to TFP shock



Panel A: Baseline

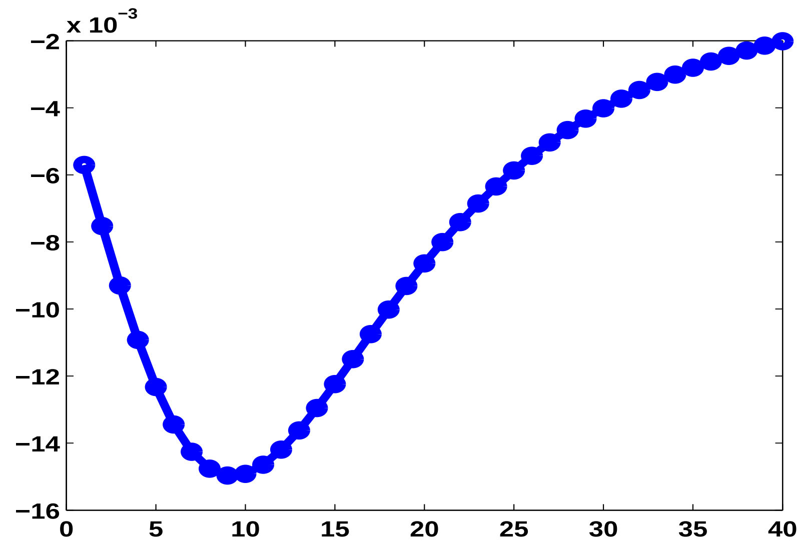


Panel B: W/o heterogeneous ability

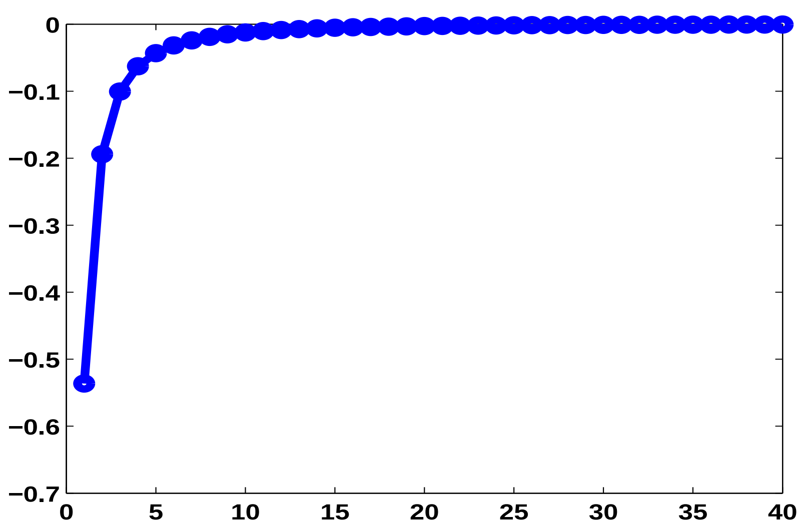


Panel C: W/o individual persistent shock

Figure 2.3: Posterior of β



Panel A: Baseline



Panel C: W/o individual persistent shock

Figure 2.4: Simulation Path of Consumption and Output

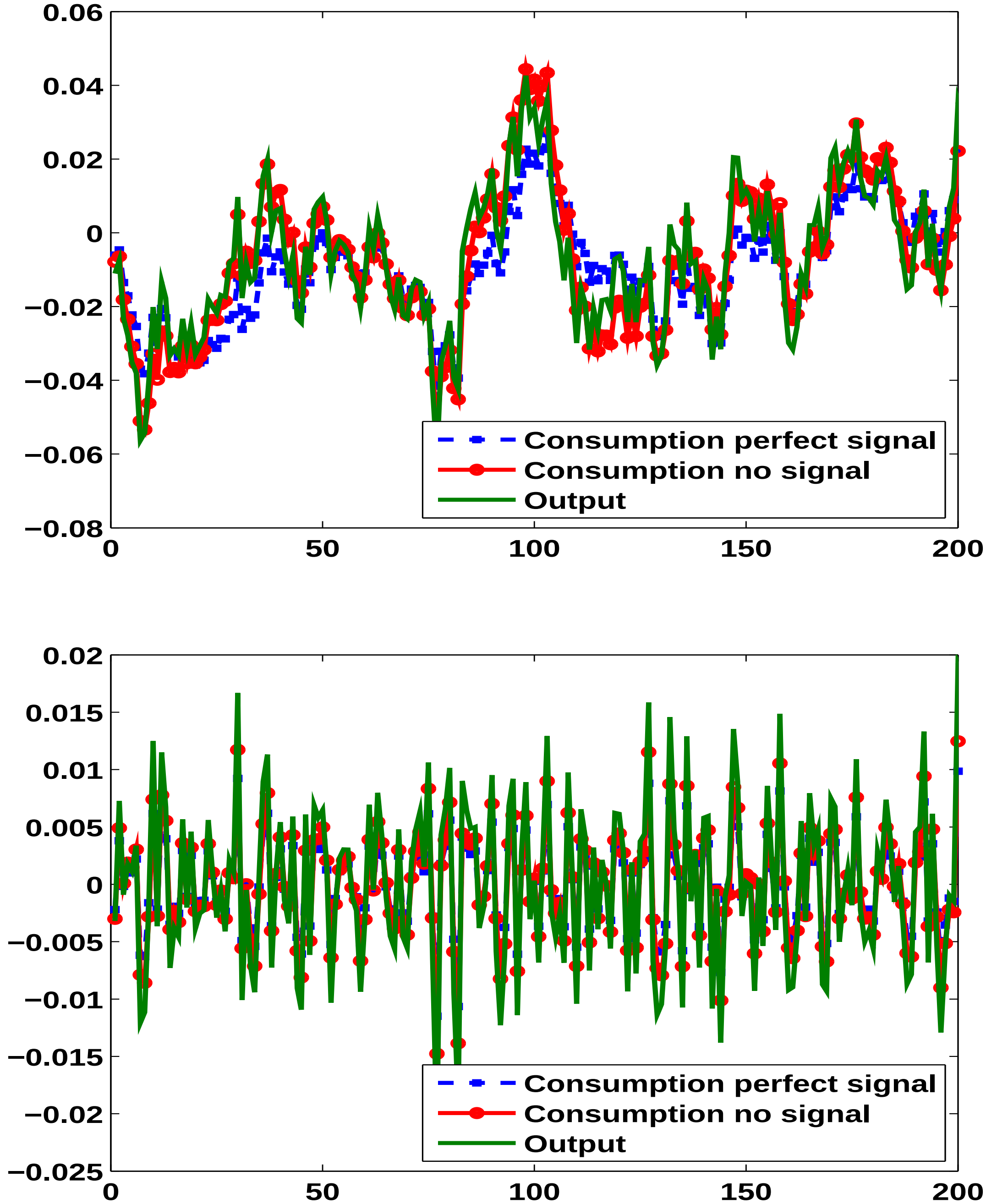


Table 2.3: Moments of Forecast Errors in EMEs and DEs

Country	Mean	RMSE	$corr(e_{t+1.t}, e_{t,t-1})$	Dispersion	Theill's U
DCs					
France	-0.02	0.30	-0.35	0.12	0.36
Italy	-0.11	0.39	-0.02	0.15	0.42
Netherlands	-0.02	0.36	0.32	0.15	0.25
Spain	0.04	0.15	-0.13	0.10	0.21
UK	0.05*	0.14	0.01	0.09	0.19
Average	**-0.01**	**0.27**	**-0.03**	**0.12**	**0.29**
Median	**-0.02**	**0.30**	**-0.02**	**0.12**	**0.25**
EMEs					
Argentina	-0.57	2.23	0.57*	0.42	0.30
Brazil	-0.28*	0.83	0.06	0.43	0.38
Chile	0.10	0.28	0.21	0.17	0.24
China	0.30*	0.55	-0.33	0.39	0.42
Colombia	0.23	0.87	0.03	0.41	0.53
India	0.30	0.85	0.06	0.48	0.44
Indonesia	0.18*	0.43	0.18	0.41	0.36
Hong Kong	0.70*	0.80	-0.16	0.68	0.22
South Korea	0.23	0.86	-0.10	0.31	0.63
Mexico	0.05	0.59	0.31*	0.36	0.27
Peru	0.43*	1.45	-0.13	0.54	0.81
Philippines	-0.35*	0.65	-0.13	0.48	0.65
Singapore	-0.37*	0.46	-0.21	0.31	0.16
Taiwan	-0.16	0.86	0.21	0.61	0.30
Thailand	-0.19*	0.42	0.16	0.41	0.29
Turkey	-0.13	3.12	0.10	1.07	0.53
Average	**0.03**	**0.95**	**0.05**	**0.47**	**0.41**
Median	**0.08**	**0.82**	**0.06**	**0.42**	**0.37**

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Appendix A

Data

Care has been taken in this thesis to minimize the use of jargon and acronyms, but this cannot always be achieved. This appendix defines jargon terms in a glossary, and contains a table of acronyms and their meaning.

A.1 National Accounts Data

The data sources and sample length of aggregate data on calculating RBC moments are obtained from OECD and IFS, mostly available from 1981, we summarize the data sources in Table A.1. Consumption is ”household consumption” and excludes government consumption. When household consumption is unavailable, we use ”private consumption”, which combines household and non-profit institution consumption. Net exports is constructed as the difference between exports and imports. The GDP deflator is used to convert all series into real values.

For Canada, employment is the Canadian Civilian Employment series. To calculate total hours, we use hours per worker in manufacturing as a proxy for average hours per worker and scale the employment series accordingly. For Mexico, the quarterly hours per worker in manufacturing was calculated from OECD data as (total hours in Manuf)/(total employment in Manuf).

Table A.1: Data Sources for National Accounts

Country	Quarters	Sources
DCs		
Australia	1979.1-2014.2	OECD
Canada	1981.1-2014.2	OECD
	1957.1-1981.1	IFS
Netherlands	1979.4-2014.2	OECD
Spain	1980.1-2014.2	OECD
EMEs		
Argentina	1993.1-2014.2	IFS
	1980.1-2002.1	Neumeyer and Perri (2004)
Brazil	1991.1-2002.1	Neumeyer and Perri (2004)
South Korea	1979.4-2014.2	OECD
Malaysia	1991.1-2014.1	IFS
Mexico	1991.1-2014.2	OECD
Peru	1990.1-2014.1	IFS
Philippines	1981.1-2014.2	OECD
Turkey	1987.1-2014.2	OECD