"The Demographic Window", Human Capital Accumulation and Economic Growth in China
-- An Applied General Equilibrium Analysis

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Abstract:

This paper investigates the contribution of human capital to economic growth and its potential scope to neutralize the effects of population ageing in China during the first half of the 21st century by using an applied general equilibrium model. In particular, it examines whether the "demographic window" which opened during the 1990s and is projected to stay open until the 2030s can be exploited to inject a growth boost into the economy. Such a boost could be delivered through policies of energetic human capital formation and significant government spending on social infrastructure. Policy simulations show that accelerating human capital formation may dramatically raise both total output and per capita real income. Public expenditure on education is, therefore, welfare enhancing, mitigating the adverse effects of population ageing while providing a respectable environment for China's rapidly increasing elderly population.

Key words: **Population ageing, Human capital, Demographic Window, Economic growth, China**

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1. Introduction

Along with many developed countries, the dramatic fertility decline since the 1970s and increasing life expectancy in China are giving rise to a serious ageing problem. Even though this problem will attain its full scope a couple of decades later than in most of the advanced economies, it is likely to be significantly more severe. China's substantially lower income and significantly faster ageing rate, relative to the typical advanced economy scenario, will give rise to substantially larger resource requirements to cope with population ageing problem. Scholars are increasingly concerned about the fallout from the rapid progress of population ageing on economic growth and living standards, and they suggest that an active policy response is urgently indicated.

However, some scholars argue that the above sketch exaggerate the negative effect of population ageing. Day and Dowrick (2004) argue that declining fertility, increasing female labour force participation and increasing human capital formation may offset the negative effects of population ageing. Fouègre and Merétte (1999) observe that by raising the present value of future real wages,[1] ageing could create new incentives for future generations to invest in human capital. This, in turn, could compensate for the potentially negative effects of ageing.

The current debate about the potential economic effects of population ageing concentrates on the contribution of human capital to economic growth. Growth of the human capital stock might mitigates the adverse effects of population ageing, since "whilst the working age population is becoming smaller relative to the aged population, it is also becoming smarter and more productive and is increasing its supply of labour" (Day and Dowrick, 2004). Human capital formation and the ensuing productivity improvement, therefore, provide a venue through which the authorities could seek to alleviate the adverse economic effects of population ageing. "If the slower growth in the labour force were to be accompanied by a faster rate of change in the labour-augmenting technical change, the slowdown in the growth of 'effective' labour might be substantially smaller than the slowdown in the working age population" (Bosworth, Bryant and Burtless, 2004).

[1] The declining increase in the labour supply as a result of population ageing will drive up the real wage.

If the above arguments are correct, then the adverse effect of population ageing in China will be reduced to some extent or may even be entirely offset by an appropriate expansion of the human capital stock in China.

This paper investigates the contribution of human capital to economic growth and its potential scope to neutralize the effects of population ageing in China during the first half of the 21st century. China's population ageing process will create a demographic window consistent with the experience of the new industrialized South-East Asian Economies. Accordingly, one aim of this paper is to explore whether the demographic dividend can be harvested by boosting productivity improvement in China through the accumulation of human capital. This productivity growth would lay a solid foundation for supporting the rapidly rising proportion of the elderly after the demographic "bonus".

The paper contains six sections. The introduction is followed by the modelling framework and identification of key assumptions of baseline and policy scenarios in section two. The third section explores the contribution of human capital to China's economic growth by over the period 2000 to 2050. The fourth section evaluates the macroeconomic effects of accelerating the rate of human capital formation by means of increased public expenditure on education. The penultimate section presents conclusions and policy implications, and the final section discusses the limitations of the model.

2. The modelling framework and key assumptions

The analysis is based on the ageing profile associated with the medium variant population projection conducted by the United Nations (2004). The growth trends of total population, working age population and elderly population from 2000 to 2050 are summarized in Table A1.

2.1 The modelling framework

The model I used in this paper is a modified version of PRCGEM, an applied general equilibrium model of China.[2] In this analysis, PRCGEM is adapted to run in a sequential long-run simulation.

Following Mankiw, Romer and Weil (1992), human capital is introduced into the production function as one of the input factors.[3] The production function in PRCGEM is accordingly modified to become

$$Y_t = A_t K_t^{\alpha} (L_t H_t)^{\beta} LAND_t^{\eta} \qquad (1)$$

where Y_t denotes real GDP at year t, A_t, K_t and L_t are total factor productivity (TFP), the physical capital stock and total employment, respectively, at year t. H_t is the human capital stock at year t represented by average years of schooling of the population aged 15 to 64. In this function, $L_t H_t$ is a skill-adjusted measure of labour input. $LAND_t$ represents natural resource land at year t. α, β, and η are the shares of the respective inputs in factor cost.[4] Taking logs and differentiating totally yields the growth equation

$$g_t = \alpha k_t + \beta(l_t + h_t) + \eta land_t + a_t \qquad (2)$$

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[2] See Zheng and Fan (1999) for details of the original PRCGEM and Peng (2005) for details of the modified version of PRCGEM.

[3] There exists a wide variety of models and theories to explore the importance of human capital for economic growth. Basically, the different models can be grouped into two theoretical perspectives on the relationship between human capital and economic growth (Aghion and Howitt, 1998; Benhabib and Spiegel, 1994; and WöБmann, 2000). The first is the 'neoclassical view' which is pioneered by Mankiw, Romer and Wail (1992). The accumulation of human capital as a factor of production drives economic growth, so that differences in levels of human capital are related to differences in output levels across countries. This implies that differences in growth rates across countries are related to differences in the rates of human capital accumulation. The effect of human capital on economic growth in this 'neoclassical view' is called 'level effect'. The second, 'technical-progress view', is the central part of many endogenous growth models. Here total factor productivity (TFP) growth depends on the stock of human capital through either the domestic production of technological innovation (Romer, 1990) or through the adoption and implementation of new technology from abroad (Nelson and Phelps, 1966). In ether case, the growth of TFP is positively related to the average level of human capital. The effect of human capital on economic growth in this 'technical-progress view' is called 'growth effect'.

[4] α, β, and η are 0.49, 049 and 0.02,respectively, in 2000 in China.

where g_t is the growth rate of real GDP at year t. k_t, l_t, h_t are the growth rates of physical capital, employment and human capital, respectively, at year t. a_t is the growth of TFP. Since the input factor land is assumed to be in fixed supply, its growth rate $land_t$ is zero. Equation (2) decomposes the growth rate of output into growth of TFP, and a weighted average of the growth rates of physical capital stock and skill-augmented labour.

The long-run perspective is achieved by assuming as exogenous the rate of return on capital and the employment level. The rate of return on capital is determined by the exogenously given world rate of return. Capital mobility, both internally between sectors and externally between China and the rest of the world, maintains the domestic rate of return at the world level. Given flexible wages, changes in aggregate employment in the long run are determined by the growth of working age population and by labour force participation rates. Wages adjust to ensure that the labour market maintains equilibrium.

The path of total factor productivity is given exogenously. Its hypothesized increase is based on empirical findings and on a historical simulation of PRCGEM. The growth rate of human capital is treated as exogenous, and its effect on TFP is ignored in the following discussion.

National saving rates are exogenous. The pattern of aggregate national savings is assumed to be consistent with the life-cycle hypothesis and to display a hump shape following the evolution of the population age structure in China. Financing additional human capital formation requires public expenditure that reduces national savings. To the extent that increased investment in education is funded by foreign investors, the resulting debt service liabilities to foreigners widen the gap between GDP and GNP. This puts pressure on the current account, and may affect the terms of trade and household consumption. Accordingly, in order to analysis the welfare effects of additional human capital formation, net foreign assets are endogenously determined by the model. The additional human capital formation alters the aggregate income - expenditure balance.

These changes are reflected in net cross-border movements of goods (net exports) and funds (capital flows).

2.2 Key assumptions of the baseline and policy scenarios

Some important structural characteristics of the economy are established in the baseline simulation and retained in the policy simulation.

2.2.1 Growth of Total Factor of Productivity:

The growth rate of Total Factor Productivity (TFP) is treated as exogenous and set at 2.5 per cent per annum. This assumption is informed by the following considerations:

- **Existing empirical research**: Young (2000) estimates that the annual growth rate of TFP in China from 1978-98 is 1.4 per cent after a few adjustments to the official GDP growth rate. Wang and Yao (2003) find that the average annual growth rate of TFP from 1978 to 1999 is 2.41 per cent.
- **Historical CGE simulation from 1993 to 2000:** I have used the PRCGEM to determine the implicit rate of TFP improvement in China for the period 1993 to 2000. This historical simulation yields an annual growth rate of TFP over that period of 3.5 per cent.
- **The macroeconomic environment in China:** With entry into the WTO and with the continued progress of globalization, economic activity in China is exposed increasingly to global markets. Increasing openness and the associated stimulus to competition and innovation are likely to raise the average productivity growth rate beyond historical levels.

These three sources of information yield quite varied estimates of TFP growth that range from 1.4 per cent to 3.5 per cent. The systematic econometric estimates by Young (2000) and Wang and Yao (2003) place the productivity growth rate below 2.5 per cent. At the same time, the changes in China's economic environment establish a presumption in favor of a shift to a higher growth rate. Consequently, a rate of the order of 2.5 per cent would seem to be a plausible working hypothesis.

2.2.2 Labor force participation rate: The aggregate labour force participation rate (ALFPR) depends on the legal retirement age, demographic age structure and a host of other socioeconomic factors. Following Dugan and Robidoux (1999), I use a simple accounting framework to determine the trend of the aggregate participation rate from 2000 to 2050.

$$PR_t = \sum_{i=1}^{j} s_{i.t} PR_{i,t} \quad \text{where} \tag{3}$$

$$s_{i,t} = WP_{i,t} / WP_t \tag{4}$$

where PR_t denotes ALFPR in year t, $PR_{i,t}$ is the participation rate of cohort i in year t, and $s_{i.t}$ is the share of cohort i in the total working age population aged 15 to 64 (WP_t) in year t. Equation (3) shows that changes in the ALFPR reflect either changes in cohort participation rates or in cohort shares. That is, changes in labour force participation may be symptomatic of changes in the composition of the working age population for given cohort participation rates - the demographic composition effect.

Retirement policy affects cohort participation rates. In China, the retirement age is 55 for women and 60 for men. I assume that the retirement age will not change until 2050. The development of education affects all cohort participation rates. Increases in the school enrolment rate, especially in upper secondary and tertiary enrolments, tends to reduce the participation rate, especially for the population aged 15 to 29. However, higher educational attainment of the young generation will increase their participation rate as they reach age 40 years and older. Evidence from Australia and Canada shows that there exists a positive relationship between education level and labour force participation, especially for women (Day and Dowrick, 2004; Dugan and Robidoux, 1999). Given the fact that at age 45 to 65 women's participation rate in China is substantially lower than men's (Table A2), the educational attainment of women will increase their participation rate when they reach 45 years. In this case, the net effects of education development on the ALFPR of all cohorts aged 15 to 64 are not quite clear. So I ignore the effects of human capital accumulation on the cohort participation rates during the simulation period and only calculate the demographic composition effect.

Data from China's one-percent-population-sample-survey of 1995 shows that the ALFPR was 85 per cent. The detailed cohort and gender specific participation rates are shown in Table A2. I estimate the trend of ALFPR during 2000 to 2050 by assuming that the cohort participation rates remain at their 1995 level. It is convenient to define this effect with the following equation:

$$\overline{PR_t} = \sum_{i=1}^{j} s_{i.t} PR_{i,95} \qquad (5)$$

$\overline{PR_t}$ is the aggregate participation rate that would have been observed at time t if all cohort participation rates remained at their 1995 levels. The estimation result is shown in Table A2. The evolution of the demographic age structure reduces the ALFPR from 85 percent in 1995 to approximately 80 percent in 2050. Accordingly, the demographic composition effect over the period of 2000 to 2050 amounts to five percentage points.

2.2.4 The unemployment rate: According to the China Statistical Yearbook the unemployment rate has fluctuated around 3 per cent since 1999**.** It is assumed that this level of the unemployment rate will be maintained until 2100.

3. Baseline scenario: the contribution of human capital to economic growth

Human capital has come to be regarded as a primary source of long-term economic growth along with physical capital (Azariadis and Drazen, 1990; Barro and Lee, 1993; Mankiw, Romer, and Weil, 1992). Existing empirical research has demonstrated that human capital has played an important role in the process of China's rapid economic growth. Wang and Yao (2003) estimate that human capital has contributed 11 per cent to China's economic growth during the reform period (1978-1999).

3.1 The key assumptions in the baseline scenario

3.1.1The growth path of human capital stock during the period 2000 to 2050

In the baseline scenario, the assumed growth path of human capital is based on the historical evidence, the current education situation, and on China's low expenditure on education.[5] This information maps a conjectural growth path of human capital that declines from an initial level of one per cent per annum (2000-2010), to a level of 0.5 per cent (2010-2030), and further to 0.25 per cent (2030-2050). Under these assumptions, the average years of schooling of the working age population will be 6.90 in 2010, 7.63 years in 2030. By 2050, it reaches 8.02, representing an increase of 2.1 years (approximately 30 per cent) over the starting level (5.96) in 2000.

- **Existing empirical results**

  Table 1 reports the results of two major empirical studies of human capital formation in China: Wang and Yao (2003) and World Education Indicator Programme (2002 edition).[6] Note in particular that the average growth rate of human capital was lower in the 1990s than in the 1980s. One potential explanation for this declining growth rate is that it is easier to increase the extent of schooling if one starts from a relatively low base. Another relevant factor is that the unit cost of secondary education is significantly higher than that of primary education. According to estimates of the World Education Indicator Programme (WEIP), annual expenditure on primary education per student in China in 1999 was PPP$372 (Purchasing Power Parity), PPP$467 on junior secondary education. Expenditure on senior secondary school per student increased sharply to PPP$1768, and to PPP$5798 on tertiary education. In other words, the cost of one year senior secondary schooling corresponded to almost five years primary schooling and more than three years junior secondary education.

The average educational attainment of the working age population in year 2000 was 5.96, which corresponded approximately to the level of completed primary education. Since further increases in average schooling extend into the secondary tier, and given the proportionately higher cost of secondary education, I assume that the growth rate

[5] The literature on long-run forecasts of China's human capital stock is quite limited. The very important work in this field is Cao and Lutz (2004). Since their research does not forecast the graduation rates of different education levels and, furthermore, and does not distinguish between junior and senior secondary education, it is difficult to calculate the average years of schooling based on their projected result.

[6] Two other studies (Barro and Lee, 2000; Ahuja and Filmer,1995) come up with reasonable findings, but I did not report the result because of both studies use different age ranges.

of average years of schooling will continue to decline if the Chinese government continues to maintain the current low share of GDP spent on education.

Table 1: The estimation of human capital stock in China

(Average years of schooling of working age population aged 15-64)

	1980	1990	1999	2000	Average annual growth rate (per cent) 1980-1990	1990-2000
Wang and Yao	4.18	5.13	5.89	…	2.27	1.65*
WEIP**	4.1	5.06	…	5.96	2.34	1.78

* This average annual growth rate covers the year 1990 to 1999

** WEIP is World Education Indicator Programme

Sources: Wang and Yao (2003) and WEIP (2002 edition).

- **Current education situation and low education spending in China**

  China has developed a wide base of primary education. The net enrolment rate of primary school reached 98.6 per cent in 2002 (Ministry of education of China, 2003). However, development of secondary and tertiary education is relatively low. Gross enrolment rate of secondary school was 64 per cent while the gross enrolment rate of upper secondary school was 38 per cent in 2002 (Ministry of education of China, 2003). The graduation rate from upper secondary was only 16 per cent in 2000. The gross enrolment rate of tertiary education developed fast in recent years. It reached to 11 per cent in 2000, which is still lower than the average level of world total (16.2 per cent in 1996). The stagnant ratio of public expenditure on education to GDP is one major reason for the slow development of upper secondary and tertiary education (Figure 2). Since the 1980s, public expenditure on education in China has fluctuated around 2.5 per cent of GDP, which is even lower than the average level of low-income countries (around 3 per cent).

Considering China's huge population size, low income, and low enrolment and graduation rates of upper secondary and tertiary school, given the proportionately higher cost of the secondary education and substantially higher cost of tertiary education, a conjectural growth path of human capital that increase from a starting level of 5.96 years in 2000 to 8.02 years in 2050 would seem to be a plausible working hypothesis if the Chinese government does not change the current low share of GDP on education.

3.1.2 The national saving rate

In the baseline scenario I assume that the government will not change the proportionate expenditure of national output on education. Hence, I ignore the effects of public education expenditure on national saving rates and only consider the demographic effects. The projected change of the national saving rate during the simulation period (2000 to 2050) is consistent with the life-cycle hypothesis and based on the empirical research conducted by Heller and Symansky (1998).[7] I assume that China's national saving rate will increase to 40.8 percent in 2010. Subsequently it will fall to 23 per cent by 2050. To reach this "target", I shock the saving rate from 2000 to 2010 to rise by 0.2 percent annually, and to fall by approximately 1.4 per cent annually from 2010 to 2050.

3.1.3 Shocks in the baseline scenario

Given the foregoing assumptions, annual percentage changes of the supply of labour and population derived from population projection (refer to Table A1) are fed into the model as well as the growth rate of TFP, national saving rate, and human capital stock. Table 2 summaries the shocks in the baseline scenario.

Table 2: Shocks in the baseline scenario

(p.a., per cent)*

Year	2000-2010	2010-2020	2020-2030	2030-2040	2040-2050
Population	0.63	0.51	0.16	-0.09	-0.29
Labour force	1.07	0	-0.55	-0.67	-0.64
Total factor productivity	2.50	2.50	2.50	2.50	2.50
Saving rate	0.2	-1.45	-1.45	-1.45	-1.45
Human capital stock	1.0	0.5	0.5	0.25	0.25

∗ The growth rate refers to the average annual growth rate over each decade.

3.2 Baseline simulation result

Table 3 reports the growth paths of real GDP and primary factor inputs during the simulation period. The average annual growth rate of real GDP is 7.7 per cent during the first decade, and then decreases gradually to 3.3 per cent in the fifth decade. The annual

[7] See Peng (2005) for the detained discussion on the change of national saving rate from 2000 to 2050.

growth rate of GDP is the result of the change in employment, physical capital stock, human capital stock and productivity improvement.

Table 3: Average annual growth rate of real GDP and factor inputs (per cent)

Year	Real GDP	Physical Capital stock	Employment	Total factor productivity	Human capital stock
2000-2010	7.7	7.3	1.07	2.5	1.0
2010-2020	5.1	4.4	0	2.5	0.5
2020-2030	4.1	3.0	-0.55	2.5	0.5
2030-2040	3.4	2.3	-0.67	2.5	0.25
2040-2050	3.3	2.0	-0.64	2.5	0.25

As Table 3 shows, after the initial increase during the first two decades, employment falls continually. This reflects the progress of population ageing. As a result, China has to rely on increases in the physical capital stock and productivity improvement to sustain her rapid growth, given the fixed land resource. However, the rate of growth of the capital stock deteriorates sharply after the first twenty years to approximately two per cent at the end of 2050. The reason for the low increase of the physical capital stock is that the demand for capital falls when the rate of growth of the labour force falls.[8]

The rapid decline in the labour force and the low growth of capital indicate that the growth rate of output must be supported by productivity improvement which may be achieved through increased total factor productivity or through expansion of the human capital stock. Table 4 compares the economic growth paths with and without incorporating human capital into the model. Note that with constant growth of TFP (ignore the effect of human capital on TFP) of 2.5 per cent per annum, human capital formation will mitigate the adverse effect of rapid population ageing on economic growth by raising the growth rates of all the relevant macroeconomic indicators. On average, human capital lifts the growth rate of GDP by 17 per cent, investment by 8 per cent and households' consumption by 12 per cent during the observation period.

[8] See Back of the Envelope analysis for detailed explanation for the low growth of physical capital stock in Peng (2005).

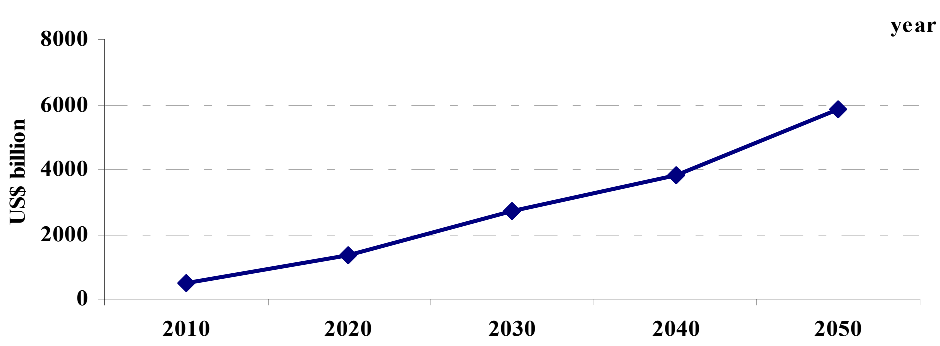
Table 4: Baseline scenario: the contribution of human capital to China's economic growth (Annual growth rate, per cent)

year	Real GDP		Investment		Households' consumption		Export		Import	
	without HP*	with HP	without HP	with HP	without HP	With HP	Without HP	with HP	without HP	with HP
2001-2010	6.5	7.7	6.6	7.3	7.0	8.2	6.9	8.1	4.9	6.4
2011-2020	4.4	5.2	4.0	4.4	5.7	6.3	4.5	5.8	4.0	5.5
2021-2030	3.4	4.1	2.7	3.0	4.6	5.3	3.9	4.6	3.7	4.5
2031-2040	3.1	3.4	2.2	2.3	4.0	4.4	3.5	4.0	3.3	3.9
2041-2050	3.0	3.3	1.9	2.0	3.7	4.0	2.9	3.3	2.6	3.1

* HP: Human capital

The simulation also shows that China accumulates net foreign assets (Figure 1). The projected path of net foreign assets implies a net surplus in the saving-investment balance. Even though the national saving rate is almost cut in half during the observation period (from 40 to 23 percent), China continues to run capital outflows. This implies that domestic investment declines even more[9]. This simulation result is consistent with standard neoclassical growth theory and the empirical findings in the literature[10]: slower labour force growth associated with population ageing will reduce investment demand. The fall in investment demand will tend to exceed the reduction in saving at some stage of the population ageing process (Bosworth, Bryant and Burtless, 2004).

Figure 1: The stock of Net foreign assets in the baseline scenario



[9] The assumption of a fixed capital-investment ratio ties the growth path of investment rigidly to physical capital formation (Table 4).
[10] Bloom and Williamson (1998), Higgins and Williamson (1997), and Higgins (1998).

4. Policy shock: accelerating human capital accumulation – taking advantage of the demographic window

4.1 The growth potential of human capital stock

The important role of human capital in the process of economic growth is very clear from the baseline simulation. Now I will explore the macroeconomic implications of a higher growth rate of human capital beyond the levels specified in the baseline. The experience of other recently industrializing countries is examined to provide some coarse indication of a plausible target level for educational attainment that Chinese policy-makers might strive for.

Singapore, Hong Kong, Taiwan and Korea have achieved remarkable economic growth performance during the past 50 years -- a performance that has been regarded as the "Asian economic miracle". The dramatic progress in education (Table 5) was one important reason (Tilak, 2002). Not unexpectedly, this achievement was supported by a substantial commitment of resources. In Korea, the average ratio of the public expenditure on education to GDP during 1980 to 2000 was around 3.8 per cent per annum (Figure 2).

Table 5: Educational attainment of the total population aged 15 and over
(Average years of schooling)

Year	Hong Kong	Korea	Taiwan	Singapore
1960	**5.17**	**4.25**	**3.87**	**4.30**
1970	6.31	4.91	5.31	5.05
1980	7.95	7.91	7.61	5.50
1990	9.15	9.94	7.98	5.96
1995	9.28	10.56	8.37	6.72
2000	**9.41**	**10.84**	**8.76**	**7.05**
Average annual growth rate (%)	1.6	2.6	3.2	1.6

Source: Barro and Lee (2000)

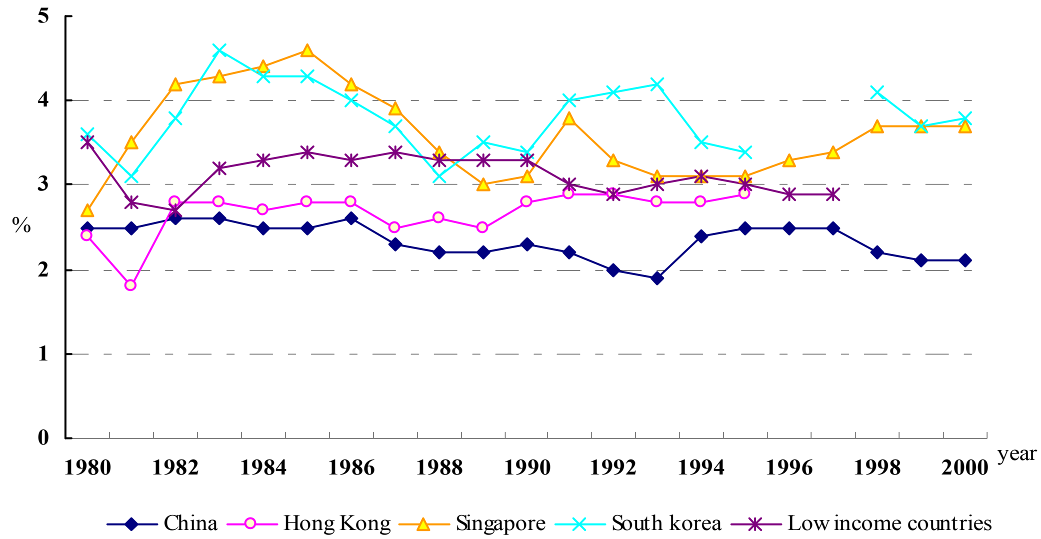
Another important reason for the dramatic increase in human capital is that these countries have fully taken advantage of the demographic dividend. The declining school age population and low total dependency ratio driven by the fertility transition during the last half-century have created the demographic windows in these countries. The demographic window combining with the substantial investment in education and effective education reform has boosted the human capital formation.

This common experience provides an instructive example that China could profitably follow. It involves two basic elements:

First, a significant increase in public expenditure on education

Compared with the "Asian tigers", China's public spending on education is quite low (Figure 2). It has stagnated around 2.5 per cent of GDP since the 1980s. At the same time, roughly 30 percent of GDP is devoted to physical investment. "In the U.S. these figures are 5.4 and 17 percent, respectively. In South Korea, they are 3.7 and 30 percent. China's ratio of annual investment in physical capital to human capital is much higher than in most countries around the world" (Heckman, 2002). The goal of China's government is to increase the share of public expenditure on education to four per cent of GDP (Ministry of Education, 1996). This goal has been set up in 1996. However, the share continues to stagnate at 2.4 percent in 2003. If the Chinese government can manage to fulfill its goal, then the growth rate of human capital will be significantly accelerated.

Figure 2: Public expenditure on education (as per cent of GDP)

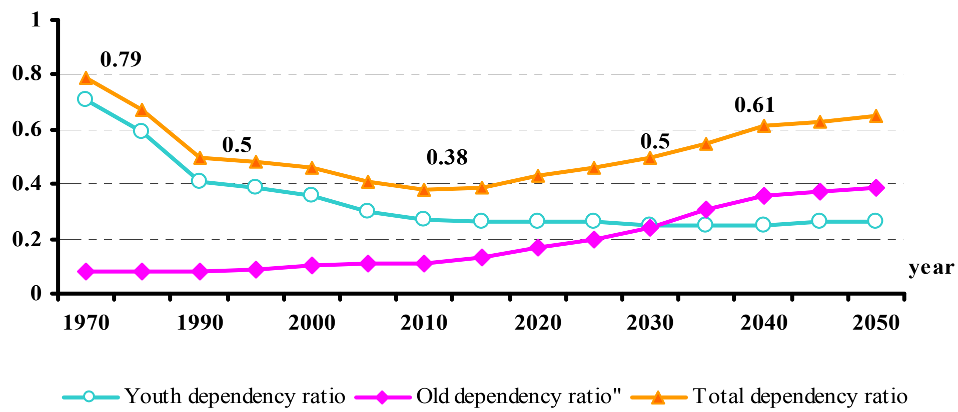


* Data for South Korea in 1996 and 1997 were unavailable
Sources: World Bank (2004) and UNESCO (2003).

Secondly, exploit the opportunity of 'demographic window'

The dramatic fertility rate decline since the early 1970s has created a demographic window for China (Figure 3). The total dependency ratio has been declining since 1970. In year 1990, the total dependency ratio declined to the level below 0.5. This "golden age structure" characterized by total dependency ratio below 0.5 percent will last approximately 40 years (from 1990 to around 2030) in China. After 2030, the total dependency ratio will once again rise above 0.5 since population ageing drives up the old dependency ratio. The rapidly increasing old population will impose a heavy burden on China's public expenditure. This implies that China may not be able to afford to increase the share of public expenditure on education beyond 2030. However, before total dependency ratio rises up 0.5 again, China can take advantage of this demographic window to expand her education rapidly. This argument is based on the following facts:

Figure 3: Trends of dependency ratios and the "Demographic Window" in China



Source: United Nations (2004)

- Declining School age population: the fall in youth dependency ratio permits schooling per child to rise, adding further to future economic growth (Bloom, Canning and Malaney, 1999). In China the rapid fertility decline has caused a notable reduction of the school-aged population (Table A3). The percentage of school age population aged 5-14 (including primary and lower secondary school) has declined since the early 1980s. From 2000 to 2050, the school age population aged 5-14 is expected to decline by 33 per cent and upper secondary education population (aged 15-19) is expected to decline by 27 per cent. Together, the total school age population (aged 5-24) is expected to decline by 29 per cent.
- Changing Composition: As fertility rates fall, demand for primary education continues to drop and, over time, this effect will be repeated at the secondary level. However, demand for higher education will simultaneously be rising (at least for a period of time), as those leaving secondary education consider attempting to gain more advanced qualifications (Bloom, Canning and Sevilla, 2003). The dramatic decline in primary school age students permits the transfer of education expenditure from primary to lower and upper secondary school or to tertiary education. Empirical research suggests that human capital may play a stronger role in the growth process once it reaches a certain threshold. Upper secondary

and tertiary achievement is important for economic growth to translate into steady growth (WEIP, 2002 Edition). Policy-makers can use the demographic dividend, i.e. the saving from the reduction in number of primary level, to shift resources toward broadening access to more advanced forms of education.

The net result of these demographic changes in an environment of stable spending on education is to raise the level of educational attainment. The retiring population is characterized by low educational attainment. The young school-age cohort is the beneficiary of additional education. The interaction of these processes increases the average educational attainment of labour force.

However, the potential benefit of the "demographic window" can not be reaped automatically. It occurs only when a country has social, economic and political institutions and policies that allow it to realize and capture this growth potential (Bloom and Williamson, 1998; Asian Development Bank, 1997; Bloom, Canning and Sevilla, 2003). The demographic transition creates conditions where people will tend to invest in their and their children's health and education, offering great economic benefits, especially in the modern world's increasingly sophisticated economies. But government invariably plays a vital role in creating an environment where high-quality health and education provision is possible (Bloom, Canning and Sevilla, 2003).

The demographic dividend is time-limited. If the Chinese government takes advantage of this demographic window of opportunity and increases education spending significantly, then it may accelerate the growth rate of human capital formation, possibly achieving by 2050 average education levels typical of developed countries in the early 1990s of more than ten years. In order to achieve this goal, I assume that the Chinese government substantially increases the spending on education to the level that ensures the average years of schooling of working population increase by 1.5 per cent per annum during the first three decades, and by 0.5 per cent during the last two decades of the first half century. Based on this assumption, the average years of schooling of the working age population will be 10.48 years by year 2050.

4.1.2 National saving rates in policy scenario

The significant increase in education expenditure by the government will reduce the public saving rate. Since detailed data of the public education cost per student at different school levels is not available for China, I cannot estimate the effects of additional human capital formation on national saving rates. I will use the findings of Heller and Symansky (1998) to roughly represent the effects. Their estimation of the change in the national saving rate takes account of the additional effects of government policy change such as education, medical outlays and pension coverage besides the effects of population ageing. According to their estimation, China's national saving rate will decline from 40 percent in 2000 to 38.3 in 2010, and further to 20 percent by 2050 (three percentage points lower than the baseline scenario).

Based on the foregoing discussions, the deviations from baseline of the growth rates of human capital stock and national saving rates in the policy scenario are put into the model

4.2 Policy simulation result

The policy simulation shows that rapid human capital accumulation is expected to boost all macroeconomic variables (Table 6). For example, the annual average growth rate of real GDP is likely to be raised by 0.66 percentage points during the first half century. By 2050, real GDP will be 24 per cent larger than baseline. The rapid expansion of China's economy provides a relatively solid foundation for supporting the rapid growth of the elderly population.

Households' living standards also improve. The annual growth rate of per capital real consumption increases by approximately 0.6 percentage points during 2000 to 2050. By the end of 2050, per capital real consumption exceeds the baseline scenario by 22.3 per cent. Notice that the resource requirements of additional human capital formation reduce consumption growth below GDP growth (Table 6). Furthermore, the induced increase in physical capital formation increases investment demand. Both factors narrow the imbalance between saving and investment. The cumulative result is by 2050 net foreign assets will be US$1600 billion lower in policy simulation than in the baseline scenario (Figure 4).[11] This retards the growth of GNP compared to real GDP (Table 6) and, therefore, the growth of per capita real consumption.[12]

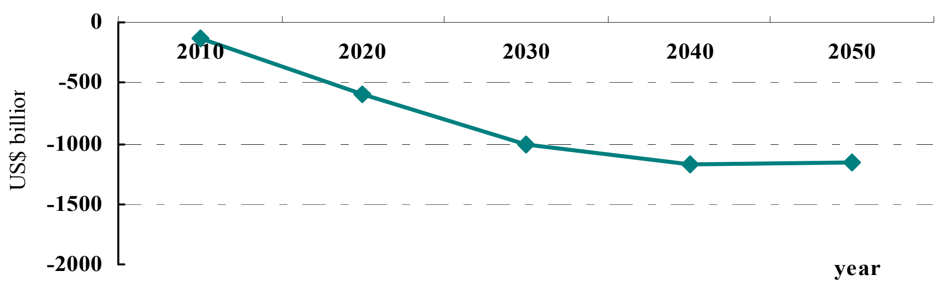
Table 6: Macroeconomic effects of higher growth rate of human capital relative to baseline

	Changes in average annual growth rate (percentage point)	**Cumulative deviation from baseline by 2050** (per cent)
real GDP	0.66	24.0
Consumption	0.60	22.2
Capital stock	0.30	11.2
Investment	0.32	13.2
export	0.69	26.0
import	0.47	16.1
Real wage rate	0.68	25.1
Per capita real GDP	0.66	24.0
Per capita real GNP	0.59	21.9
per capita real consumption	0.61	22.3

In sum, the rapid increase in human capital mitigates the adverse effects of population ageing by raising not only the growth rate of total output, but also the growth in households' living standards. These results support the finding that expanding education is likely to offset the erosion of living standards of an ageing population by promoting faster productivity growth (Fouègre and Merétte, 1999, and Day and Dowrick, 2004).

[11] Policy simulation shows that with the extra investment demand induced by additional human capital formation, China still maintains capital outflows and domestic saving is still sufficient to meet domestic investment demand.
[12] Another reason for the lower growth of per capita real consumption is that faster growth of exports causes the terms of trade to decline.

Figure 4: Cumulative deviations from baseline of the stock of net foreign assets



5. Conclusions and policy implications

This paper uses a CGE model to explore the macroeconomic effects of accelerating human capital accumulation by increasing public expenditure on education. The policy shock dramatically raises output and real consumption in both total and per capita terms to mitigate the erosion of living standards of an ageing population. ,

In general terms, the basic policy messages of the simulation exercise are:

- Investment in education is welfare enhancing.
- The Chinese government should significantly increase spending on education. This investment should be undertaken without delay because of the long implementation lags of such policies in altering the stock of human capital. Importantly, this increase in expenditure should be timed to utilize the demographic window.
- Demographic transition has significant effects on the process of human capital formation (Bloom, Canning and Sevilla, 2003). However a congenial policy environment is required to take full advantage of this demographic opportunity. Such an environment should be designed to encourage and facilitate access to education, especially in rural areas, and to promote higher retention rates.

6. Limitations and extensions

The present paper ignores the effects on total factor of productivity of changes in the size of the human capital stock. This may underestimate the actual contribution of human capital accumulation to economic growth.

Secondly, the assumptions in the present paper about the growth path of human capital over the study period are very coarse estimates. The intention of this simulation is to provide some qualitative indication of the potential contribution that human capital may make to economic growth in the context of rapidly changing age structure of population in China.

Thirdly, changes in the enrolment and completion rates, especially at the upper secondary and tertiary education affect the total labour force participation rate. I ignore these effects and only take account of the impacts of demographic structure change. This simplification may overestimate the contribution of human capital. Detailed modelling of the relationship between additional education expenditure, changes in human capital and changes in labour force participation rate will be included in an extended version of this paper.

Fourthly, Population size is assumed not to respond to changes in human capital stock. Empirical evidence shows that education attainment affects fertility rate adversely. Higher education is expected to have lower fertility level. With the increase in human capital stock, the fertility rate is expected to be reduced further in China.

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Annex:

Table A1: Population projection in China

Year	Total population		Working age population (15 -64)		Elderly population	
	Size (million)	Average annual growth rate (%)∗	Size (million)	Average annual growth rate (%)∗	Total (million)	Proportion of elderly over total population (%)
2000	1273	--	871	--	87	6.8
2010	1355	6.32	979	12.33	112	8.3
2020	1424	5.12	993	1.43	169	11.9
2030	1446	1.58	966	-2.65	236	16.3
2040	1433	-0.90	891	-7.80	319	22.3
2050	1392	-2.87	845	-5.17	329	23.6

∗ The growth rate refers to the average annual growth rate over each decade.
Source: United Nations (2004)

Table A2: Detailed Demographic composition effect on labour force participation rate in China from 1995 to 2050 (%)

Age group	1995			2000		2010		2020	
	PA* (1)	cohort shares (2)	contribution to APR* (2)*(1)/100	cohort shares (3)	contribution to APR with 1995 cohort rates (3)*(1)/100	cohort shares (4)	contribution to APR with 1995 cohort rates (4)*(1)/100	cohort shares (5)	contribution to APR with 1995 cohort rates (5)*(1)/100
Men 15-19	56.65	6.21	3.52	6.02	3.41	5.49	3.11	4.44	2.52
Women 15-19	60.99	5.81	3.54	5.55	3.39	4.93	3.01	3.99	2.44
Men 20-24	95.89	7.61	7.30	5.82	5.58	6.25	5.99	4.98	4.78
Women 20-24	90.50	7.21	6.53	5.45	4.94	5.67	5.13	4.49	4.06
Men 25-29	99.09	7.92	7.85	7.12	7.05	5.26	5.22	5.32	5.28
Women 25-29	90.95	7.58	6.89	6.77	6.15	4.89	4.44	4.81	4.37
Men 30-34	99.12	6.59	6.54	7.40	7.34	5.07	5.03	6.02	5.97
Women 30-34	91.52	6.25	5.72	7.11	6.51	4.79	4.39	5.51	5.04
Men 35-39	99.09	5.38	5.33	6.15	6.10	6.21	6.15	5.05	5.00
Women 35-39	91.32	4.94	4.51	5.86	5.35	5.95	5.43	4.75	4.33
Men 40-44	98.85	5.47	5.40	5.00	4.95	6.44	6.37	4.86	4.80
Women 40-44	89.78	5.13	4.60	4.62	4.15	6.25	5.61	4.65	4.18
Men 45-49	97.80	4.06	3.97	5.06	4.95	5.32	5.21	5.93	5.80
Women 45-49	82.39	3.71	3.06	4.78	3.94	5.12	4.22	5.77	4.75
Men 50-54	92.98	3.11	2.89	3.72	3.45	4.27	3.97	6.10	5.67
Women 50-54	66.88	2.82	1.88	3.44	2.30	4.00	2.68	6.01	4.02
Men 55-59	81.79	2.74	2.24	2.79	2.28	4.20	3.44	4.94	4.04
Women 55-59	45.93	2.58	1.18	2.58	1.18	4.08	1.87	4.87	2.23
Men 60-64	58.80	2.47	1.45	2.45	1.44	2.94	1.73	3.79	2.23
Women 60-64	28.06	2.33	0.65	2.31	0.65	2.85	0.80	3.71	1.04
Total	**84.97**	**100**	**84.97**	**100**	**85.11**	**100**	**83.79**	**100**	**82.55**

Table A2: Detailed Demographic composition effect on labour force participation rate in China from 1995 to 2050 (continued)

Age group	2030		2040		2050	
	cohort shares (6)	contribution to APR with 1995 cohort rates (6)*(1)/100	cohort shares (7)	contribution to APR with 1995 cohort rates (7)*(1)/100	cohort shares (8)	contribution to APR with 1995 cohort rates (8)*(1)/100
Men 15-19	4.85	2.75	4.75	2.69	4.53	2.57
Women 15-19	4.37	2.67	4.30	2.62	4.14	2.53
Men 20-24	4.56	4.37	5.14	4.92	4.61	4.42
Women 20-24	4.11	3.72	4.65	4.21	4.22	3.82
Men 25-29	4.49	4.45	5.19	5.14	4.95	4.91
Women 25-29	4.06	3.69	4.70	4.27	4.50	4.09
Men 30-34	5.00	4.96	4.86	4.81	5.34	5.29
Women 30-34	4.55	4.16	4.40	4.03	4.85	4.44
Men 35-39	5.32	5.27	4.76	4.72	5.38	5.33
Women 35-39	4.86	4.43	4.33	3.96	4.90	4.47
Men 40-44	6.00	5.93	5.30	5.23	5.03	4.97
Women 40-44	5.56	4.99	4.85	4.36	4.59	4.12
Men 45-49	5.02	4.91	5.61	5.48	4.92	4.81
Women 45-49	4.78	3.94	5.17	4.26	4.50	3.71
Men 50-54	4.79	4.45	6.28	5.84	5.43	5.05
Women 50-54	4.67	3.12	5.90	3.95	5.02	3.36
Men 55-59	5.75	4.70	5.17	4.23	5.66	4.63
Women 55-59	5.72	2.63	5.03	2.31	5.31	2.44
Men 60-64	5.71	3.36	4.78	2.81	6.17	3.63
Women 60-64	5.84	1.64	4.81	1.35	5.96	1.67
Total	**100**	**80.14**	**100**	**81.19**	**100**	**80.26**

* PA denotes participation rate and APR denotes aggregate participation rate.

Source: Data in column one is calculated by author based on China's one-percent-population-sample survey of 1995 and data in columns two to eight is based on United Nations medium variant population projection (2004).

Table A3: school-age populations in China 1970-2050

Year	Population aged 5-14		Population aged 15-19		Population aged 20-24	
	Percentage*	Total size (million)	Percentage	Total size (million)	Percentage	Total size (million)
1970	24.8	197.6	11.0	91.2	8.1	67.0
1980	25.5	254.8	10.8	108.2	8.7	86.8
1985	20.8	222.8	12.1	130	10.0	107.8
1990	17.4	200.9	10.6	123	11.1	128.5
1995	18.0	219.2	8.1	98.9	10.0	122.0
2000	17.3	220.2	7.9	100.7	7.7	98.2
2005	15.0	197.3	8.9	117.2	7.6	100.1
2010	13.2	178.9	7.5	102.0	8.6	116.6
2015	12.1	168.5	6.8	94.5	7.3	101.4
2020	12.2	173.9	5.9	83.7	6.6	94.0
2025	12.3	177.2	5.8	84.2	5.8	83.3
2030	11.7	168.8	6.2	89.1	5.8	83.8
2035	10.8	156.0	6.1	87.6	6.1	88.7
2040	10.4	148.6	5.6	80.7	6.1	87.2
2045	10.4	147.9	5.3	74.9	5.7	80.3
2050	10.6	148.0	5.3	73.3	5.4	74.5

* % of total population
Source: United Nations (2004).