Gundlach, Erich

Solow meets market socialism: regional convergence of output per worker in China

Kiel Working Paper, No. 726

Kieler Arbeitspapiere
Kiel Working Papers

Kiel Working Paper No. 726

Solow Meets Market Socialism:

Regional Convergence of Output per Worker in China

by

Erich Gundlach

Institut für Weltwirtschaft an der Universität Kiel

The Kiel Institute of World Economics

ISSN 0342 - 0787

Kiel Institute of World Economics

Department IV

24100 Kiel, Germany

Kiel Working Paper No. 726

Solow Meets Market Socialism:

Regional Convergence of Output per Worker in China

by

Erich Gundlach

February 1996

Solow Meets Market Socialism:
Regional Convergence of Output per Worker in China

Abstract

Regional output per worker has converged in China in the era of market socialism since 1978. The estimated speed of convergence is about 2 percent. This speed of convergence can be explained by an open economy neoclassical growth model in the tradition of Robert Solow. My empirical results show that capital mobility has been high across Chinese provinces and that the production elasticity of human capital is about twice as high as the production elasticity of physical capital. With less interprovincial capital flows as the result of an expected increase in fiscal decentralization, the speed of convergence of regional output per worker is likely to decline.

JEL: O41

Erich Gundlach
Kiel Institute of World Economics
P.O. Box 4309
D-24100 Kiel, Germany
Phone: (431) 8814284
Fax: (431) 8814500
E-mail: egundlach@ifw.uni-kiel.d400.de

1. Introduction and Summary*

Chinese provinces display large differences in growth rates and output per worker. Growth rates have differed by a factor of eight, and output per worker has differed by a factor of ten. However, these large differences have tended to decline over time, because poor provinces have grown faster than rich provinces since the beginning of economic reform in 1978. Figure 1 highlights this stylized fact as a negative correlation between output per worker in 1978 and average annual growth rates in 1978-1989.[1] That is, regional output per worker has converged across Chinese provinces in the era of market socialism.[2]

The Solow (1956) model of economic growth explains convergence of output per worker by differences in factor accumulation. This model implies that the speed of convergence depends on specific parameters such as production elasticities, depreciation rates, and labor force growth. Because these parameters can be estimated, the Solow model can be used to derive a quantitative prediction for the speed of convergence that, in turn, can be compared with the observed speed of convergence. Thus, the Solow model of economic growth may provide a reasonable account of the convergence of output per worker across Chinese

---

* This paper reports research undertaken in a project on "Decentralization and Enterprise Reform in China". I thank Martin Raiser for helpful comments on an earlier version. Financial support by the Volkswagen-Stiftung is gratefully acknowledged.

[1] The Appendix gives a definition of variables and the respective data sources. Two Appendix tables contain all the data used in this paper. The data refer to 29 Chinese provincial level localities, including 22 provinces, 3 municipalities under the central government, and 4 autonomous regions (Tibet is excluded due to data limitations). I refer to all these entities as provinces.

[2] Figure 1 actually reflects convergence and not Galton's fallacy (see Friedman (1992)), because the coefficient of variation of output per worker declines from 0.70 in 1978 to 0.51 in 1989.

provinces if the theoretically predicted speed of convergence closely matches the observed speed of convergence.

My results show that the observed speed of convergence across Chinese provinces is rather slow, namely about 2 percent. The Solow model can explain this rate of convergence if there is no capital mobility across Chinese provinces and if the production elasticity of capital is about 0.8. But I find that capital mobility is high, because saving and investment rates are uncorrelated across Chinese provinces. If one therefore assumes that Chinese provinces are open economies, the Solow model predicts that capital will move quickly to equalize marginal products and, hence, that convergence of output per worker will be rapid.

I can reconcile the observed and the theoretically predicted speed of convergence by introducing human capital as a third factor of production, and by assuming that human capital is immobile. If so, interprovincial borrowing is possible to finance accumulation of physical capital, but not accumulation of human capital. With the human capital augmented Solow model, I find that the production elasticity of human capital is about twice as high as the production elasticity of human capital, and that the combined production elasticity of all capital is about 0.8 at least.

These findings imply that according to the augmented Solow model, convergence of output per worker across Chinese provinces has been accelerated by high interprovincial physical capital mobility in the era of market socialism. Capital mobility has allowed poor regions to maintain a high rate of physical capital accumulation despite low saving rates. But interprovincial capital mobility is likely to decline once fiscal decentralization gains further momentum in the course of Chinese economic reforms, at least as long as an efficient domestic capital market is largely missing. As a result, regional convergence of output per worker is likely to decline as well.

2. The Speed of Convergence: Theory and Evidence

Suppose that all Chinese provinces have access to the same technology and share the same preferences. Then, the traditional neoclassical growth model (Solow 1956) predicts convergence of output per worker to a common steady state. Following Barro and Sala-i-Martin (1992), convergence to the steady state between times 0 and T can be described by

$$(1) \quad \frac{1}{T}\log\left[\frac{(Y/L)^i_T}{(Y/L)^i_0}\right] = B - \left(\frac{1-e^{-\lambda T}}{T}\right)\log(Y/L)^i_0 \ ,$$

where $(Y/L)^i$ is output per worker in province i, B is a constant term, and λ is the convergence rate. That is, the growth rate of output per worker is a negative function of initial output per worker.

A regression of the average annual growth rate of output per worker in 1978-1989 on output per worker in 1978 across the 29 Chinese provinces shown in Figure 1 delivers the following result (standard errors in parenthesis):

$$(2) \quad \ln(Y/L)_{1989} - \ln(Y/L)_{1978} = 1.93 - 0.22\ln(Y/L)_{1978}$$
$$(0.43)\ (0.06)$$

$\overline{R}^2$ = 0.28

s.e.e. = 0.17

No. of observations = 29.

The regression coefficient on $\ln(Y/L)_{1978}$ can be used to calculate λ according to

$$(3) \quad \lambda = -\ln(1-0.22)/11$$

and a non-linear least squares regression of equation (2) produces a point estimate for λ of 0.022 with a standard error of 0.007. This estimate lies within the range that is known from other empirical studies of convergence.[3]

A λ of about 2 percent implies that convergence towards the steady state will proceed rather slowly, because in this case half of the departure from a given steady state would remain for 35 years. Two questions arise. First, whether any parameterization of the Solow model would actually produce a convergence rate of 2 percent and, second, whether such a parameterization is indeed supported by the data.

The Solow model takes the rates of saving, population growth and technological progress as exogenous. Output (Y) is produced under constant returns to scale with two inputs, capital (K) and labor (L), which are paid their marginal products. Assuming a Cobb-Douglas production function, output at time t is given by:

(4) $\quad Y_t = K_t^{\alpha}(A_t L_t)^{1-\alpha}$, $0<\alpha<1$.

A, the level of technology, and L are assumed to grow exogenously at rates g and n. Hence, the number of effective units of labor, $A_t L_t$, grows at rate $g+n$. Furthermore, assuming constant saving (S/Y) and depreciation rates ($\delta = D/K$), and defining k as the stock of capital per effective unit of labor ($k = K/AL$) and y as output per effective unit of labor ($y = A/L$), it can be shown that the evolution of k is governed by (Mankiw et al. 1992)[4]

(5) $\quad dk/dt = sy - (n+g+\delta)k$,

---

[3] For a brief overview, see Barro et al. (1995).

[4] In the following, I delete time subscripts for convenience of presentation.

and that k converges to a steady state value

(6) $k^* = [s/(n+g+\delta)]^{1/(1-\alpha)}$.

Taking the first order Taylor expansion of the right hand side of equation (5) and substituting for s using the steady state condition (6) gives (Mankiw 1995)

(7) $dk/dt = -\lambda(k - k^*)$,

where the speed of convergence to the steady state is given by

(8) $\lambda = (1-\alpha)(n+g+\delta)$,

with α as the production elasticity of capital (see equation 4). If λ is known to be about 2 percent, equation (8) can be used to infer an estimate for α, conditional on $(n+g+\delta)$.

The standard parameterization suggested in the literature is $(n+g+\delta)$ =0.08, with a rate of labor force growth of 1 percent, a rate of technological change of 2 percent, and a depreciation rate of 5 percent (Barro et al. 1995). Because the observed speed of convergence is about 2 percent, equation (8) then implies that α is about 0.8.

An implied value of α of about 0.8 creates a first problem for the traditional Solow growth model. According to the assumptions of perfect competition and constant returns to scale, α should equal capital's share in income. The average value for α calculated from the national accounts of industrialized countries is about 0.3 (Maddison 1987). But the national accounts do not account for human capital formation. Therefore, a value of α of about 0.8 has been interpreted as a production elasticity for a broad concept of capital that includes physical and human capital (Barro and Sala-i-Martin 1992; Mankiw et al. 1992). Hence, the traditional Solow model should be augmented by human capital as a third factor of production.

A second, more serious problem for the traditional neoclassical growth model arises from the implicit assumption of capital immobility. While this assumption may be a reasonable approximation for cross-country studies, it is rather unlikely to hold within countries. But with regional capital mobility, the theoretically predicted speed of convergence towards the steady state would be high, because capital would move quickly to equalize marginal products.

The solution for both problems is an open-economy version of the Solow model (Barro et al. 1995) that assumes interregional mobility of physical capital flows, but immobile human capital. The human capital augmented production function reads

$$(9) \quad Y = K^{\alpha} H^{\beta} (AL)^{1-\alpha-\beta} \qquad 0<\alpha+\beta<1 \ ,$$

where A grows at rate g and L grows at rate n as before, and H is the level of human capital. Calculating the steady state values k^* and h^* $(h = H / AL)$ similar to equation (6) and substituting them into the production function (9) gives (see Mankiw et al. 1992)

$$(10) \quad \ln Y / L = c - \frac{\alpha+\beta}{1-\alpha-\beta}\ln(n+g+\delta) + \frac{\alpha}{1-\alpha-\beta}\ln(S_K / Y) + \frac{\beta}{1-\alpha-\beta}\ln(S_H / Y) \ ,$$

where c is a regression constant and (S_K / Y) and (S_H / Y) represent the saving rates for physical and human capital. Alternatively, combining the expression for h^* with equation (10) yields (Mankiw et al. 1992)

$$(11) \quad \ln Y / L = c - \frac{\alpha}{1-\alpha}\ln(n+g+\delta) + \frac{\alpha}{1-\alpha}\ln(S_K / Y) + \frac{\beta}{1-\alpha}\ln(h^*) \ ,$$

where it is the level of human capital per worker which enters as a right-hand-side variable, and not the rate of human capital accumulation as in equation (10).

In the human capital augmented Solow model for the open economy, the speed of convergence to the steady state is given by (Barro et al. 1995)

$$(12) \quad \lambda_{open} = \left(1 - \frac{\beta}{1-\alpha}\right)(n + g + \delta) .$$

To prove that equation (12) correctly predicts the observed speed of convergence, the empirical analysis has two tasks. First, it has to be shown that the assumption of physical capital mobility across Chinese provinces is reasonable. Second, it has to be shown that conditional on $(n+g+\delta)$, estimated production elasticities for physical and human capital can be used to predict a speed of convergence of about 2 percent.

3. Estimating the Open Economy Model

3.1 Capital Mobility across Chinese Provinces

Recent assessments of capital mobility within China do not provide clear-cut results. The World Bank (1994) maintains that there is no evidence to support a convergence of returns to capital across different provinces, suggesting that capital mobility is low. Raiser (1995) surveys the literature on fiscal decentralization which claims that capital mobility across Chinese provinces has declined. Nevertheless, Hsueh Tien-tung (1994) reports that during the 1980s the inflow of interregional capital to low income provinces has been as high as 25 percent or above of their national income, pointing to a rather high interprovincial capital mobility.

I use the approach suggested by Feldstein and Horioka (1980) to provide a more systematic picture of capital mobility across Chinese provinces. If Chinese provinces are closed economies, their saving rates equal their investment rates. But if they are open, their saving and investment rates will differ due to interprovincial capital movements. Hence, the degree of capital mobility can be

estimated by a regression of the investment rate (I/Y) on the saving rate (S/Y) across Chinese provinces:

$$(13) \quad (I/Y)_t^i = c + \gamma (S/Y)_t^i \quad ,$$

where γ is the so-called savings retention coefficient. If γ equals 1, any change in the saving rate in province i leads to an identical change in the investment rate of province i. Thus, a γ of 1 would imply that province i is a closed economy, because no net interprovincial capital flows occur. By contrast, if γ equals 0, investment and saving rates are uncorrelated at the provincial level. In this case, perfect interprovincial capital mobility would prevail.[5]

I use average saving and investment rates for various time periods to estimate the saving retention coefficient γ according to equation (13).[6] This procedure is likely to bias upward the estimate for γ (Sinn 1992), i.e. towards finding capital immobility. However, the results in Table 1 show that saving and investment rates across Chinese provinces are uncorrelated since the savings retention coefficient is statistically not different from zero in three out of four cases.

A statistically significant negative savings retention coefficient arises for average saving and investment rates in 1978-1989. This finding would imply that any increase in the average provincial saving rate reduces that province's investment rate. Such an outcome may indicate that during the 1980s, the central planning authorities still held a certain power of control over the regional distribution of

---

5 For a brief survey of the empirical evidence on the relation between saving and investment rates from cross-country and inter-regional studies, and for the controversies with regard to an interpretation of the saving retention coefficient that have arisen in the literature, see Feldstein (1994).

6 See the Appendix for a definition of variables, and Table A2 for the data.

capital accumulation (Hsueh Tien-tung 1994). However, this finding is based on 14 observations only.

Taken together, I interpret my findings as indicating high capital mobility across Chinese provinces. High capital mobility would be compatible with a low speed of convergence if the economic efficiency of interprovincial capital flows is low, as suggested by Hsueh Tien-tung (1994). But if the efficiency of interprovincial capital flows is low, it is difficult to explain how China has managed to achieve average annual growth rates of real GDP per capita of about 8 percent during the 1980s (World Bank 1995). Therefore, I use the augmented Solow model for the open economy to explain the observed low speed of convergence. The empirical relevance of this approach can be assessed by estimating production elasticities for physical and human capital according to equations (10) and (11). If α and β are known, it is possible to predict λ according to equation (12). This prediction can be compared with the estimated value for λ of about 2 percent.

3.2 Production Elasticities for Physical and Human Capital

To estimate production elasticities according to equations (10) and (11), I use investment rates for physical and human capital to proxy the theoretical variables (S_K / Y) and (S_H / Y). In contrast to flow measures of physical capital formation such as the investment rate (I / Y), direct measures of human capital formation are generally not available. Therefore, I use the number of students enrolled in secondary education divided by the population (*SCHOOL*) to measure investment in human capital. Hence, I assume that variations in the fraction of the population devoted to formal education reflect variations in provincial investment in human capital. Alternatively, I use the number of newspapers, magazines, and books published divided by the labor force (*PUBL*) to measure the stock of

human capital. Here I assume that the provincial supply of written information is correlated with the provincial quantity of human capital.

Furthermore, equation (10) and (11) can be restricted to increase the precision of estimates. The restriction that can be imposed on equation (10) is that the regression coefficients on $\ln(n+g+\delta)$, $\ln(S_K / Y)$, and $\ln(S_H / Y)$ sum to zero. The restriction that can be imposed on equation (11) is that the regression coefficients on $\ln(n+g+\delta)$ and $\ln(S_K / Y)$ sum to zero.

Taking into account these empirical modifications, the restricted versions of equations (10) and (11) read

$$\text{(10a)} \qquad \ln(Y/L) = c + \frac{\alpha}{1-\alpha-\beta}\left[\ln(I/Y) - \ln(n+g+\delta)\right] + \frac{\beta}{1-\alpha-\beta}\left[\ln(SCHOOL) - \ln(n+g+\delta)\right]$$

and

$$\text{(11a)} \qquad \ln(Y/L) = c + \frac{\alpha}{1-\alpha}\left[\ln(I/Y) - \ln(n+g+\delta)\right] + \frac{\beta}{1-\alpha}\ln(PUBL) \quad .$$

Table 2 presents the results of an OLS estimation of the restricted and unrestricted empirical specifications (10a) and (11a).[7] The stock specification of human capital (11a) performs better with regard to statistical criteria such as $\overline{R}^2$ and p-value. The p-value indicates that the restriction imposed on equation (10a) is rejected by the data at the 5 percent level of statistical significance, while the restriction imposed on equation (11a) is not rejected. The point estimates for α are not statistically different from each other and their size suggests that capital's

---

[7] The results presented in Table 2 are conditional on the previous assumptions that g equals 2 percent and δ equals 5 percent. The rate of labor force growth, n, can be directly observed for each Chinese province (see Table A1).

share in income in China is not that different from capital's share in income in industrialized countries.[8] However, the point estimates for β differ. If investment in human capital ($SCHOOL$) is used as a right-hand-side variable, β is estimated to be about 0.16. But if the stock of human capital ($PUBL$) is used as a right-hand-side variable, β is estimated to be 0.46.

Several reasons exist why the point estimates for β may differ. First, the different estimates may simply reflect that the share of secondary education in income as measured by the production elasticity of $SCHOOL$ is much smaller than the share of all human capital in income as measured by the production elasticity of $PUBL$. In this case, the more comprehensive measure is more likely to reflect the true impact of human capital formation on economic growth.

Second, the low estimate for β derived from the investment specification of human capital may be correct, while the high estimate for β derived from the stock specification of human capital may be biased upward due to a correlation between $\ln(PUBL)$ and the disturbance term. Such a correlation could arise because changes in h, like changes in k, could depend on y. That is, if the accumulation of human capital is correctly described by the same data generating process as the accumulation of physical capital (see equation (5)), then $\ln(PUBL)$ will be correlated with the disturbance term in equation (10b). In this case, an OLS estimate of equation (10b) will produce an upward biased estimate of β.

Third, the low estimate for β derived from the investment specification of human capital may result from a measurement error in $SCHOOL$. A measurement error would tend to bias downward the estimated regression coefficient on

---

[8] A profit share of about 0.3 was also estimated for a cross section of 98 countries (Mankiw et al. 1992).

$\ln(SCHOOL) - \ln(n+g+\delta)$ in equation (10a) and, hence, the implied point estimate for β. To see why this is so, define the regression coefficients in equation (10a) as $a = \alpha/(1-\alpha-\beta)$ and $b = \beta/(1-\alpha-\beta)$. It follows that $\beta = b/(1+a+b)$. Thus, a downward biased estimate of b due to measurement error in *SCHOOL* would reduce the point estimate for β. In this case, the true impact of human capital formation would again be measured by the high estimate for β derived from the stock specification of human capital.

Fourth, because both measures of human capital formation used in equations (10a) and (10b) have to be considered as rather crude proxies at best, not only *SCHOOL*, but also *PUBL* could be measured with error. In this case, the true impact of human capital formation would even be larger than measured by the previous OLS estimate of β of about 0.5.[9]

I use two econometric procedures to identify direction and size of the presumed biases of the regression coefficients. The instrumental variable (*IV*) method can clarify whether the high estimate for β is upward biased due to an endogeneity problem, and an error in variables model can clarify whether the low estimate for β is downward biased due to a measurement error.

To check whether the previous high estimate of β is due to a correlation between my proxy for the stock of human capital ($\ln(PUBL)$) and the disturbance term, I run an *IV* regression of equation (10b) using investment in human capital

---

[9] A further reason for biased regression coefficients can arise from the potential correlation between the variable measured with error and other variables in the equation. However, this problem does neither arise in equation (10a) nor in equation (10b), because both measures of human capital formation are uncorrelated with the measure of physical capital formation: The coefficient of correlation between $\ln(I/Y) - \ln(n+g+\delta)$ and $\ln(SCHOOL) - \ln(n+g+\delta)$ is 0.28 with an F-statistic of 2.39; the coefficient of correlation between $\ln(I/Y) - \ln(n+g+\delta)$ and $\ln(PUBL)$ is 0.15 with an F-statistic of 0.65.

($\ln(SCHOOL)$) as an instrument. Under reasonable assumption, investment in human capital will be correlated with the stock of human capital. But investment in human capital will not be correlated with the disturbance term, if the data generating process for human capital is identical to the data generating process for physical capital as described in equation (5). Therefore, $\ln(SCHOOL)$ seems to be a good choice as an instrument for $\ln(PUBL)$. My estimation results support a high point estimate for β of 0.8 (Table 3, first column), which is statistically different from the previous low estimate of 0.16. This finding suggests that the previous OLS estimate for β of 0.46 was not biased upward due to a correlation between $\ln(PUBL)$ and the disturbance term. If this interpretation is correct, it should be possible to demonstrate directly that the previous low estimate for β was downward biased.

I use an error in variables model to estimate the potential downward bias in the previous low estimate of β. The classical errors in variables model amounts to running a reverse regression, if one of two explanatory variables is measured with error.[10] That is, the variable measured with error in equation (10a), $\ln(SCHOOL) - \ln(n + g + \delta)$, enters as the dependent variable, and $\ln(Y / L)$ enters as a right-hand-side variable. As before, the resulting regression coefficients can be used to recover point estimates for α and β. I find a statistically significant point estimate of β of 0.74 (Table 3, second column) that confirms the high IV estimate of β. The point estimate for α is inconsistent, but the standard error is large. This result confirms that the previous low estimate for β is downward biased due to measurement error in my proxy for investment in human capital. Furthermore, it seems to indicate that even the previous high OLS

[10] For a textbook exposition, see Maddala (1992).

estimate for β may be biased downward due to a measurement error in my proxy of the stock of human capital.

Therefore, I also use the errors in variables model to control for the potential downward bias caused by a measurement error in $PUBL$. Using $\ln(PUBL)$ as the dependent variable, I find statistically significant point estimates for α of 0.23 and for β of 0.64 (Table 3, third column). These findings largely confirm the results derived from the OLS estimation of equation (10b) (see Table 2, second column), although the new point estimate for β is somewhat higher. Thus, OLS estimation of equation (10b) only seems to suffer from a small downward bias in the estimation of β due to measurement error, and not from an upward bias due to the endogeneity of the stock of human capital.

Taken together, I interpret my findings as confirming the hypothesis that a high estimate of β in the range of 0.6 rather than a low estimate in the range of 0.15 is more likely to measure the true impact of human capital formation on economic growth. The implication is that the impact of human capital formation is about twice as large as the impact of physical capital accumulation.[11] Hence, a production function that is compatible with my regression results reads $Y = K^{0.25}H^{0.6}L^{0.15}$. The remaining question is whether the estimated production elasticities can predict a speed of convergence that closely matches the observed speed of convergence of about 2 percent.

3.3 The Predicted Speed of Convergence

Once the two production elasticities α and β are known, equation (12) describes how the predicted speed of convergence can be derived conditional on the rate of

---

[11] For the same result derived from a cross-country sample, see Gundlach (1995).

labor force growth (n), the rate of technological change (g), and the depreciation rate (δ). I measure n as the average annual provincial growth rate of the labor force in 1978-1989, weighted by the labor force in 1989. I find that for my sample, the average growth rate of the labor force is 3 percent, so $n = 0.03$.

The rate of technological change can only be measured indirectly as a residuum, namely as the rate of total factor productivity growth. Therefore, measured rates of technological change depend on the specification of the production function. Jefferson et al. (1992) estimate a production function with capital, labor, and intermediate inputs and find a rate of technological change of about 2 percent for Chinese state owned industry and about 4 percent for Chinese collective industry. These results may serve as a first approximation of g, although human capital accumulation is not taken into account and the focus is on technological change in industry rather than in the aggregate economy. Another approximation may be derived from the estimates for countries such as Taiwan and South Korea, which experienced similar growth rates as China in the 1980s. Taking into account human capital accumulation and focusing on the aggregate economy, Young (1995) finds average rates of total factor productivity growth of 1.6 percent for South Korea and of 2.4 percent for Taiwan. These results suggest that the standard parameterization of g of 2 percent may also be reasonable for the case of China. That is, I assume that $g = 0.02$, which is compatible with the findings for Chinese industry given that aggregate total factor productivity growth figures are usually somewhat lower than industry figures.

Reliable data on the stock of physical capital and its depreciation are not available for China, so the depreciation rate cannot be measured directly. Given that the share of depreciation in GDP is about 10 percent, which is an average figure for industrialized countries (Maddison 1987), the rate of depreciation can be calculated once the capital output ratio is known, since $\delta = (D/Y)/(K/Y)$.

For leading industrial countries such as the United States, the capital output ratio is about 3, so δ would be about 3 percent (Mankiw et al. 1992). But for developing countries, it is reasonable to assume a smaller capital output ratio. For example, δ is 5 percent for a capital output ratio of 2. Actually, the capital output ratio may be even lower than 2 in developing countries, but then the share of depreciation in GDP may also be lower than 10 percent. On balance, therefore, I assume a depreciation rate of 5 percent for China, so $\delta = 0.05$.

With these parameterizations for $(n+g+\delta)$, the speed of convergence to the steady state can be calculated according to equation (12) as

(12a) $$\lambda_{open} = \left(1-\frac{0.6}{1-0.25}\right)(0.03+0.002+0.05)$$
$$= 0.02 \ .$$

Hence in the case of China, the human capital augmented Solow model for the open economy predicts a speed of convergence of output per worker of 2 percent, which closely matches the actually observed speed of convergence across Chinese provinces.

Further economic reforms in China are likely to increase the fiscal autonomy of provinces. That is, provinces with high saving rates will be able to use a higher share of their savings for their own investment instead of having to transfer them to provinces with low saving rates. In the absence of an efficient domestic capital market, fiscal decentralization is, therefore, likely to reduce the extent of interprovincial capital mobility. If capital is immobile, i.e. for the closed economy, the model predicts a lower speed of convergence according to equation (8). Modifying equation (8) to allow for a broad concept of capital, the predicted speed of convergence for the closed economy is

(8a) $$\lambda_{closed} = (1-(\alpha+\beta))(n+g+\delta) = (1-0.25-0.6)(0.03+0.02+0.05)$$
$$= 0.015 \ .$$

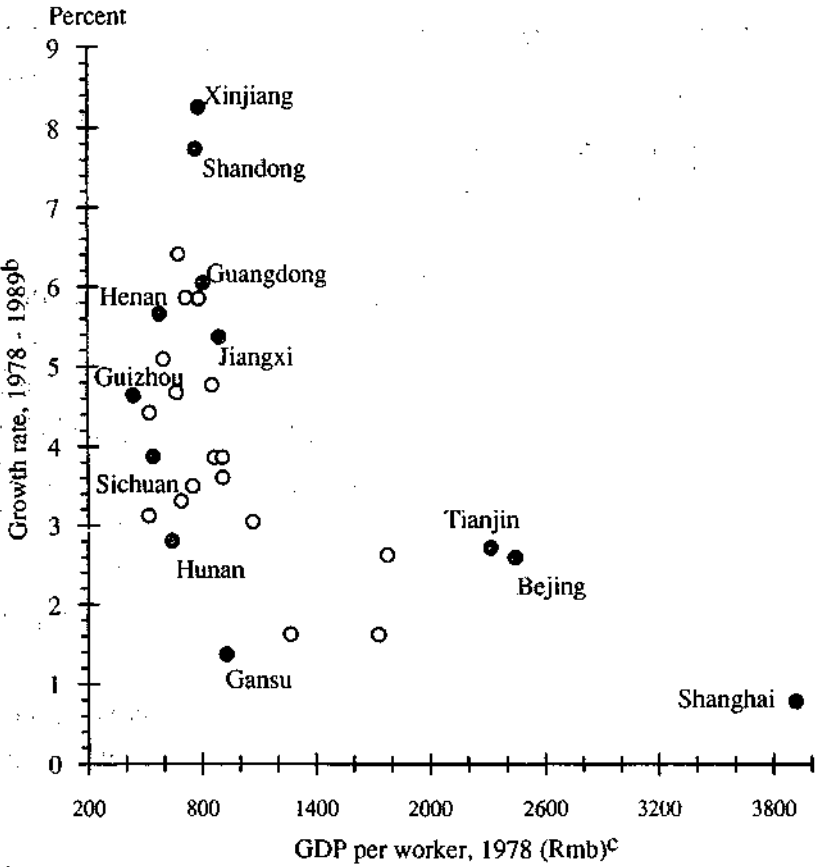
The difference between convergence rates of 2 percent and 1.5 percent is large. If the convergence rate is 2 percent, the average province would reach halfway to steady state in about 35 years. By contrast, if the convergence rate is 1.5 percent, the average province would reach halfway to steady state in about 47 years. Thus, with the higher convergence rate, halfway to steady state would be reached in about half a generation earlier.

4. Conclusions

My empirical findings reveal that the human capital augmented Solow model for the open economy provides a reasonable account of the observed speed of convergence of output per worker across Chinese provinces in the era of market socialism. A production function that is compatible with my empirical results reads $Y = K^{0.25}H^{0.6}L^{0.15}$. My point estimates for the production elasticities indicate the large impact of human capital accumulation relative to physical capital accumulation in explaining interprovincial differences in output per worker. With the estimated production elasticities, I end up predicting the actually observed speed of convergence of about 2 percent.

Further economic reforms in China aiming at fiscal decentralization are likely to reduce the previous extent of interprovincial capital mobility. Hence, poor provinces may find it increasingly difficult to maintain physical investment rates that are higher than their saving rates. If so, the speed of convergence of output per worker across Chinese provinces will tend to slow down in the absence of an efficient domestic capital market. If physical capital is completely immobile, I predict a lower speed of convergence of 1.5 percent for the same parameterization as before. The difference between the two rates of convergence is large: halfway to steady state is reached in about half a generation earlier with 2 percent than with 1.5 percent.

Figure 1 - Convergence of Output per Worker across Chinese Provinces[a], 1978-1989



[a]22 provinces, 3 municipalities, and 4 autonomous regions. — [b]Average annual growth rate of Gross Domestic Product per worker, measured in 1978 prices. — [c]Gross Domestic Product divided by Total Employed Labor Force of Society.

Source: Table A1.

Table 1 — Saving Investment Regressions across Chinese Provinces

Estimated equation: $(I/Y)_t^i = c + \gamma (S/Y)_t^i$			
Time period (t)	γ	$\overline{R}^2$	No. of observations
1978-1983	-0.12 (0.6)	0.15	24
1984-1989	-0.12 (0.08)	0.04	29
1980-1989	-0.09 (0.06)	0.03	27
1978-1989	-0.18 (0.07)	0.31	14

Note: Dependent and independent variable are averages for specified time periods, standard errors in parentheses.

Table 2 — OLS Estimation Results[a]

Dependent variable: $\ln(Y/L)$		
	Equation (10a)	Equation (11a)
Constant	7.09 (0.33)	4.62 (0.28)
$\ln(I/Y) - \ln(n+g+\delta)$	0.37 (0.32)	0.37 (0.17
$\ln(SCHOOL) - \ln(n+g+\delta)$	0.26 (0.10)	-
$\ln(PUBL)$	-	0.63 (0.07)
$\overline{R}^2$	0.23	0.77
s.e.e.	0.38	0.21
No. of observations	29	29
p – value	0.049	0.93
Implied α	0.23 (0.15)	0.27 (0.09)
Implied β	0.16 (0.07)	0.46 (0.08)

[a]Standard errors in parentheses.

Table 3 — Alternative Estimation Results[a]

	Instrumental variables[b]	Errors in variables (reverse regression)	
Dependent variable	$\ln(Y/L)$	$\ln(SCHOOL)-\ln(n+g+\delta)$	$\ln(PUBL)$
Constant	3.43 (1.10)	-6.77 (2.10)	-4.82 (0.91)
$\ln(I/Y)-\ln(n+g+\delta)$	0.23 (0.27)	0.42 (0.56)	-0.36 (0.24)
$\ln(PUBL)$	0.99 (0.33)	-	-
$\ln(Y/L)$	-	0.78 (0.30)	1.21 (0.13)
$\bar{R}^2$	0.76	0.21	0.75
s.e.e.	0.30	0.66	0.29
No. of observations	29	29	29
Implied α	0.19 (0.17)	-0.31 (0.56)	0.23 (0.11)
Implied β	0.80 (0.38)	0.74 (0.22)	0.64 (0.13)

[a]Standard errors in parentheses. — [b]List of instruments: Constant, $\ln(I/Y)-\ln(n+g+\delta)$, $\ln(SCHOOL)$.

Appendix

All data used in the paper are listed in the two Appendix Tables. They are derived from Hsueh Tien-tung et al. (1993). In defining variables, I refer to the classification scheme and the definitions given in Hsueh Tien-tung et al. (1993). My definition of variables is as follows:

1. *Output per worker (Y / L)*

   Gross Domestic Product (v1f) deflated by the Retail Price Index (v12a) rebased to 1978=100, divided by Total Employed Labor Force of Society (v5a).

2. *Investment rate (I / Y)*

   Total Investment in Fixed Assets (v2b) divided by Gross Domestic Product (v1f), averaged for 1978-1989 (Table A1) and other specified time periods (Table A2).

3. *Saving rate (S/Y)*

   Total saving (S) is calculated as a residuum. The first step is to calculate net exports (NETEX) as Gross Domestic Product (v1f) minus Total Investment in Fixed Assets (v2b) minus Total Consumption (v3a) minus Public Expenditures of Local Governments (v4a2). The second step is to calculate total saving (S) as net exports (NETEX) plus Total Investment in Fixed Assets (v2b). The saving rate is total saving (S) divided by Gross Domestic Product (v1f). The saving rate is averaged for 1978-1989 and other specified time periods (Table A2).

4. *Labor force growth (n)*

Labor force growth in 1978-1989 is calculated as the growth rate of Total Employed Labor Force of Society (v5a) according to $\ln\left[\left(v5a_{1989} / v5a_{1978}\right)\right] / 11$.

5. *Investment in human capital (SCHOOL)*

Student Enrollment in Secondary School (v13c2) divided by Total Population (v6a), averaged for 1978-1989. For Beijing, the entry has been estimated according to a regression of $\ln(SCHOOL)$ on $\ln(Y / L)$.

6. *Stock of human capital (PUBL)*

Newspapers, Magazines and Books Published (v14c) divided by Total Employed Labor Force of Society (v5a). The entry for Qinghai has been revised due to an obvious data error in Hsueh Tien-tung et al. (1993). The entry for 1989 (v14c) is 5.5480 (p. 501); I use 0.5548 instead.

Table A1 — Basic Data for the Regression Analyses

	Output per worker (Y/L)		n	I/Y	School	PUBL
	1989	1978	Averages for 1978-1989			1989
	(1978 Rmb)	(1978 Rmb)	(percent)	(percent)	(percent)	(10,000 copies)
Anhui	1054	603	3.5	21.6	4.7	24.596
Bejing	3259	2450	2.9	26.9	9.2	98.775
Fujian	1377	723	3.2	24.2	4.3	42.707
Gansu	1085	933	3.6	24.0	5.1	29.737
Guangdong	1577	812	2.9	24.9	4.7	61.568
Guangxi	735	522	3.1	25.2	3.8	24.976
Guizhou	736	442	3.6	22.4	0.1	21.411
Hainan	1119	670	2.8	29.0	5.2	23.826
Hebei	1325	868	3.0	28.2	5.3	26.640
Heilongjiang	2069	1731	3.0	26.6	7.2	69.519
Henan	1081	580	3.2	24.0	5.6	27.543
Hubei	1504	791	2.2	21.5	5.9	38.607
Hunan	877	645	2.8	21.2	5.2	28.272
Inner Mongolia	1450	859	3.0	29.6	6.3	28.892
Jiangsu	1617	897	2.5	13.8	5.0	35.338
Jiangxi	997	694	3.1	18.4	4.9	31.703
Jilin	1519	1270	5.1	24.2	7.3	42.254
Liaoning	2373	1780	3.6	26.8	6.7	60.814
Ningxia	1395	913	3.7	35.4	6.2	31.328
Qinghai	1500	1074	3.0	46.1	5.6	27.629
Shaanxi	1107	754	3.2	27.9	6.0	31.393
Shandong	1806	771	2.6	27.0	5.1	27.690
Shanghai	4268	3919	0.8	23.4	5.7	275.772
Shanxi	1354	912	2.7	34.3	6.6	51.027
Sichuan	834	546	2.8	21.7	4.3	28.692
Tianjin	3129	2322	2.3	26.7	6.4	112.826
Xinjiang	1945	785	1.7	36.4	7.2	32.888
Yunnan	854	526	3.3	24.9	3.3	18.398
Zhejiang	1381	683	3.1	22.0	4.5	35.871

Source: Hsueh Tien-tung et al. (1993); own computations.

Table A2 — Average Saving and Investment Rates

	Average saving rates (percent)				Average investment rates (percent)[a]		
	1978-1983	1984-1989	1980-1989	1978-1989	1978-1983	1984-1989	1980-1989
Anhui	23.86	29.40	27.18	NA	15.76	25.58	21.65
Bejing	47.35	45.96	46.82	46.65	22.09	31.76	28.03
Fujian	18.63	20.61	19.95	NA	19.85	26.39	24.21
Gansu	24.56	16.38	19.65	NA	19.40	27.05	23.99
Guangdong	27.68	34.55	31.89	31.12	19.27	30.62	27.10
Guangxi	NA	12.05	NA	NA	NA	25.16	NA
Guizhou	-1.32	8.99	5.55	NA	21.06	23.00	22.36
Hainan	NA	30.01	28.43	NA	NA	31.19	28.98
Hebei	37.06	34.69	35.48	NA	27.09	28.74	28.19
Heilongjiang	34.99	29.76	32.10	32.14	21.34	31.06	27.75
Henan	31.42	35.64	34.23	NA	19.33	26.36	24.01
Hubei	33.81	30.31	32.05	32.06	18.93	24.04	21.89
Hunan	24.91	26.95	26.27	NA	18.28	22.62	21.18
Inner Mongolia	NA	4.21	3.27	NA	NA	30.81	29.56
Jiangsu	41.57	44.69	43.50	43.13	10.09	17.45	14.76
Jiangxi	17.00	24.62	21.57	NA	14.52	21.01	18.41
Jilin	15.75	17.77	17.09	16.76	21.11	27.26	24.67
Liaoning	38.78	38.17	38.37	NA	22.04	29.21	26.82
Ningxia	-5.40	1.30	-0.77	-2.05	28.22	42.59	36.01
Qinghai	NA	6.13	NA	NA	NA	46.13	NA
Shaanxi	15.74	19.44	17.30	17.59	25.01	30.69	28.69
Shandong	31.42	40.65	37.22	36.04	22.43	31.48	28.11
Shanghai	69.08	56.76	61.77	62.92	16.13	30.76	25.87
Shanxi	31.97	33.10	32.72	NA	25.48	38.70	34.29
Sichuan	NA	23.32	23.93	NA	NA	23.51	21.66
Tianjin	45.20	43.17	43.75	44.10	24.43	28.55	26.81
Xinjiang	-4.64	10.31	7.24	4.33	34.79	37.55	36.75
Yunnan	6.35	8.46	8.16	7.61	22.01	26.82	25.23
Zhejiang	34.04	39.69	38.28	36.87	17.83	26.22	22.87

[a]For average investment rates 1978-1989, see Table A1.

Source: Hsueh Tien-tung et al. (1993); own computations.

References

Barro, Robert J., Xavier Sala-i-Martin (1992), Convergence. Journal of Political Economy, 100: 223-251.

Barro, Robert J., N. Gregory Mankiw, Xavier Sala-i-Martin (1995), Capital Mobility in Neoclassical Models of Economic Growth. American Economic Review, 85:103-115.

Feldstein, Martin, Charles Horioka (1980), Domestic Saving and International Capital Flows. Economic Journal, 90: 314-329.

Feldstein, Martin (1994), Tax Policy and International Capital Flows. Kiel Institute of World Economics, Bernhard-Harms-Lectures, 16.

Friedman, Milton (1992), Do Old Fallacies Ever Die? Journal of Economic Literature, 30: 2129-32.

Gundlach, Erich (1995), The Role of Human Capital in Economic Growth: New Results and Alternative Interpretations. Weltwirtschaftliches Archiv, 131: 383-402.

Hsueh Tien-tung, Li Qiang, Lin Shucheng (eds.) (1993), China's Provincial Statistics 1949-1989. Boulder.

Hsueh Tien-tung (1994), Pattern of Regional Development in the People's Republic of China. Asian Economic Journal, 8: 1-38.

Jefferson, Gary H., Thomas G. Rawski, Yuxin Zheng (1992), Growth, Efficiency, and Convergence in China's State and Collective Industry. Economic Development and Cultural Change, 40: 239-266.

Maddala, G.S. (1992), Introduction to Econometrics. 2nd ed. New York.

Maddison, Angus (1987), Growth and Slowdown in Advanced Capitalist Economies. Journal of Economic Literature, 25: 649-698.

Mankiw, N. Gregory, David Romer, David N. Weil (1992), A Contribution to the Empirics of Growth. Quarterly Journal of Economics, 107: 408-437.

Mankiw, N. Gregory (1995), The Growth of Nations. Brookings Papers on Economic Activity, (1): 275-326.

Raiser, Martin (1995), Decentralisation, Autonomy and Efficiency: Inconsistent Reforms and Enterprise Performance in China. Kiel Institute of World Economics, Working Papers, 689.

Sinn, Stefan (1992), Saving-Investment Correlations and Capital Mobility: On the Evidence from Annual Data. Economic Journal, 102: 1162-1170.

Solow, Robert (1956), A Contribution to the Theory of Economic Growth. Quarterly Journal of Economics, 70: 65-94.

World Bank (1994), China. Internal Market Development and Regulation. Washington, DC.

World Bank (1995), World Development Report 1995. World Development Indicators. Oxford.

Young, Alwyn (1995), The Tyranny of Numbers: Confronting the Statistical Realities of the East Asian Growth Experience. Quarterly Journal of Economics, 110: 641-680.