

Human Capital Convergence and Regional Disparities:
The Case of China

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Abstract

Based on an open-economy neoclassical growth model of Barro et al. (1995), this paper examines the regional convergence of per capita GDP and various indicators of human capital stock, and the role of human capital accumulation in economic growth across 25 provinces in China during the 1996-2006 period. The analysis follows the empirical methodology of Coulombe and Tremblay (2001). The empirical results indicate that various indicators of human capital stock do converge over time, but unconditional convergence of per capita GDP at the provincial level does not happen. The dispersion of per capita GDP is widening across provinces during the sample period. Additionally, the estimates of human capital's share in per capita GDP for higher education are between 0.42 and 0.51. These estimates are consistent with a broad capital share of 0.8 required to reconcile the predictions of the neoclassical growth model with stylized facts. Finally, the growth rate of per capita GDP is significantly positively related to the initial level of all but one indicators of human capital.

1. Introduction

China's economy has experienced remarkable growth since the economic reforms started in 1978. From 1979 to 2006, China achieved an annual average growth rate of Gross Domestic Product (GDP) of around 9.8 percent. During the period 1991-2006, the growth rate of GDP was even faster, at 10.2 percent. However, this rapid growth was accompanied by serious regional disparities and income inequalities. In 2006, per capita GDP in Shanghai, the richest province, was 57,695 Yuan (US\$ 7,396), almost ten times that of Guizhou's, 5,787 Yuan (US\$ 742).¹ Income gap became larger across different provinces and regions in China.² Meanwhile, many growth theories and empirical studies of economic growth show that there is a close relationship between human capital accumulation and economic growth. As a result, it is worth examining the following questions: Do the regional disparities across provinces decline or increase over time in China? What role does human capital play in explaining the regional disparities and growth performance? Do regional differences in human capital tend to decline over time in China? Focusing on the three questions, this paper aims to evaluate regional convergence of income per capita and human capital in China.

This paper adopts a neoclassical open-economy growth model proposed by Barro et al. (1995) and follows an empirical approach of Coulombe and Tremblay (2001) to test its theoretical implications. In the open-economy model with perfect

¹ Source: "China Statistical Yearbook" (2007), Table 3-11, "Gross Regional Product (2006)".

² Source: Ma, J. (2000), "The Chinese Economy in the 1990s".

physical capital mobility and a borrowing constraint on human capital, the dynamics of human capital is the driving force of per capita income. Per capita income disparities across economies can be explained by disparities in human capital accumulation. In this paper, the dynamics of various indicators of human capital and income per capita are examined, and the role of human capital on growth and regional disparities is discussed using the data for 25 provinces in China during the period 1996-2006.

The contributions of the paper relative to the existing literature are as follows. First, this study uses the recent data set (from 1996 to 2006) that captures the latest features of economic growth in China. Also, regional income disparities are analyzed by using the convergence regression based on the panel data. Many articles have discussed regional disparities and growth in China from different perspectives.³ However, most researchers have focused on the pre-reform period 1952-1977 or the post-reform period in the 1980s and 1990s. Moreover, the conclusions on regional disparities are mixed, due to the differences in the time spans. Second, this study examines the impact of human capital on growth using a convergence regression approach. Furthermore, the regional differences and patterns of human capital accumulation are discussed in the context of the convergence regression. In examining the role of human capital accumulation in economic growth in China, most previous studies, such as, Wang and Hu (1999), Wang and Yao (2003) and Qian

³ See, for example, Tsui (1991), Chen and Fleisher (1996), Ying (1999), Lee (2000), Song et al. (2000), Bao et al. (2002) and Qian and Smyth (2006).

and Smyth (2006), are based on the non-econometric standard growth accounting approach in the framework of the neoclassical growth model. Third, this study takes a small step forward measuring the human capital more accurately. The percentage of the population that has attained at least a given level of education is considered to measure human capital. Specifically, this empirical analysis relies only on relative measures of human capital across provinces. Most previous empirical studies, such as Wang and Hu (1999), Wang and Yao (2003) and Qian and Smyth (2006), use schooling years or enrolment rate as a proxy of human capital stock.

The rest of this paper is organized as follows. Relevant studies on convergence and economic growth with human capital are reviewed in section 2. Section 3 introduces the theoretical and empirical frameworks. First, the predictions of Barro et al. (1995)'s open-economy growth model are explained. Then the empirical model proposed by Coulombe and Tremblay (2001) is described. Section 4 presents data and discusses several econometric issues. In particular, it focuses on the measures of human capital stock used in this study. Section 5 analyzes the empirical results of the dynamics of per capita GDP and six indicators of human capital stock. The conclusion of this paper is presented in Section 6.

2. Literature Review

This section describes the related literature on convergence and the role of human capital in economic growth. The first two subsections focus on the basic growth theories and convergence issues. The following two subsections review empirical studies, emphasizing empirics of human capital and economic growth in China.

2.1. Convergence and neoclassical growth theory

In growth theory, convergence indicates that poor economies should grow faster than rich ones. According to the definition of Barro and Sala-i-Martin (1995, Ch.11), there are two main types of convergence: β -convergence and σ -convergence. The concept of β -convergence means that poor economies tend to grow faster than rich ones, so that the poor economies tend to catch up with the rich ones in terms of the level of per capita income. The second type of convergence is σ -convergence, which concerns cross-sectional dispersion. It refers to the reduction of cross-sectional dispersion of macro variables over time. The dispersion can be measured by the standard deviation of the logarithm of a selected macro variable, for example, of the logarithm of per capita income, across a group of countries or regions. Convergence of the first kind (β -convergence) tends to generate convergence of the second kind (σ -convergence), but this process is offset by new disturbances or shocks that tend to increase cross-sectional dispersion.

The literature separates β -convergence in two types: unconditional β -convergence and conditional β -convergence (Sala-i-Martin, 1996). Unconditional β -convergence refers to the hypothesis that poor economies should grow faster per capita than rich economies, without conditioning on any other characteristics. Econometrically, this hypothesis indicates that the growth rates of macro variables are expected to be negatively related to their initial economic levels. Under the hypothesis of unconditional β -convergence, all economies are predicted to converge to identical steady-state values. In contrast, conditional β -convergence refers to the hypothesis that poor economies should grow faster per capita than rich economies, conditional on economy-specific characteristics. Econometrically, this hypothesis means that the growth rates of macro variables are expected to be negatively related to their initial economic levels, holding fixed other variables, such as saving rates, population growth rate, measures of government policies, production function, etc. Hence, individual economies are predicted to converge to different steady state values under the hypothesis of conditional convergence.

The concept of convergence is firstly considered in the influential paper by Solow (1956). Based on the neoclassical production function with diminishing returns to physical capital, the Solow model predicts that economies eventually converge toward their own steady states. The rates of saving and population growth, which are taken as exogenous, determine the steady-state levels of income per capita. Along the balanced growth path, various per capita economic variables grow at a constant rate equal to the exogenous growth rate of technological progress. The Solow model gives

a simple theory of growth.

However, the Solow model encounters some problems in explaining some stylized facts of economic development. For example, one problem deals with the magnitudes of the effects of saving and population growth on income. Mankiw et al. (1992) test of the Solow model empirically. Based on available data for a large set of countries, their results correctly show the directions of the effects of saving and population growth on income. Nevertheless, if physical capital share in income is limited to one third, the estimated impacts of saving and population growth are much larger than the model predicts. The implied capital share is around 0.6. This implied share is not plausible if capital is limited to physical capital. One fruitful direction to modify the model is to think about other forms of capital, such as human capital. This direction is discussed next.

2.2. New growth theory with human capital

Although the Solow growth model gives predictions on conditional convergence and the determinants of the steady states of income per capita, it encounters some problems. One of the problems deals with the magnitudes of the effects of saving and population growth on income. Therefore, new growth theories have been developed. Two examples are the augmented Solow model with physical and human capital proposed by Mankiw et al. (1992), and the open-economy growth model proposed by Barro et al. (1995). In these two growth models, the role of human capital in economic growth is taken into account. Theoretically, accounting for human

capital may change one's view of the nature of the growth process. Empirically, ignoring human capital can lead to incorrect conclusions, like too large value of the implied capital share in income mentioned in the last subsection.

Mankiw et al. (1992) extend the Solow model with exogenous technology to include human capital stock in addition to physical capital stock in the production function. The model predicts conditional convergence, although its transitional dynamics are more complex due to two types of capital. Country-specific steady state is now determined not only by differences in savings, the growth rate of population, but also by differences in the initial levels of human capital. Among countries with similar technology, saving rates and population growth, poor countries will catch up with rich ones. Mankiw et al. (1992) test the augmented Solow model. They consider investment in secondary education as a proxy for human capital stock, which is measured by the percentage of the working age population in secondary school. Their empirical results strongly support the augmented Solow model. Specifically, human capital variables enter significantly in each of the three samples, and adding human capital improves the overall fit of estimation regressions. The size of the coefficient on physical capital investment is reduced. The implied value of the physical capital share in income is around 0.33. Additionally, Mankiw et al. estimate that controlling for the initial level of human capital, investment rate and population growth rate, conditional convergence occurs in each of the three samples. Differences in population growth and investments in physical and human capital explain almost 80 percent of the cross-country differences in income per capita.

Barro et al. (1995) develop an open-economy growth model to highlight the important role of human capital in economic growth. In a neoclassical open-economy growth model, they assume that physical capital is perfectly mobile, but the financing of human capital has a borrowing constraint. The model predicts that human capital accumulation is the driving force of economic growth. Cross-country differences can be explained by differences in the human capital. More discussion of this model is provided in the section 3.1.

2.3. Empirics of human capital and economic growth

The issue of whether or not poor economies grow faster than rich ones has attracted considerable attention in empirical work on economic growth. In addition, some studies estimate and emphasize the effect of human capital on growth by choosing human capital as explanatory or control variable.

Some regional studies find evidence of unconditional convergence, where no explanatory variable other than the initial level of per capita income or product is held constant. Barro and Sala-i-Martin (1991) study the behaviour of the U.S. states since 1880, Japanese prefectures since 1930, and the regions of eight European countries since 1950. The empirical results indicate that unconditional convergence occurs in these regional economies. It means that poor regions of these countries tend to grow faster per capita than rich ones. Barro and Sala-i-Martin (1991) interpret the results as consistent with the traditional neoclassical growth model if regions within a country have roughly similar tastes, technologies, and political institutions. The estimates of

the speed of convergence are around two to three percent per year in the various contexts. Coulombe and Lee (1993, 1995), Lefebvre (1994) and Coulombe and Day (1999) conclude that the hypothesis of unconditional convergence is significantly supported across ten Canadian provinces for alternative indicators of per capita income, output and productivity. Cashin and Sahay (1995) find evidence of unconditional convergence across Indian states between 1961 and 1991.

Some empirical studies examine conditional convergence by choosing various control variables. One such variable is human capital. Barro (1991) shows that the growth rate of real per capita GDP is substantially negatively related to the starting level of real per capita GDP, if initial human capital (the level of school enrolment) is held constant. He also indicates that, given the level of initial real per capita GDP, the growth rate of real per capita GDP is positively related to the starting level of human capital. Therefore, poor countries tend to catch up with rich one if they are enough educated initially. Mankiw et al. (1992) test conditional convergence based on the augmented Solow model in three country samples. Their empirical results support conditional convergence when holding population growth rate, investment rate and school enrolment. They find that the speed of conditional convergence is around two percent per year in 22 OECD countries, and human capital has a significantly positive effect on growth rate of income per capita in three different samples.

Based on an open-economy growth model proposed by Barro et al. (1995), Coulombe and Tremblay (2001) perform an empirical study of unconditional convergence across Canadian provinces and test the role of human capital

accumulation on economic growth between 1951 and 1996. They choose two different education levels to measure human capital: at least Grade 9 and university degree. They find that the dynamics of human capital determine the evolution of per capita income and output, and per capita income and output converge at the identical speed as human capital.

Coulombe (2003) study the role of urbanization and human capital in explaining conditional convergence of the Canadian provinces. Extending the model used by Coulombe and Tremblay (2001) for an open economy, he uses data on the relative rates of urbanization across provinces to examine the relative long-run provincial steady states of human capital indicator and per capita income. The empirical results suggest that per capita income at the provincial level converge at the speed of five percent per year. He concludes that human capital alone cannot contribute to the regional disparities and a relatively higher degree of urbanization seems to be important for a higher long-run growth.

2.4. Existing studies on human capital and economic growth of China

In the case of China, many researchers have studied the patterns of economic growth and income disparities and examined the role of human capital on growth. Lardy (1978) is one of the earliest studies to review the patterns of income distribution of China. He indicates that “the degree of interregional income inequality in China substantially exceeds the inequality found in several countries that are treated in the economic development literature as classic cases of north-south

dualism” (Lardy (1978, p.156)). Tsui (1991) indicates the change in regional inequality in China from 1952 to 1985 and finds that the inter-provincial income gaps did not narrow but widen mildly since the economic reform started in 1978.

Chen and Fleisher (1996) analyze post-reform income inequality in China. They find evidence of conditional convergence of per capita output across Chinese provinces from 1978 to 1993, applying the human capital-augmented Solow model, proposed by Mankiw et al., to cross-section time series data. They choose physical investment share, employment growth, human capital investment, foreign direct investment and coastal location as long-run control variables. They conclude that overall regional disparity is likely to decline modestly but income gap between coastal and inland regions is likely to increase during the 1978-1993 period.

In another study, Gundlach (1997) estimates unconditional convergence of output per capita across Chinese provinces from 1978 to 1989. Based on the neoclassical growth model including human capital, the empirical results suggest an inter-provincial income convergence rate of 2.2 percent per year. He also estimates an inter-provincial income convergence rate of 2.7 percent per year using the open-economy growth model of Barro et al. (1995) that assumes interregional mobility of physical capital, but immobile human capital. The empirical estimations also indicate that “convergence of output per capita across Chinese provinces has been supported by high inter-provincial physical capital mobility since economic reforms began in 1978” (Gundlach (1997, p.425)). In addition, Gundlach (1997) uses the approach suggested by Feldstein and Horioka (1980) to check capital mobility

across Chinese provinces.⁴ He finds that provincial saving and investment rates are uncorrelated since the correlation coefficient is not significantly different from zero. Thus, he concludes that capital mobility has been high across Chinese provinces since economic reforms began in 1978.

The convergence rate of output per capita is expected to decline as economic reforms encourage fiscal decentralisation and then hinder interregional capital mobility. This is confirmed by Raiser (1998), who find a reduced pace of income convergence after 1985 in China. Raiser (1998) attributes this finding to the shift of rural to industrial reforms and the system of fiscal transfers in the post-reform period. The former transition benefits the relatively richer coastal provinces and thus slows down the convergence process. The latter system provides fiscal aids to the relatively richer inland provinces, which becomes a serious obstacle to income convergence across the inland provinces in China.

Yao and Zhang (2001) employ the panel data approach and use the human capital-augmented Solow model, proposed by Mankiw et al., to examine the convergence of income per capita across different Chinese provinces and regions. The empirical results indicate unconditional divergence of income per capita during the 1978-1995 period. The results also show conditional convergence after controlling for population growth, investment rate, human capital investment, trade and

⁴ A common test of the assumption of perfect physical capital mobility posed by Feldstein and Horioka (1980) is to estimate the correlation coefficient between domestic saving and investment across countries. If the correlation coefficient is not significantly different from zero at a given confidence level, then capital is perfectly mobile. Otherwise, capital is not perfectly mobile across economies. See more detail in the work paper of Coulombe and Tremblay (1999, Appendix).

transportation. Yao and Zhang argue that the three geographical regions of China (the coastal, central, and western regions) may converge into “three distinctive geo-economic clubs of economic growth, within each economic club, there is a tendency of convergence, but between the clubs, there is a tendency of divergence” (Yao and Zhang (2001, p.182)). In a more recent study, Lei and Yao (2008) adopt the model applied by Yao and Zhang (2001) to regress the growth rate of real GDP per capita against its initial level using both cross-sectional and panel data. They find evidence of unconditional convergence across Chinese provinces, Hong Kong and Macau from 1978 to 2002.⁵

Overall, empirical studies of regional convergence in China provide conflicting evidence on the hypothesis of unconditional and conditional convergence. This result may be attributed to the length of the sample periods and the choice of different provinces. China, a large developing country, may share heterogeneous characteristics across different provinces and regions.

In growth empirics of China, some empirical studies have recently paid attention to specifying the effects of education on economic growth recently, mainly based on new growth theories. For example, Chen and Fleisher (1997) adopt university-level education as measure of human capital and find a positive relationship between human capital and total factor productivity (TFP) growth at the provincial level of China. In a later study, Chen and Feng (2000) use cross-provincial

⁵ Hong Kong and Macau became two Special Administrative Region (SAR) of China in 1997 and 1999, respectively.

pooled data from 1978 to 1989 in China. They find that increases of investment in higher education, the number of private and semi-private enterprises and trade stimulate economic growth. They also find that these factors contribute to uneven growth in China.

A number of studies examine the effects of human capital on growth of China implied by the neoclassical growth model including human capital, mostly using growth accounting method. For example, Young (2003) estimates an annual growth rate of 1.1 percent for human capital in the non-agricultural sector from 1978 to 1998 at the national level in China. He indicates that improvement of labour quality may reflect changes in educational achievement or human capital accumulation. Wang and Yao (2003) use time series data to examine the sources of economic growth based on growth accounting at the national level. They find that after incorporating human capital, the growth of TFP still plays a positive and significant role during the reform period 1978-1999. The growth of TFP contributes to 25.4 per cent of economic growth, while human capital stock accounts for 11 per cent of GDP growth in the reform period.

Wang and Hu (1999) examine the economic sources of uneven regional development in a growth accounting study at the provincial level from 1978 to 1995. They use the average years of schooling for the population as a proxy of human capital stock. Their empirical results demonstrate that human capital stock plays little role in explaining economic growth for all provinces, and contribute barely five percent of growth during the period. In a later study, Qian and Smyth (2006) also use

a growth accounting framework, incorporating human capital stock (average years of schooling). They find that human capital stock contribute to 13 percent of output growth across Chinese provinces during the period 1990-2000. Physical capital stock plays an important role in economic growth, contributing to around 55 per cent of GDP growth across provinces. They also indicate that regional income disparities between coastal and inland provinces are great from 1990 to 2000 in China.

In conclusion, the empirical studies explain the role of human capital in economic growth in China to varying degrees. The results depend on the level of education and the growth models used for analysis. The empirical results demonstrate that higher or university-level education improve economic growth. Based on a growth accounting framework incorporating human capital accumulation, the empirical results show the relative importance of factor accumulation (physical capital and human capital) versus the growth of total factor productivity.

3. Theoretical and Empirical Framework

3.1. Theoretical model

This subsection reviews a neoclassical open-economy growth model with credit-market constraints developed by Barro et al. (1995), on which empirical analysis of this paper is based. Consider an open economy, with total output produced with three inputs: physical capital, human capital and raw labour. The production function is assumed to be Cobb-Douglas:

$$Y = F(K, H, L) = AK^\alpha H^\eta (Le^{gt})^{1-\alpha-\eta} \quad (1)$$

where α is the share of physical capital, η is the share of human capital, and $0 < \alpha < 1$, $0 < \eta < 1$, and $0 < \alpha + \eta < 1$. The condition $0 < \alpha + \eta < 1$ ensures diminishing returns in the accumulation of broad capital (physical and human capital). Y is the total output, K is the stock of physical capital, H is the stock of human capital, L is the quantity of raw labour, A is the fixed level of technology, g is the constant, exogenous growth rate of technology.

In units of effective labour, the production function can be described as follows:

$$y = f(k, h) = Ak^\alpha h^\eta \quad (2)$$

where $y = Y/(Le^{gt})$ is output per effective worker, $k = K/(Le^{gt})$ is the stock of physical capital per effective worker, $h = H/(Le^{gt})$ is the stock of human capital per effective worker.

The open economy is assumed to be small relative to the rest of the world and to face a constant and exogenous world real interest rate r . If capital is perfectly mobile, the open economy will instantaneously converge to its steady state. An infinite rate of convergence contradicts empirical evidence. The empirical estimates of the speed of convergence range from 1.4 percent to 3.5 percent per year. For example, Mankiw, Romer and Weil (1992) estimate the conditional convergence rate of 1.4 percent per year across 98 countries based on the augmented Solow model incorporating human capital accumulation. Barro and Sala-i-Martin (1991, 1995) find that absolute convergence occurred for the U.S. states and Japanese prefectures at a rate of about 2 percent per year. Coulombe and Lee (1995) estimate that the absolute

convergence speed of personal income per capita across regions in Canada is about 2.4 percent per year.

One way to generate a finite speed of convergence is to assume that capital is only partially mobile in the open-economy model, as done by Barro et al. (1995). This involves two key assumptions: perfect physical capital mobility across open economies and a limited/restricted mobility of human capital. The assumptions are explained in more detail below.

The first assumption is the perfect physical capital mobility across open economies. Physical capital can be used as collateral for international borrowing. Domestic residents own physical capital stock and may finance this stock by issuing bonds to foreigners or by direct foreign investment. An implication of this assumption is that the net return on physical capital is equal to the constant and exogenous world interest rate. That is,

$$f_k - \delta = r \quad (3)$$

where f_k is the marginal product of physical capital in the production function (2) and δ is the depreciation rate of physical capital.

Using the production function (2), the formula for the marginal product of physical capital f_k becomes

$$f_k = \alpha A k^{\alpha-1} h^\eta = \alpha y / k \quad (4)$$

Combining the formula (3) with the formula (4), the following equation can be obtained:

$$k = \alpha y / (r + \delta) \quad (5)$$

This equation implies that the ratio of physical capital to GDP is constant. This is consistent with one of Kaldor's (1963) stylized facts about economic growth: the ratio of capital to output is approximately constant.

The second assumption is the existence of a borrowing constraint for the financing of human capital. Domestic residents cannot use human capital or raw labour as collateral for borrowing on world markets, and foreigners cannot own domestic human capital or raw labour. Therefore, human capital can be financed only with domestic saving.

Under the above assumptions on capital mobility, the credit-constrained open economy behaves like a closed economy with a broad capital share $\eta/(1-\alpha)$. To show why the credit-constrained open economy is similar to a closed economy, the production function (2) is substituted by the expression for physical capital from the equation (5). A reduced-form production function could be obtained as:

$$y = Bh^{\eta/(1-\alpha)} \quad (6)$$

where B is a constant term, which is a nonlinear function of the model's parameters and is independent of h . Note that $0 < \alpha + \eta < 1$ implies $0 < \eta/(1-\alpha) < 1$. That is, the condition $0 < \eta/(1-\alpha) < 1$ ensures diminishing returns in the accumulation of human capital. Then the reduced-form production function (6) expresses y as a function of h with positive and decreasing returns to human capital stock. Therefore, the convergence implications of this model are similar to those of the neoclassical closed economy with a broad capital share $\eta/(1-\alpha)$.

The neoclassical open-economy model of Barro et al. (1995) has the unique

steady state. The model has the following four main implications for convergence of output and capital as well as for the relationship between human capital and output.

First, the economy's human capital stock per effective worker h converges toward its own steady state value. If the initial human capital stock per effective worker is less than the steady-state level of human capital stock per effective worker, then the growth rate of h is positive, and h increases toward its steady-state level. The diminishing returns to human capital are the key for this result. Along the transition from the initially low human capital stock per effective worker, the growth rate of h declines monotonically toward constant (possibly zero).

Second, the economy's per capita output (in effective units of labour) converges toward its own steady state value. Equation (6) implies that the growth rate of y is proportional to the growth rate of h , with the coefficient of proportionality equal to the capital share $\eta/(1-\alpha)$. Hence, behaviour of the growth rate of y mimics that of the growth rate of h . Therefore, along the transition from the initially low value of human capital toward its steady state value, the growth rate of y also declines toward constant (possibly zero), like the growth rate of h .

Third, the dynamics of human capital accumulation determines the evolution of physical capital and per capita output (in effective units of labour). Because the growth rate of y is the capital share $\eta/(1-\alpha)$ times the growth rate of h , and $\eta/(1-\alpha)$ is between 0 and 1, the ratio h/y increases steadily during the transition. However, the ratio k/y is constant, according to the implication of the assumption of perfect physical capital mobility. Hence, physical capital k grows at the same rate

as y , and the ratio h/k increases during the transition. Note that, even though physical capital is perfectly mobile, physical capital k increases only gradually toward its steady state value. The reason is the borrowing constraint for the financing of human capital and the complementarity between h and k in the production function. When h is low, the schedule for the marginal product of k is low. Hence, k is below its steady state, despite perfect physical capital mobility. Then the increase of human capital h increases the marginal product of k and thereby moves k towards its steady state. In conclusion, the dynamics of per capita output and physical capital (in effective units of labour) are determined by the dynamics of human capital accumulation. In other words, poor economies originally with less endowment of human capital should grow faster than rich economies.

Fourth, the convergence speed of human capital stock is equal to the convergence speed of per capita output (in effective units of labour). The convergence implications of this model are similar to those of the neoclassical closed economy with a broad capital share $\eta/(1-\alpha)$. Therefore, the fundamental dynamic equation for β -convergence in the neoclassical growth model (Barro and Sala-i-Martin (1995, Ch.2)) can be used to analyze convergence of per capita output as follows:

$$\ln y_t = e^{-\beta t} \ln y_o + (1 - e^{-\beta t}) \ln y^* \quad (7)$$

Here y_t is per capita output (in effective units of labour) at time t , y_o is the initial level of per capita output (in effective units of labour), and y^* is the steady-state level of per capita output (in effective units of labour). The parameter β is the convergence speed of per capita output.

From the reduced-form production function $y = Bh^{\eta/(1-\alpha)}$ and the fundamental dynamic equation (7) for per capita output (in effective units of labour), the dynamic equation of human capital stock can be expressed in the following form:

$$\ln h_t = e^{-\beta t} \ln h_0 + (1 - e^{-\beta t}) \ln h^* \quad (8)$$

Here h_t is human capital stock per effective worker at time t , h_0 and h^* are respectively the initial level and the steady-state level of human capital stock per effective worker. The equation (8) is used for the analysis of β -convergence. The convergence speed of human capital stock is given by the parameter β . The dynamic evolution of the human capital can then be expressed by the same type of the fundamental dynamic equation for per capita output (in effective units of labour). Thus, the model predicts identical convergence speeds of per capita output and human capital stock.

3.2. Empirical model

As shown in the previous section, the open-economy growth model of Barro et al.(1995) has four main implications for convergence and the role of human capital accumulation in economic growth. This section focuses on empirical tests of these implications. The analysis is based on the empirical methodology proposed by Coulombe and Tremblay (2001).

Coulombe and Tremblay (2001) apply the model of Barro et al.(1995) to study regional convergence of per capita income and human capital stock in Canada from 1951 to 1996. Their empirical results confirm the predictions of the theoretical

model. They find that the relative growth of per capita income in Canada can be explained by the accumulation of the relative human capital stock, and that the convergence speed of human capital stock is equal to the convergence speed of per capita income during the sample period. In this paper, the methodology of Coulombe and Tremblay (2001) is used to study the regional convergence in 25 Chinese provinces during the 1996-2006 period. The rest of the section describes the tests.

3.2.1. Convergence of human capital stock

The first prediction of the theoretical model is that the economy's human capital stock converges to its own steady state. To test this prediction, tests of β -convergence and σ -convergence are used.

First, consider β -convergence of human capital stock. Regions within a country are more likely to share similar determinants that account for different long-run equilibrium levels of economic indicators (Aghion and Howitt (1998)). Thus, unconditional β -convergence is examined in this study of Chinese provinces. The estimated regression for unconditional β -convergence of various human capital indicators can be specified as follows:

$$\ln(RH_{i,t+p} / RH_{i,t}) = -\gamma_H \ln(RH_{i,t}) + \mu_{i,t+p}^H \quad (I)$$

where the subscript i denotes regions in a country, t is the time, p is the length of the period. In my study, p equals 2 when t is set to each of the years 1996, 1998, 2000, 2002 and 2004. The variables $RH_{i,t}$ and $RH_{i,t+p}$ are relative human capital indicators obtained by dividing a human capital indicator by the un-weighted

average of the same human capital indicator across regions i at time t and time $t + p$. The relative level of human capital stock, instead of the actual level, is used to overturn some problems associated with the imperfect measurement of human capital (Coulombe and Tremblay, (2001)).

The variable $\mu_{i,t+p}^H$ is the error term for the regression. It is assumed that the mean of μ_i^H is zero, and μ_i^H and μ_j^H are statistically independent, $\forall i, j, i \neq j$. In the pooled time series and cross-section data the residuals are expected to show cross-section heteroskedasticity (Coulombe and Tremblay (2001)). Generalized least squares (GLS) estimation (cross-section weights method) is used to control for cross-section heteroskedasticity of the residuals. Note that the residual terms $\mu_{i,t+p}^Y, \mu_{i,t}^{YL}$ and $\mu_{i,t+p}^{YR}$ shown in the following equations (III), (VII) and (VIII) will be assumed to satisfy the same restrictions.

The convergence speed of a human capital indicator, β_H , can be computed from the estimated coefficient γ_H of the regression (I) as follows:

$$\beta_H = -[\ln(1 - \gamma_H)] / p \quad (II)$$

Here p is the same definition as that in the equation (I). If the estimated coefficient γ_H in the equation (I) is positive and less than one, then the unconditional β -convergence of the corresponding human capital indicator can be confirmed.

Second, consider σ -convergence of human capital. The standard deviation of the logarithm of relative human capital indicators can be used to measure σ -convergence. If the dispersion of human capital indicators decreases over time, then σ -convergence occurs. The standard deviation of the logarithm of the relative

human capital indicators is used as a measure of the dispersion.

3.2.2. Convergence of per capita GDP

The prediction of convergence of per capita GDP is tested using the same methodology as that of convergence of human capital stock. For completeness, the regression specifications are reproduced in this subsection.

First, consider unconditional β -convergence of per capita GDP. The unconditional β -convergence of relative per capita GDP can be specified as follows:

$$\ln(RY_{i,t+p} / RY_{i,t}) = -\gamma_Y \ln(RY_{i,t}) + \mu_{i,t+p}^Y \quad (\text{III})$$

where the variable $RY_{i,t}$ is relative per capita GDP obtained by dividing per capita GDP of each region by the un-weighted sample average across regions i at time t .

The speed of convergence of the relative per capita GDP, β_Y , can be computed from the estimated coefficient γ_Y of the regression (III) as follows:

$$\beta_Y = -[\ln(1 - \gamma_Y)] / p \quad (\text{IV})$$

If the estimated coefficient γ_Y of the equation (III) is positive and less than one, then unconditional β -convergence of the relative per capita GDP can be confirmed.

Second, consider σ -convergence of per capita GDP. The standard deviation of the logarithm of relative per capita GDP can be used to measure σ -convergence. If the dispersion of per capita GDP decreases over time, then σ -convergence occurs.

3.2.3. Comparison of convergence speeds of per capita output and human capital indicators

According to the prediction of Barro et al. (1995), the convergence speed of

per capita output should be equal to the convergence speed of human capital. To test this prediction, the Wald statistics can be used. The empirical analysis of this paper is based on several human capital indicators. The Wald statistics can also be used to compare the convergence speeds of various human capital indicators.

The Wald statistics is defined in the following form:

$$W = (\beta_1 - \beta_2) / [\text{Var}(\beta_1) + \text{Var}(\beta_2)] \quad (\text{V})$$

where β_1 and β_2 denote different convergence speeds of human capital indicators or per capita output. Since $\beta = -[\ln(1 - \gamma)] / p$, that is, β is the function of γ , and γ is the estimated coefficient of relative logarithm of human capital indicators or per capita output, then the Wald statistics also can be computed in the following form:

$$W = (\gamma_1 - \gamma_2) / [\text{Var}(\gamma_1) + \text{Var}(\gamma_2)] \quad (\text{VI})$$

Therefore, the Wald statistics can be directly computed from the estimated coefficients and their standard deviations. In this paper the Wald statistics are computed using the equation (VI).

3.2.4. The share of human capital in per capita GDP

When several indicators of human capital are available, it is normal to ask which of them is better. The estimation of the share of human capital in per capita GDP can be used to examine which measure is better as a proxy of human capital. A criterion applied in this paper is that a better proxy of human capita should make the quantitative predictions of the neoclassical growth model consistent with most stylized facts about economic development. According to Mankiw (1995), a broad capital share of 0.8 reconciles the predictions of the neoclassical growth model with

stylized facts. For the given value of the share of physical capital, set to equal to 0.33 in this paper, the share of human capital should be in the neighborhood of 0.5.

Based on the equation (6) expressed in logarithm, $\ln y = \ln B + (\frac{\eta}{1-\alpha}) \ln h$, the relative per capita GDP of a region i can be described as a function of the relative human capital indicators of the region i :

$$\ln(RY_{i,t}) = \frac{\eta}{1-\alpha} \ln(RH_{i,t}) + \mu_{i,t}^{\eta} \quad (\text{VII})$$

The physical capital share α is measured residually from non-wage income in the national accounts. In this study, I will use the value suggested by Barro et al. (1995) from international data, where α is about 0.33. For the given value of α , the share of human capital η can be obtained from the estimated coefficient $\frac{\eta}{1-\alpha}$ of the regression (VII). A better proxy of human capital should be the one which gives the value of η in the neighborhood of 0.5.

3.2.5. The contribution of human capital to regional economic growth

According to the third prediction of Barro et al.(1995), the dynamics of human capital accumulation is the driving force of economic growth. To test this prediction, it is useful to analyze the relationship between income growth and the initial level of human capital.

The following regression shows the relationship between income growth and the initial level of human capital:

$$\ln(RY_{i,t+p} / RY_{i,t}) = C \ln(RH_{i,t}) + \mu_{i,t+p}^{\eta R} \quad (\text{VIII})$$

If the model is true, the estimated coefficient $C = -\gamma_Y \cdot (\frac{\eta}{1-\alpha})$. This regression is

derived by combining equation (VII) and equation (III). The equation (VII) illustrates a relationship between relative per capita GDP and relative human capital indicators. The equation (III) provides the standard convergence regression of relative per capita GDP. When the initial relative level of relative human capital stock replaces the initial level of relative per capita GDP on the right-hand side of equation (III), the above modified convergence regression (VIII) can be obtained. Since unconditional β -convergence of relative per capita GDP requires that γ_Y is positive and less than one, then C should be negative. The definition of the other variables is the same as before.

The estimated regression (VIII) explains the relationship between the growth rate of per capita GDP and the initial level of human capital indicators. Comparing the estimation results with those from the standard convergence regression (III) enables better understanding of the impact of the initial level of relative human capital and the initial level of relative per capita GDP on economic growth. Therefore, “the explanatory power of the model could then be highlighted by comparing the results with those of the standard convergence regression (Coulombe and Tremblay (2001, p.173)).”

4. Data Description and Econometric Issues

4.1. Econometric issues and data source

This paper uses pooled time-series cross-sectional observations for 25 Chinese provinces from 1996 to 2006. The period of analysis is limited to 1996-2006 because of data availability of human capital. The census data of human capital, which measures the percentage of the population that has attained at least a given level of education, is not complete before 1996 in China. In the literature on China's economic growth, most researchers use schooling years or enrolment rate to measure human capital when researching a longer time period before 1996. In this paper, I use two-year intervals, and hence there are six two-year sub-periods and 25 cross-section observations, resulting in a sample of 150 panel observations. To estimate the regressions (I), (III), (VIII), the generalized least squares (GLS) estimations with cross-sectional weights are used in order to make up for the presence of cross-sectional heteroskedasticity. The estimations are done by Eviews 3.1.

In the sample period, the raw data come from "China Statistical Yearbook" (1997, 1999, 2001, 2003, 2005, 2007). "China Statistical Yearbook" is published by the China Statistics Bureau. It includes the data on social, political and economic development for the preceding year. The data of per capita GDP of 25 Chinese provinces in 1996, 1998, 2000, 2002, 2004, 2006 come from Table 3-11 "Gross Regional Product". The human capital indicators are proxied by data on education. The raw data on education come from Table 4-11 "Population by Gender, Educational Level and Region". The table provides data on the population aged six years and over

by gender that attains different levels of education. The levels of education involve illiterate, primary school, junior secondary school, senior secondary school and college and higher education.

4.2. Human capital data set

This section introduces measures of human capital, and then specifies the indicators of human capital used in this study. Theoretically, a measure of human capital should consider education, on-the-job training, health and some aspects of social capital. However, most of these aspects are not exchanged as physical capital in markets due to the intrinsic nature of human capital. It is difficult, if not impossible, to find an ideal measure of human capital, and one has to rely on proxies. For example, although on-the-job training contributes to human capital, it is difficult to measure the training efforts of employers and workers. The health situation of the population, or of the labour force, and other aspects of social capital are important for human capital formation. However, they are also difficult to measure. Thus, many studies about human capital focus on education.

To proxy human capital by education, one can consider quantity proxies, such as enrolment rate, the percentage of school attained and schooling years, and quality proxies, like literacy skills test scores. Barro and Lee (1993, 1996) and Barro (2001) discuss quantitative indicators of educational achievement, such as enrolment rate, average years of schooling. They construct a human capital data set covering 138 countries. Hanushek and Kim (1995) find that scores on international examinations

explain economic growth better than schooling years. Coulombe and Tremblay (2007) use two human capital indicators, the percentage of school attained and literacy skills test scores, to analyze Canadian provincial disparity.

In this paper, as a result of the availability of data, the percentage of school achievement is used to measure human capital. More precisely, this measurement of human capital refers to the percentage of the population that has attained at least a given level of education. Moreover, this study only focuses on relative measures of human capital indicators of a province with respect to the average of all the 25 provinces in China. Given all the data on educational achievement by province, I construct six indicators of human capital: the percentage of the population that has attained at least junior secondary school in the total population (RJSTPOP), in the male population (RJSMPPOP) and in the female population (RJSFPOP), the percentage of the population that has attained at least College and higher education in the total population (RCHTPOP), in the male population (RCHMPOP) and in the female population (RCHFPOP). For all measures, the population includes everyone aged 6 years and over.

However, as argued by Coulombe and Tremblay (2001), this measurement of educational achievement is not perfect. Some problems associated with it need to be taken into account when interpreting the empirical results of this study. Firstly, human capital stock of the labour force, not of the total population, determines the growth dynamics. Yet, it is not practically impossible to account for the entry and exit flows of the labour force. It is more feasible to construct an index of the educational

achievement of the total population.

Secondly, Barro and Lee (1993) argue that it is important to consider the quality proxies of education, not just quantity proxies of education that may cause measurement error. However, the data on quality proxies of education, like adult literacy, are difficult to obtain in China. Additionally, one can argue that it is more appropriate to put weights on different levels of education. Barro and Lee (1993) indicate that one can weight each level of education according to its average market return, but they also point out that this method may cause a bias. The reason is that, as explained by Coulombe and Tremblay (2001, p.159), “on the one hand, the level of education is likely to be positively correlated with individual skills and, on the other hand, market returns of education exclude external benefits generated by human capital.”

Finally, on-the-job training (efforts spent by employers and employees on training) is an important human capital proxy, which gives information on human capital investment flows. However, this proxy is difficult to measure and to compare with data on educational achievement. Overall, one should keep in mind these measurement problems while analyzing the empirical results, since these problems may cause measurement error on the data of human capital indicators.

5. Empirical Results

5.1. Preliminary analysis of relative levels of per capita GDP and relative levels of human capital indicators

Some interesting facts are found when relative levels of human capital indicators are compared with relative levels of per capita GDP. Relative per capita GDP and human capital data, with respect to the provinces' average, are presented in Table I for 25 provinces of China in 1996 and in 2006. The cross-provincial relationship between relative per capita GDP and relative human capital indicators in 1996 and in 2006 is also shown in Figures 1 and 2. These Figures are scatter plots based on the data from Table I.

Firstly, compare relative per capita GDP with relative human capital indicators across 25 provinces of China. From Table I, we can see that the provinces with lower per capita GDP, such as Anhui, Henan, Hubei, Hunan, Guangxi, Guizhou, Yunnan, Gansu, Qinghai, Ningxia, tend to have less educated population in terms of junior secondary school or college and higher education. These provinces with lower per capita GDP, except Guangxi, are located in inland of China. In general, the rich provinces with higher per capita GDP, such as Beijing, Tianjin, Liaoning, Shanghai, Zhejiang and Guangdong, tend to have better educated population in terms of junior secondary school or college and higher education. All the six provinces are coastal provinces. Moreover, Heilongjiang, Jiangsu, Shandong, three provinces with per capita GDP close to the provinces average, have educational achievement close to the average. However, there are several notable exceptions: Hebei, Shanxi, Inner Mongolia and Jilin. These four provinces have lower per capita GDP but higher

education achievement in terms of junior secondary school. Another exception is Fujian, the province with higher per capita GDP and less educated population in terms of junior secondary school and college and higher education.

The facts above indicate that China's coastal provinces and inland provinces are very differently endowed with human capital resources and have developed to different degrees in the recent ten years. According to relative levels of per capita GDP in 1996 and in 2006, nine out of eleven coastal provinces are above the provinces' average, while all the fourteen inland provinces are lagging behind. Coastal provinces, Beijing, Tianjin, Liaoning, Shanghai, Zhejiang and Guangdong, take advantage of their geographic superiority and have great economic performances driven by open economic policies and well educated population.

Panels (A) of Figures 1 and 2 provide a visual illustration of a clear positive relationship between relative per capita GDP and relative human capital indicators based on college and higher education in 1996 and in 2006. In contrast, Panels (B) of Figures 1 and 2 show no significant positive relationship between relative per capita GDP and relative human capital indicators based on junior secondary school, especially for the case of the year 2006. Based on this finding, it seems that higher education is more positively related to relative levels of per capita GDP than junior secondary education in China from 1996 to 2006.

Secondly, relative levels of per capita GDP and human capital are unevenly dispersed across some provinces. Beijing, Tianjin and Shanghai have very high relative levels of per capita GDP and human capital indicators, which are two or three times

higher than the provinces' average. In contrast, Guizhou and Gansu have low relative levels of per capita GDP and human capital indicators. The income gap and the difference of education achievement across these provinces are large. The fact corresponds to the phenomenon that there exists unequal distribution of wealth and human capital resources across provinces in China.

Thirdly, compare relative levels of per capita GDP in 1996 with those in 2006. Provinces with high initial levels of per capita GDP reached higher relative levels of per capita GDP in 2006, while provinces with low initial levels of per capita GDP obtained lower relative levels of per capita GDP in 2006. This indicates that the income gap across provinces became larger during the ten-year period.

5.2. σ -convergence of human capital

There is the evidence of σ -convergence of human capital, if the dispersion of the cross-sectional distribution on human capital indicators tends to decrease through time. In my study, even though the convergence pattern is not significant, the dispersion of five out of six human capital indicators has a general tendency to decrease over time.

For the case of the population aged 6 years and over, Panels (A) and (B) of Figures 3 present the trends in two relative human capital indicators: RJSTPOP (at least junior secondary school in the total population) and RCHTPOP (at least college and higher education in the total population) for the 25 provinces in China. A visual examination of Panel (A) of Figure 3 based on the RJSTPOP measure (at least junior

secondary school) suggests that the provinces which have initially less educational achievement, such as Qinghai, Jiangsu, Guizhou, Gansu, Fujian, Hunan, Xingjiang, Anhui and Guangxi, seem to get closer to or even above the average during the ten-year period. The provinces which have initially better educational achievement, such as Liaoning, Heilongjiang, Tianjing, Shanghai and Jiangsu, tend to come back to the average.

In Panel (B) of Figure 3, based on the RCHTPOP measure (at least college and higher education), the provinces which have initially less educational achievement, such as Guangxi, Shandong, Guangdong, Guizhou, Jiangsu and Hubei, seem to get closer to the average during the ten-year period. The provinces which have initially better educational achievement, such as Beijing, Shanghai, Xingjiang, Heilongjiang, Ningxia and Jilin, tend to come back to the average. Furthermore, there is an interesting pattern to mention: Beijing and Shanghai have extremely high relative levels of educational achievement compared with other provinces based on college and higher education indicator shown in Panel (B) of Figure 3. Yet, educational achievements in the two provinces still decrease to lower levels during the period. In particular, the educational achievement in Beijing declines to 3.74 in 2006 from 4.52 in 1996, and in Shanghai it declines to 2.78 in 2006 from 3.24 in 1996. This fact may be explained by the potential role of inter-provincial migration in the distribution of human capital across provinces. Inter-provincial migration may affect the relative human capital across provinces if the education achievement of inter-provincial migrants differs from the non-migrant population. There has probably

been massive migration from inland provinces to Beijing and Shanghai over the period. For example, according to the census data from the 2005 National 1% Sample Survey on Population Changes in China, inter-provincial migrants to Beijing are 44,903 persons, which is about 60 percent of the total population in Beijing. Among the inter-provincial migrants to Beijing, the migrants from inland provinces to Beijing are 31,796 persons, which is about 71 percent of the population of inter-provincial migrants to Beijing.⁶ The migrants from inland provinces to Beijing and Shanghai may not be better educated than the local non-migrants in Beijing and Shanghai. This massive migration tends to reduce the human capital stocks (measured by education achievement) in Beijing and Shanghai. Consequently, the educational achievement of Beijing and Shanghai, relative to the other provinces, has decreased over the period. Inter-provincial migration may tend to reduce provincial human capital disparities.

Figure 4 uses standard deviations of relative levels of the six human capital indicators to measure the dispersion of relative levels of human capital. This Figure demonstrates that the dispersion of five out of six human capital indicators has a general tendency to decrease through time during the entire period, even though there are some different increases during the 2002-2006 period. The human capital indicator based on junior secondary school for males is an exception. However, their patterns of decrease differ. The dispersion of the human capital indicators based on college and higher education decreases more greatly than that of the indicators based on junior secondary school over time. For the indicator based on junior secondary school for

⁶ Source: "China Statistical Yearbook" (2006).

both sexes, the standard deviation decreases from 0.19 in 1996 to 0.16 in 2006. For the indicator based on junior secondary school for males, the standard deviation increases from 0.15 in 1996 to 0.19 in 2006. For the indicator based on junior secondary school for females, the standard deviation decreases from 0.25 in 1996 to 0.14 in 2006. For the indicator based on college and higher education for both sexes, the standard deviation decreases from 0.95 in 1996 to 0.76 in 2006. For the indicator based on college and higher education for males, the standard deviation decreases from 0.90 in 1996 to 0.82 in 2006. For the indicator based on college and higher education for females, the standard deviation decreases 1.06 in 1996 to 0.73 in 2006. In general, there is the evidence of σ -convergence of human capital in terms of the decrease of the standard deviation of five out of six human capital indicators.

Figure 4 also shows three additional interesting patterns. Firstly, for both levels of educational achievement (junior secondary school, college and higher education), the standard deviations of the indicators for the female population are higher in the initial year and decrease faster than the indicators for the male population. Secondly, the indicator of human capital based on junior secondary school for males demonstrates a divergence pattern. The standard deviation increases from 0.15 to 0.19 during the period. Thirdly, while the standard deviations of the indicators for at least junior secondary school decrease from 2004 to 2006, the standard deviations of the indicators for college and higher education increase during the same period. This pattern implies that rich provinces are improving investment in college and higher education in China from 2004 to 2006. The poor endowed provinces are

improving investment in junior secondary education, and these provinces focus on basic education during the same period.

5.3. β -convergence of human capital

For the analysis of β -convergence of human capital indicators, I estimate the equation (I) from the section 3.2.1 using GLS (cross-section weights), and compute the speeds of convergence of all six indicators of human capital. The estimation results are presented in Table II. The table shows the estimated coefficients γ_H for each of the six human capital indicators, the standard errors of coefficients, the adjusted R^2 and the estimated annual speeds of convergence β_H of the six human capital indicators, given by equation (II).

The detailed analysis of Table II shows four interesting findings. First, we can reject the null hypothesis of no-convergence ($\beta_H = 0$) at the one percent level for five out of the six indicators, except for the human capital indicator based on the males with at least junior secondary school. Therefore, with one exception, the provinces originally endowed with poor educational achievement grow faster than the provinces originally endowed with better educational achievement. Five out of the six human capital indicators show significant unconditional β -convergence.

Second, the estimated speeds of convergence of the human capital indicators differ greatly. Based on the theoretical prediction of Barro et al. (1995), the speed of convergence of per capita output and human capital should be in the interval between 0.014 and 0.035 in the open-economy neoclassical growth model with a credit

constraint on human capital. Note that the interval [0.014, 0.035] is computed from the expression of the convergence rate based on the baseline specification of parameters' values. In this study, only the estimated convergence speed of the human capital indicator based on at least college and higher education in the male population is in this interval, with the value of 0.030. For the other four human capital indicators (junior secondary school for both sexes, females, and college and higher education for both sexes, females), convergence speeds are much faster: they take values of 0.046, 0.077, 0.039 and 0.079.

Third, the estimated convergence speed of the indicator RJSTPOP (at least junior secondary school in the total population) is faster than that of the indicator RCHTPOP (at least college and higher education in the total population). Here we can use the Wald statistics, described in section 4.2, to compare the estimated convergence speed of RJSTPOP with that of RCHTPOP. Table III reports the Wald statistics for the comparison of the convergence speeds of different levels of educational achievement.

From Table III, the null hypothesis of equality of the estimated convergence speeds of two different levels of educational achievement (junior secondary school, college and higher education) can not be rejected at the one percent level. That is, there is no significant difference between the estimated convergence speeds of the human capital indicators for at least junior secondary school and college and higher education during the human capital catch-up process.

To interpret the result from the Wald statistics, it is useful to recall a few features of the Chinese educational system. On the one hand, since the

implementation of “an obligatory (mandatory) nine-year education policy” in the 1960s,⁷ the junior secondary education is made considerably universal across provinces. On the other hand, as the regional economies of China have developed rapidly recently, families gradually realize the importance of higher education. Further, the wealth of families has improved. Even though the opportunity cost of higher education is greater than that of junior secondary school, a person with higher education level could find a job more easily. The person with higher education level may have better wage income, implying higher return for his investment in higher education, than a person only with junior secondary education. Therefore, Chinese government and families have invested more in higher education in the recent ten years. These policies may help interpret the Wald statistics result, which indicates that there is no significant difference in the estimated convergence speeds between at least junior secondary school and college and higher education during the human capital catch-up process.

Finally, considering the population with at least college and higher education, the convergence speed of human capital indicator for males is larger than that for females (Table II). Based on the Wald statistics computed for the convergence speeds of human capital indicators by gender, shown in Table IV, the null hypothesis of equality of the convergence speeds for males and females can be rejected at the 95 percent confidence level. This indicates that for the college and higher education levels, the convergence speed of human capital indicator for females are significantly

⁷ This policy required six years in primary school and three years in junior secondary school.

larger than that for males. This interesting finding might indicate the existence of gender discrimination in the labour market of China. Males find jobs more easily than females in the labour market. Therefore, the opportunity cost of investing in higher education for males is higher than that for females. Families may not have a clear incentive to invest in higher education for males.

5.4. σ -convergence and β -convergence of per capita GDP

There is the evidence of σ -convergence of per capita GDP, if the dispersion of the cross-sectional distribution on per capita GDP tends to decrease through time. Figure 5 presents the change of the dispersion of relative per capita GDP, measured by the standard deviation of relative per capita GDP, of Chinese provinces during the 1996-2006 period. The Figure shows that the dispersion of relative per capita GDP increases from 1996 to 2002 and then decreases from 2002 to 2006. This is largely explained by exceptional growth in a few coastal provinces, such as Beijing, Liaoning, Shanghai, Fujian. Particularly, the relative per capita GDP of Beijing increases to 2.327 in 2006 from 2.242 in 1996, and the relative per capita GDP of Shanghai increases to 3.612 in 2006 from 3.319 in 1996, according to the data of Table I. Thus, there is no clear evidence of σ -convergence of relative per capita GDP during the entire 1996-2006 period. In Figure 5, the standard deviation of relative per capita GDP increases from 0.66 in 1996 to 0.75 in 2002. The standard deviation of relative per capita GDP then decreases from 0.75 in 2002 to 0.73 in 2006. It indicates that σ -convergence of relative per capita GDP only happened from 2002 to 2006.

However, there is no evidence of σ -convergence of relative per capita GDP during the entire 1996-2006 period.

Furthermore, equation (III) from section 3.2.2 can be used to test whether or not unconditional β -convergence of per capita GDP occurs across the provinces during the entire 1996-2006 period. The estimation results are presented in Table V. This table shows the estimated coefficient γ_Y for relative per capita GDP, the standard errors of the coefficient, the adjusted R^2 and the estimated annual speed of convergence β_H of relative per capita GDP, given by equation (IV).

From Table V, the coefficient of the estimated convergence regression is positive and significant at the one percent level. This indicates that there is no unconditional β -convergence of relative per capita GDP across the provinces during the entire period. The result is consistent with the conclusion for the absence of σ -convergence of relative per capita GDP during the entire period.

The results for per capita GDP demonstrate that poor provinces do not grow faster than rich provinces from 1996 to 2006 in China. The distributions of per capita incomes appear to be diverging away from each other with the poor provinces becoming poorer, and the rich provinces richer. Note that the divergence trend of economic growth does not take into account any province-specific characteristics.

5.5. Human capital share in the national income

Equation (VII) from section 3.2.4 can be used to estimate the human capital share in per capita GDP. This equation examines a relationship between relative

income per capita and relative human capital stock. The estimation results are presented in Table VI. This Table reports the estimated coefficients of the logarithm of six human capital indicators, the standard errors of the coefficients, the adjusted R^2 and human capital share in per capita GDP η . The value of the physical capital share α equal to 0.33 is used to construct η .

Several interesting findings emerge from the detailed analysis of Table VI. First, all the estimated human capital shares in per capita GDP η for college and higher education are higher than for at least junior secondary education. This finding may follow from the facts that Chinese families have recently placed more importance on investment in college and higher education, and that human capital stock based on college and higher education improves labour productivity more greatly than that based on junior secondary school.

Second, two estimated human capital shares in per capita GDP η based on college and higher education for both sexes and males are close to 0.5, with the confidence interval at 95 percent ranging from 0.42 to 0.51. These two estimates are consistent with Mankiw's (1995) estimation of the human capital share for the US, which is around 0.5. They are also similar to Coulombe and Tremblay's (2001) income (minus transfers) elasticity of human capital based on university degree, which is ranging from 0.42 to 0.59 at the 95 percent confidence interval. Note that a human capital share of 0.5 is consistent with a broad capital share of 0.8. According to Mankiw (1995), the value of a broad capital share of 0.8 is required to reconcile the predictions of the neoclassical growth model with stylized facts. If the value of the

physical capital share α is equal to 0.33, then the broad capital share (the sum of α and η) in my empirical study is between 0.75 and 0.84 at the 95 percent confidence interval. The values are based on college and higher education for both sexes and males.

Table II implies that only the estimated convergence speed of human capital indicator based on college and higher education for males is in the interval [0.014, 0.035]. This interval indicates the range of convergence speeds of human capital and per capita GDP in the open-economy neoclassical growth model of Barro et al. (1995). Linking with this point, the results of this section suggest that the best proxy for the overall human capital stock in the neoclassical growth model is the indicator based on college and higher education for males aged 6 years and over.

5.6. The relationship between income growth and human capital

This subsection considers the relationship between the growth rate of relative per capita GDP and the initial level of human capital indicators. The estimation results, based on equation (VIII) from section 3.2.5, are presented in Table VII. The Table shows estimated coefficients of the logarithm of the six relative human capital indicators, the standard errors of the coefficients and the adjusted R^2 .

From Table VII, we can reject the null hypothesis that the coefficient estimates are equal to zero ($C = 0$) at the five percent level for all but one measure of human capital. All six coefficient estimates C are positive. The estimates indicate that the growth rate of per capita GDP is significantly positively related to the initial level of

all six indicators of human capital, except for the indicator based on junior secondary school for males. This result is related to the absence of unconditional β -convergence of per capita GDP. Recall that the previous analysis (section 5.4) showed that poor provinces with less educated population do not catch up with rich provinces with well educated population in China during the 1996-2006 period.

In Table V, the R^2 for the standard convergence regression with the initial relative level of per capita GDP is 0.07. The R^2 for the modified convergence regression with the initial relative level of human capital indicator, based on males with college and higher education, is 0.08. Although the explanatory power from both regressions is low, the initial relative level of human capital indicator based on males with college and higher education explains more of the growth rate of relative per capita GDP than does the initial relative level of per capita GDP. This result suggests that the disparities of the initial relative level of human capital, especially for males with college and higher education, explain the regional disparities of per capita GDP to some extent.

5.7. Discussion of empirical results

From the empirical results, two key implications can be obtained. First, per capita GDP in Chinese provinces does not show unconditional β -convergence during the 1996-2006 period, even though human capital stocks show unconditional β -convergence. Second, the growth rate of relative per capita GDP is positively related to the initial level of relative human capital indicators. Consequently, there is

no need to examine the equality of the speeds of convergence of between per capita GDP and human capital stocks and the relationship between human capital accumulation and the convergence of per capita GDP.

More precisely, there exists a discrepancy between the theoretical predictions of Barro et al. (1995) and my empirical results for the case of China. According to the prediction of Barro et al. (1995), in the open-economy growth model with perfect physical capital mobility and a credit constraint on the financing of human capital, the dynamics of human capital accumulation is the driving force of per capita income growth. Coulombe and Tremblay (2001) show that a substantial part of the relative growth of per capita income across Canadian provinces since the early 1950s can be explained by the convergence process of human capital indicators. In contrast, my empirical study of Chinese provinces suggests that the dynamics of human capital accumulation seems not to be the driving force of economic growth from 1996 to 2006. The reason is that per capita income does not show unconditional β -convergence while human capital indicators do.

Why does the theoretical model not fit the data very well? Why is there a discrepancy between the two patterns of convergence (human capital stock and per capita GDP) in China? Cohen (1996) argues, from the theoretical view, that human capital and physical capital may show unconditional convergence, even if per capita income does not. To explain this discrepancy, Cohen uses a vintage model of human capital accumulation to analyze some reasons, such as the Solow residuals, the knowledge handicap and the inappropriate measure of human capital. Applying the

arguments of Cohen (1996) to the case of China, one can conjecture that the differences in convergence results for human capital and per capita GDP may happen for at least one of the following three reasons.

First, provinces in China are rather heterogeneous. Because of geographic factors and preferential policies, the spatial distribution of resources across provinces in China has been highly uneven, especially between coastal and inland provinces. The absence of unconditional β -convergence may be due to the importance of provinces' idiosyncrasies, such as saving rate, the investment share, coastal location, international openness level, foreign direct investment, population growth, etc. Specifically, the degree of openness of provinces to international trade would be expected to be a very important factor. The richest provinces, most coastal provinces, have become very open to international trade due to the open-door policy and export promotion strategies and the superiority of the coastal location. If the degree of openness to international trade is measured by total value of imports and exports, some evidence of heterogeneity of international openness between richer and poorer provinces can be found. For example, for the year 2006, total values of imports and exports of Jiangsu and Guangdong, the two richest coastal provinces, are US\$ 283.9 billion and US\$ 527.2 billion, while total values of imports and exports of Guizhou and Gansu, the two poorest inland provinces, are US\$ 1.6 billion and US\$ 3.8 billion.⁸ Many empirical studies of inter-provincial conditional convergence in China

⁸ Source: "China Statistical Yearbook" (2007), Table 18-11 "Total value of imports and exports by location of importers/exporters".

can be taken as evidence. For instance, Chen and Fleisher (1996), Wang and Hu (1999), Yao and Weeks (2000), Yan (2002) and Qian and Smyth (2006) find conditional convergence of per capita output in China after controlling for the determinants of the steady states.

The second reason might be related to difficulties in measuring of human capital stock. As mentioned before in the section 4.2, educational achievement is not a perfect measure, which brings out some problems. An ideal measure of human capital would include both educational achievement and on-the-job training. Yet, it is very difficult to measure on-the-job training. Additionally, Cohen (1996) gives some thoughts to explain the differences in convergence results for human capital and per capita GDP. He argues that poor economies are behind because “they failed to raise their investment decisions above what it would have taken to compensate for their initial knowledge disadvantages.” The initial knowledge disadvantages refer to the initial knowledge stocks handicap on which training of agents depends. In China, the reason why poor provinces fail to catch up with rich province may be the large disparities of the initial knowledge stocks.

The third reason is related to total factor productivity differences. For the analysis of growth patterns across provinces of China, total factor productivity might be the main factor explaining the relative evolution of regional economies. This point coincides with the empirical results of Wang and Yao (2003) on economic growth of China. Wang and Yao (2003) find that the growth of total factor productivity contributes 25.4 percent of economic growth while human capital stock accounts for

11 percent of GDP growth at the national level in the reform period (1978-1999) of China in the framework of growth accounting incorporating human capital accumulation. At the provincial level, Qian and Smyth (2006) conclude that economic growth in Chinese provinces depends heavily on the accumulation of physical capital stock, which accounts for about 55 percent of GDP growth. Human capital stock contributes to 13 percent of output growth on average between 1990 and 2000.

Finally, other factors may affect the empirical results. For example, human capital flows, migration and inter-provincial redistribution from central government affect the satisfaction of the assumption that there is a binding constraint on human capital accumulation across provinces in China. In addition, even though Gundlach (1997) concludes that capital mobility has been high across Chinese provinces during the period 1978-1989 on the basis of a Feldstein-Horioka empirical analysis, this result cannot be interpreted as an empirical proof of the assumption of perfect capital mobility across Chinese provinces. The financial system in China is composed by large multi-branch state-owned banks and national and provincial finance organizations to redistribute savings across provinces. Capital should flow freely to finance the most profitable investments. However, China has begun to decentralize its fiscal system since the mid-1980s, and all provinces have become financially more independent as a result of fiscal decentralization. Consequently, inter-provincial physical capital flows may have been reduced substantially. Thus, the assumption of perfect physical capital mobility across provinces in China may not be valid.

6. Conclusion

Based on the neoclassical open-economy growth model with perfect physical capital mobility and a binding constraint on the financing of human capital, this paper analyzed the economic evolution of per capita GDP and six indicators of human capital stock across 25 provinces in China. It discussed the role of human capital accumulation in economic growth across provinces. The paper shed new light on understanding the regional pattern of economic growth and regional disparities: regional disparities across Chinese provinces did not disappear but increased during the 1996-2006 period. Provincial differences in human capital, and especially investment in higher education, seemed to decrease over time. Although the dynamics of human capital accumulation explained the growth performance to some extent, other factors that varied across provinces should be considered for economic growth, such as the growth of total factor productivity.

The main findings of this empirical study are unconditional convergence of various indicators of human capital stock and the absence of unconditional convergence of per capita GDP for Chinese provinces from 1996 to 2006. The dispersion of per capita GDP is widening across provinces during the period. Additionally, the estimates of human capital's share in per capita GDP for higher education are between 0.42 and 0.51, which is consistent with a broad capital share of 0.8 required to reconcile the predictions of the neoclassical growth model with stylized facts. The growth rate of per capita GDP is significantly positively related to the initial level of five out of six indicators of human capital. This result demonstrates

that poor provinces with less educated population do not catch up with rich provinces with well educated population.

My findings suggest that the effect of human capital accumulation is not the main factor that can explain the relative evolution of regional economies in China during the ten years period 1996-2006. Although this study does not directly examine other factors that may be the driving forces of growth, it suggests that the analysis of regional economic growth should pay more attention to provinces' idiosyncrasies, the dynamics of technology progress and the initial knowledge stocks of each province. The empirical results show the differences in convergence results for human capital and per capita GDP in Chinese provinces from 1996 to 2006, which is inconsistent with the prediction of Barro et al. (1995). This discrepancy between the theoretical prediction and the empirical results for China may be due to at least three reasons: the importance of China's heterogeneous characteristics across provinces, the difficulties in measuring human capital stock and the failure of account for the dynamics of total factor productivity.

Focusing on the dynamics of human capital indicators suggests that the best proxy for human capital stock within the framework of the neoclassical growth model is the indicator based on college and higher education for males. Moreover, the empirical results on human capital share in national income (section 5.5) show that human capital share in national income based on higher education is larger than that based on junior secondary education. These findings are useful to understand the importance of investment in advanced education level during the process of

developing regional economy in China in the recent ten years.

In conclusion, despite the fact that the theoretical model of Barro et al. (1995) does not work very well for the case of China, this model still gives some useful hints about sources of economic growth and helps to understand regional disparities. For instance, the initial human capital stock between poor and rich provinces, total factor productivity, and geographic superiority may affect economic growth and regional disparities. The dispersion of per capita income across provinces in China is not narrowing in the recent ten years. If China is to sustain its growth and welfare improvement in the next decade, it needs to address its insufficient and uneven distribution of all resources related to economic growth between rich and poor provinces, to attach importance to the growth of technology process, and to take the problem of regional disparities seriously.

Table I. Relative levels of per capita GDP and human capital indicators
(provinces average = 1)

Provinces (25)	RGDP		RCHTPOP		RJSTPOP	
	1996	2006	1996	2006	1996	2006
Coastal provinces (11)						
Beijing (BJ)	2.242	2.327	4.523	3.737	1.043	0.776
Tianjin (TJ)	1.829	1.873	1.542	1.938	1.144	0.96
Hebei (HEB)	0.797	0.813	0.404	0.501	1.126	1.247
Liaoning (LN)	1.152	1.183	1.202	1.219	1.346	1.19
Shanghai (SH)	3.319	3.612	3.236	2.779	1.178	0.877
Jiangsu (JS)	1.259	1.251	0.884	0.921	1.082	1.017
Zhejiang (ZJ)	1.409	1.412	0.475	1.072	1.052	0.917
Fujian (FJ)	1.212	1.266	0.456	0.743	0.803	0.899
Shandong (SD)	1.018	1.017	0.407	0.729	1.048	1.103
Guangdong (GD)	1.418	1.375	0.394	0.726	1.012	1.108
Guangxi (GX)	0.608	0.486	0.233	0.582	0.973	1.08
Inland provinces (14)						
Shanxi (SAX)	0.629	0.554	0.982	0.846	1.221	1.245
Inner Mongolia (IM)	0.635	0.627	0.947	0.828	1.056	1.047
Jilin (JL)	0.769	0.744	1.007	0.894	1.169	1.106
Heilongjiang (HLJ)	0.964	0.898	1.149	0.778	1.224	1.172
Anhui (AH)	0.578	0.552	0.389	0.601	0.926	1.014
Henan (HEN)	0.601	0.574	0.517	0.527	1.173	1.264
Hubei (HUB)	0.763	0.764	0.722	0.982	0.975	0.985
Hunan (HUN)	0.615	0.599	0.569	0.645	0.962	1.05
Guizhou (GZ)	0.312	0.29	0.581	0.346	0.69	0.797
Yunnan (YN)	0.554	0.522	0.504	0.395	0.64	0.746
Gansu (GS)	0.432	0.43	0.643	0.42	0.748	0.812
Qinghai (QH)	0.559	0.547	0.691	0.758	0.609	0.73
Ningxia (NX)	0.556	0.525	1.045	0.925	0.938	0.87
Xinjiang (XJ)	0.77	0.759	1.498	1.107	0.863	0.988

Data Source: China Statistical Yearbook (1997,2007)

Note: RGDP denotes relative levels of per capita GDP. RCHTPOP denotes relative levels of the percentage of the population that has attained College and Higher level in the total population over 6 years old. RJSTPOP denotes relative levels of the percentage of the population that has attained at least junior secondary school in the total population over 6 years old.

Table II. Human capital convergence between Chinese provinces from 1996 to 2006

Human capital indicators				
	Relative levels of the percentage of the population with at least junior secondary school		Relative levels of the percentage of the population with college and higher education	
	γ_H	β_H	γ_H	β_H
Both sexes	-0.076 (0.025) 0.07	0.039	-0.087 (0.024) 0.09	0.046
Males	0.012 (0.029) 0.001	NA	-0.059 (0.025) 0.04	0.030
Females	-0.146 (0.027) 0.19	0.079	-0.143 (0.026) 0.17	0.077

Observations: 125 panel (balanced)

Estimated equation: $\ln(RH_{i,t+p} / RH_{i,t}) = -\gamma_H \ln(RH_{i,t}) + \mu_{i,t+p}^H$ (Equation I)

$$\beta_H = -[\ln(1 - \gamma_H)] / p \quad (\text{Equation II})$$

Note: The numbers in each column γ_H are the estimated coefficients of the logarithm of the human capital indicator in equation I, the standard errors of coefficients in parentheses and the adjusted R^2 , respectively. The numbers in each column β_H are the estimated annual speeds of convergence of the human capital indicator according to equation II. The estimation method is GLS (cross-section weights). Estimation is done using Eviews 3.1. The notation “NA” indicates that the convergence speed can not be computed, since there is no convergence of this human capital indicator.

Table III. Wald statistics for the comparison of the speed of convergence between at least junior secondary and college and higher education

Both sexes	0.101 *
Females	0.135 *
Males	NA

Note: The critical values of the Wald statistics are respectively 3.84 and 6.63 at the confidence levels of 95 percent and 99 percent. The notation * means that can not reject the null hypothesis that the speed of convergence for at least junior secondary school is equal to the speed of convergence for college and higher education at confidence levels of 95 per cent. The notation “NA” indicators that the Wald statistics is not computed since there is no convergence for the males with at least junior secondary school.

Table IV. Wald statistics for the comparison of the speed of convergence between males and females

College and higher education	5.4235 **
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Note: The critical values of the Wald statistics are respectively 3.84 and 6.63 at the confidence levels of 95 percent and 99 percent. The notation ** means that can reject the null hypothesis that the speed of convergence for males is equal to the speed of convergence for females at confidence levels of 95 percent.

Table V. Convergence of per capita GDP in 25 provinces of China (1996-2006)

The estimated coefficient γ_Y	0.019055
The convergence speed β_Y	-0.009438
Standard deviation	0.006122
Adjusted R^2	0.07

Observations: 125 panel (balanced)

Estimated equation: $\ln(RY_{i,t+p} / RY_{i,t}) = -\gamma_Y \ln(RY_{i,t}) + \mu_{i,t+p}^Y$ (Equation III)

$$\beta_Y = -[\ln(1 - \gamma_Y)] / p \quad (\text{Equation IV})$$

Note: The estimated coefficient of the logarithm of per capita GDP is obtained using equation (III). The estimation method is GLS (cross-section weights). Estimation is done using Eviews 3.1.

Table VI. Measuring the share of human capital in national income in 25 provinces of China (1996-2006)

	Measures of GDP and human capital indicators			
	Percentage of the population with at least junior secondary school		Percentage of the population with college and higher education	
	$\frac{\eta}{1-\alpha}$	η	$\frac{\eta}{1-\alpha}$	η
Both sexes	0.53 (0.0706) 0.25	0.36 [0.26, 0.45]	0.68 (0.0279) 0.79	0.46 [0.42, 0.50]
Males	0.498 (0.0983) 0.10	0.33 [0.19, 0.46]	0.7 (0.0265) 0.82	0.47 [0.43, 0.51]
Females	0.46 (0.0485) 0.37	0.31 [0.24, 0.37]	0.63 (0.0301) 0.73	0.42 [0.38, 0.46]

Observations: 150 panel (balanced)

Estimated equation: $\ln(RY_{i,t}) = \frac{\eta}{1-\alpha} \ln(RH_{i,t}) + \mu_{i,t}^y$ (Equation VII)

Note: The numbers in each column $\frac{\eta}{1-\alpha}$ are the estimated coefficients of the logarithm of the human capital indicator in equation (VII), the standard errors of coefficients and the adjusted R^2 , respectively. The numbers in each column η are the human capital share in per capita GDP. In brackets is the 95 per cent confidence interval for the share of human capital. The estimation method is GLS (cross-section weights). Estimation is done using Eviews 3.1.

Table VII. Regression of the growth rate of per capita GDP and the initial level of human capital

	Measures of per capital GDP and human capital indicators	
	Percentage of the population with at least junior secondary school	Percentage of the population with college and higher education
Both sexes	0.048* (0.020) 0.05	0.020* (0.006) 0.08
Males	0.036 (0.022) 0.02	0.020* (0.006) 0.08
Females	0.049* (0.016) 0.07	0.018* (0.005) 0.08

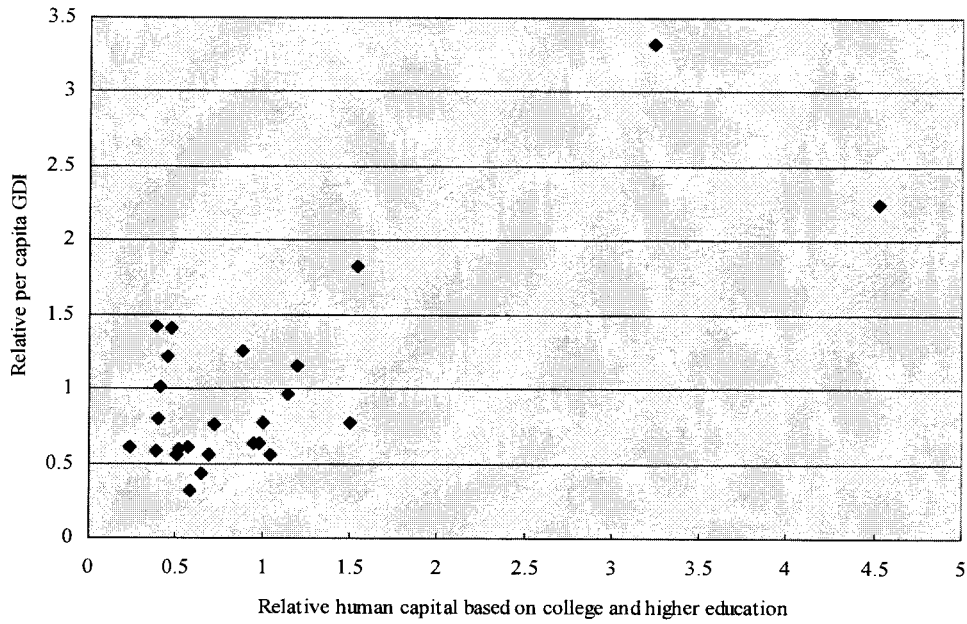
Observations: 125 panel (balanced)

Estimated equation: $\ln(RY_{i,t+p} / RY_{i,t}) = C \ln(RH_{i,t}) + \mu_{i,t+p}^{YR}$ (Equation VIII)

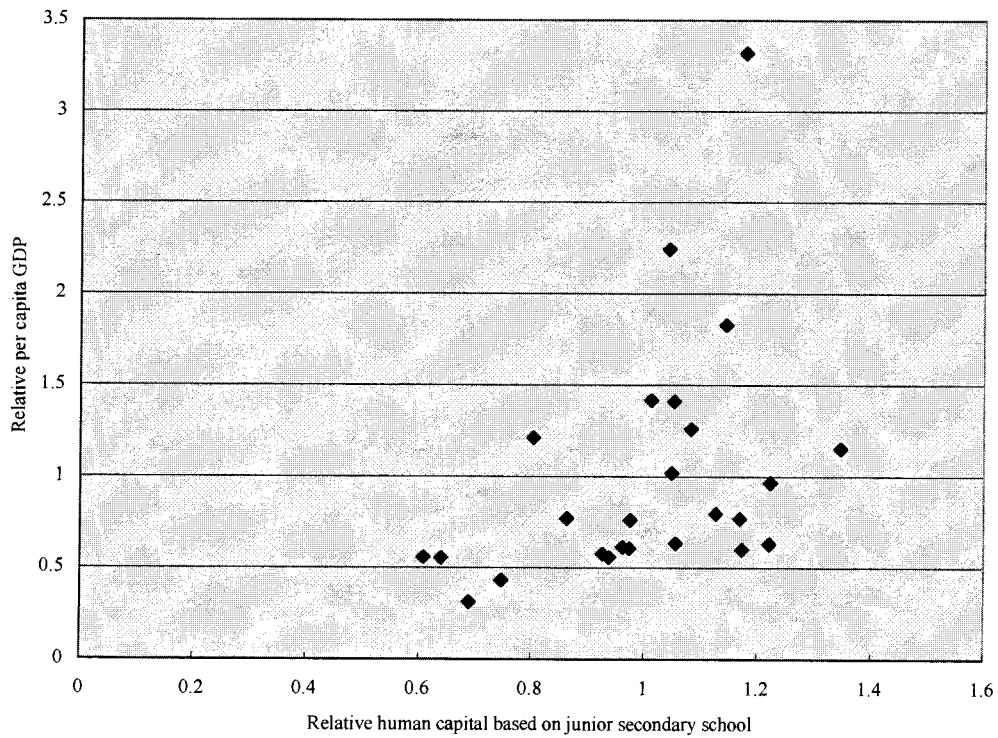
Note: The numbers in each column are the estimated coefficients of the logarithm of the human capital indicator in equation (VIII), the standard errors of coefficients and the adjusted R^2 , respectively. The estimation method is GLS (cross-section weights). Estimation is done using Eviews 3.1. The notation * means that the estimated coefficient is significantly different from zero at five percent level.

Figure 1. Cross-provincial relationship between per capita GDP and human capital indicators in 1996

(A). RCHTPOP vs. RGDP



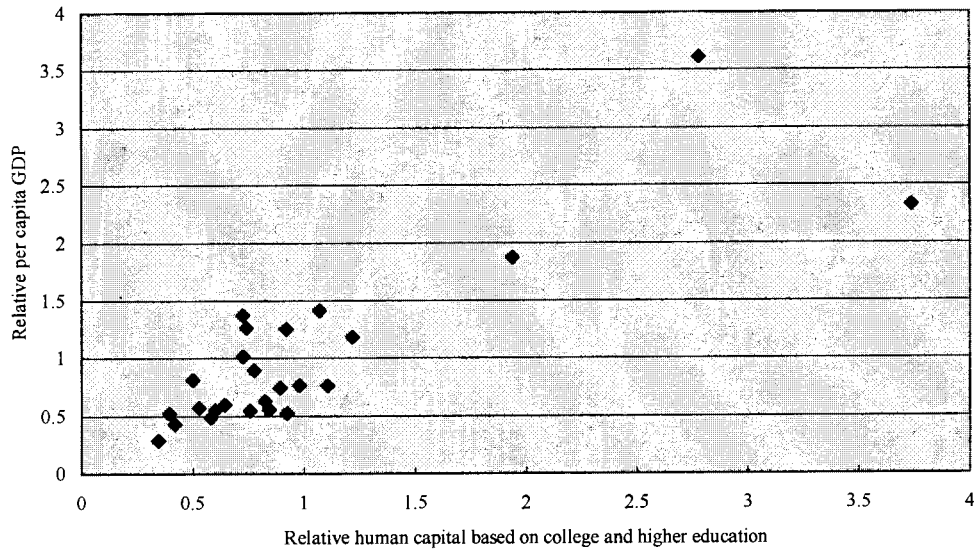
(B). RJSTPOP vs. RGDP



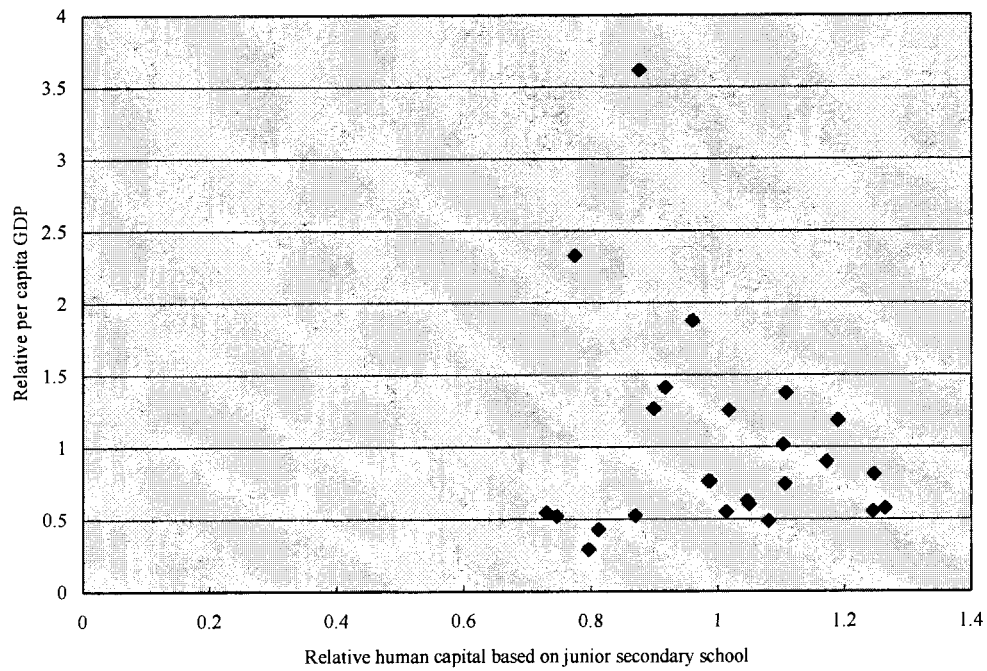
Note: The scatter plots are based on the data from Table I. Panel (A) shows the relationship between relative levels of per capita GDP and relative levels of human capital indicator RCHTPOP based on college and higher education. Panel (B) shows the relationship between relative levels of per capita GDP and relative levels of human capital indicator RJSTPOP based on junior secondary school.

Figure 2. Cross-provincial relationship between per capita GDP and human capital indicators in 2006

(A). RCHTPOP vs. RGDP

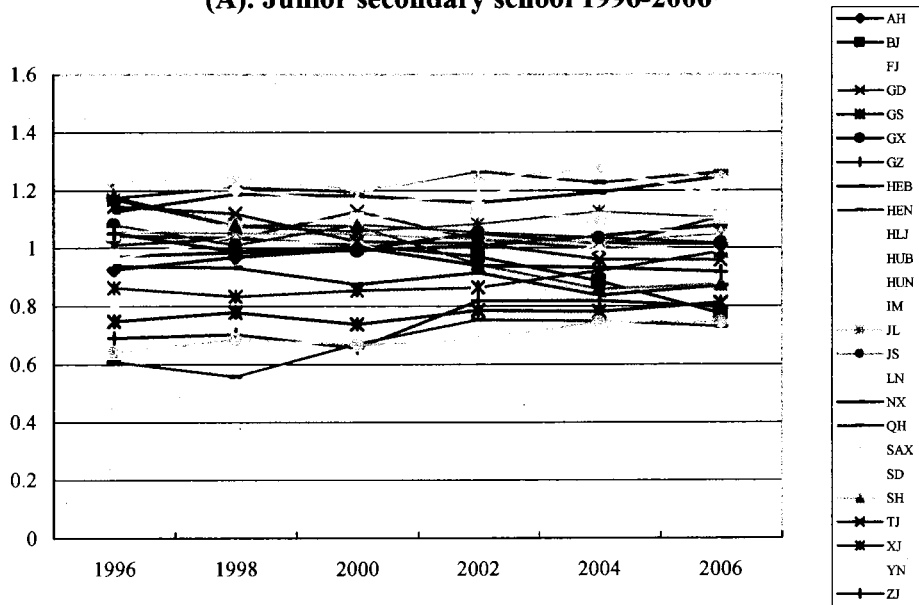


(B). RJSTPOP vs. RGDP

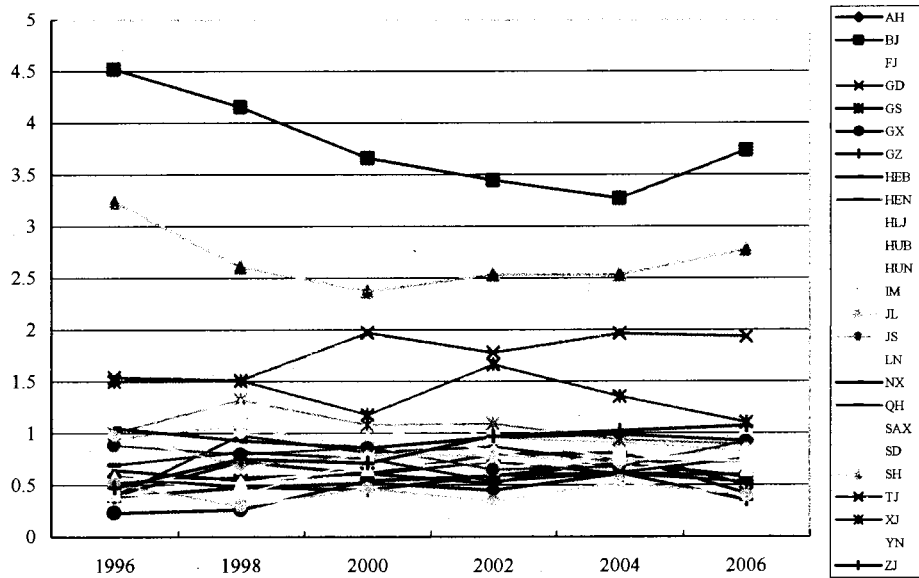


Note: The scatter plots are based on the data from Table I. Panel (A) shows the relationship between relative levels of per capita GDP and relative levels of human capital indicator RCHTPOP based on college and higher education. Panel (B) shows the relationship between relative levels of per capita GDP and relative levels of human capital indicator RJSTPOP based on junior secondary school.

Figure 3. Relative levels of human capital
(A). Junior secondary school 1996-2006

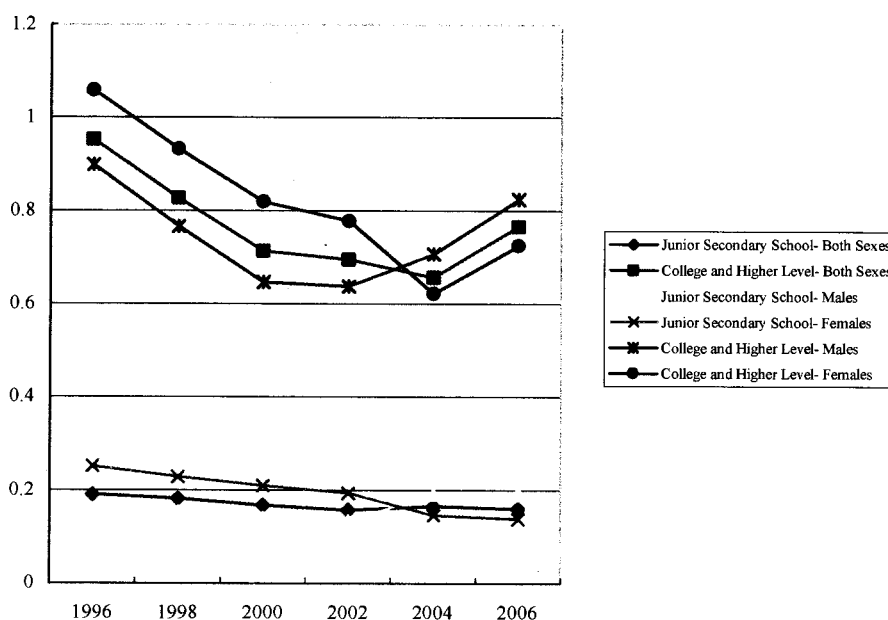


(B). College and higher education 1996-2006



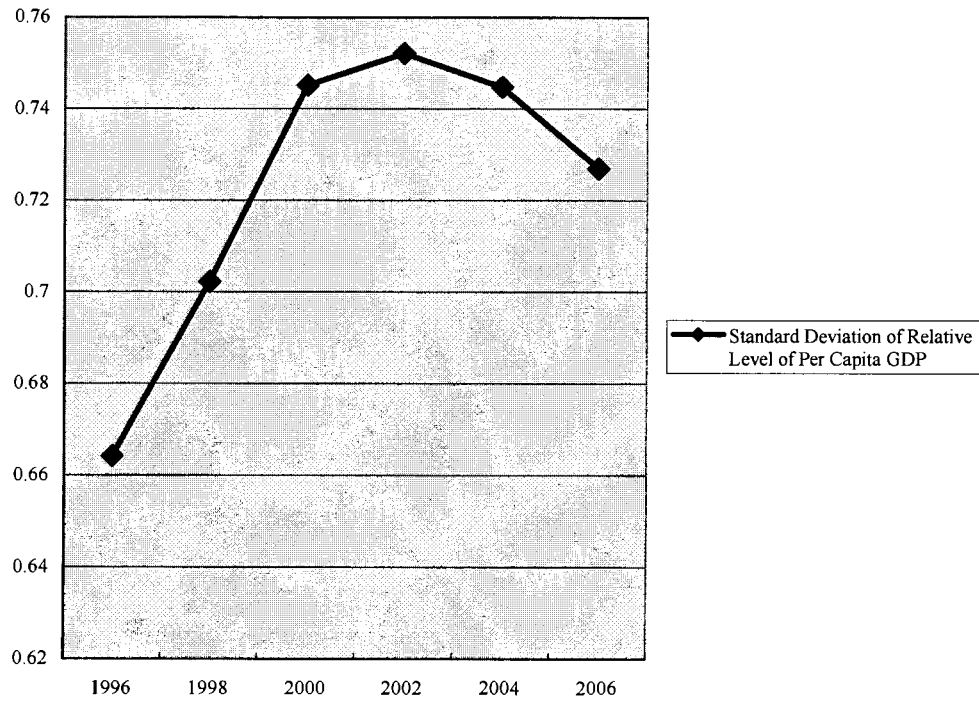
Note: Panel (A) and (B) are obtained using the data of relative levels of human capital indicators based on at least junior secondary school and college and higher education across 25 provinces in 1996, 1998, 2000, 2002, 2004, 2006, respectively. Each line denotes the change of relative levels of human capital indicators in a province over ten years.

Figure 4. Regional dispersion of human capital indicators



Note: The figure plots standard deviations of six human capital indicators from 1996 to 2006. For the indicator based on junior secondary school for both sexes, the standard deviation decreases from 0.19 in 1996 to 0.16 in 2006. For the indicator based on junior secondary school for males, the standard deviation increases from 0.15 in 1996 to 0.19 in 2006. For the indicator based on junior secondary school for females, the standard deviation decreases from 0.25 in 1996 to 0.14 in 2006. For the indicator based on college and higher education for both sexes, the standard deviation decreases from 0.95 in 1996 to 0.76 in 2006. For the indicator based on college and higher education for males, the standard deviation decreases from 0.90 in 1996 to 0.82 in 2006. For the indicator based on college and higher education for females, the standard deviation decreases 1.06 in 1996 to 0.73 in 2006.

Figure 5. Regional dispersion of per capita GDP



Note: The figure presents the change of the dispersion of relative per capita GDP of Chinese provinces from 1996 to 2006. The dispersion of relative per capita GDP is measured by the standard deviation of relative per capita GDP. The values of the standard deviation of relative per capita GDP in 1996, 1998, 2000, 2002, 2004, 2006 are respectively 0.66, 0.70, 0.74, 0.75, 0.74 and 0.73.

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