Economic Growth and Convergence in China's Provinces:

Theory and Evidence

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Abstract

This paper uses both cross-sectional and panel data on Chinese provinces over the reform period 1978-1998 to examine the pattern of China's regional economic growth on the basis of a theoretical model on convergence. We find a tendency to converge in terms of real GDP per capita both unconditionally and unconditionally. In addition, the cross-section regression supports the hypothesis that the growth rates of real GDP per capita are higher in provinces with greater openness to foreign countries, lower level of agricultural activity and higher investment in human capital.

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Key words: China: economic growth: Convergence: panel data analysis: fixed and random effects

1. Introduction

It is now well acknowledged that the rate of economic growth in China since 1978 has been rapid by any standard in the last two decades. Since China is a large country, it is interesting to ask whether the fast economic growth has been equal across Chinese provinces. In accord with the recent neo-classical growth theory, rapid economic growth rate at the national level should lead to regional convergence. Problems of regional income inequalities have been a major topic of discussion in the current literature on economic growth. A clear understanding of the factors that help or hinder the process of convergence or the reduction of regional inequalities has serious implications not only for economic policy but also for the extension of the reforms that China introduced in 1978. Such an analysis of factors yielding convergence in Chinese provinces, as witnessed in the USA or Japan (see Barro and Sala-i-Martin, 1995), provides the main motivation for writing this paper.

A recent critical review of the literature concludes that the effect of inequality on growth is rather inconclusive (Xu, 2000). Some argue, on the basis of empirical evidence that greater equality in income distribution does not guarantee a higher rate of growth (Galor and Zeira, 1993). Others, like Perroti (1996), argue that inequality can affect growth positively through its impact on fertility. It is further argued that greater equality can lead to greater human capital accumulation and higher rate of growth (Alesina and Rodrik, 1994; Chiu, 1998; Clarke, 1995; Persson and Tabellini, 1994). Some point out that higher inequality by lightening the socio-political tensions, can harm the process of economic growth (Benabou, 1996) It is, of course, possible to understand such arguments and their relevance to China which experienced the existence of large scale regional income disparities in history.

Current studies on China mainly focus on inequalities between coastal and non-coastal regions, between rural and urban Chinese households (see Hussain, 1994; Lippit, 1987; Knight and Song, 1993; Li and Zhao, 1999; Jian, Sachs and Warner, 1996; Gundlach, 1997; Raiser, 1998; Tsui, 1996). Most of these writers analyse the changes in regional/household inequalities by analysing the indicator like the Gini coefficient. A few have also tried to measure the changes by examining the Theil index of inequality and the coefficient of variation (for a good summary, see Wu, 2000). Li, Liu and Rebelo (1998) and Chen and Fleisher (1996) tried to test a model of neo-classical economic growth as illustrated by Mankiw et al (1992) or Islam (1995). Given the inconclusive results of these studies, we have another strong motivation for writing this paper. Here at first, we develop a simple theoretical growth model to analyse convergence. The next section deals with empirical specification of the model and the results. Section 4 concludes and provides policy recommendations.

2. A theoretical model of convergence

A theoretical model of spatial convergence in per capita output can be developed from the neo-classical model of growth as developed by Solow (1956) and Koopman (1965). Following Barro et al (1995), the production function in intensive form can be written as

Y=minAF[K, L] (1) or

$$\hat{y} = f(\hat{k}) \Rightarrow f'(k) > 0, f''(\hat{k}) < 0 \quad (2)$$

where $\hat{y}$ =Y/L and $\hat{k}$ =K/L, K is capital and L is units of effective labour. There are two exogenous sources of growth in effective labour units: the rate of technical progress, x, and the rate of growth of working population, n. Hence, we have

$$L=Ne^{xt}=N_0e^{(n+x)t} \quad (3)$$

With a closed economy and without a government sector, the rate of investment is equal to the rate of saving which is Y-C, where Y is income and C is consumption. Thus,

$$\dot{K} + \delta K = Y - C \quad (4)$$

where δ is depreciation. The capital accumulation growth path then is

$$\dot{\hat{k}} = f(\hat{k}) - \hat{c} - (\delta + n + x)\hat{k} \quad (5)$$

where $\hat{c}$ =C/L. The representative household maximises utility by

$$U=u(c),\ u'(c)>0,\ u''(c)<0 \quad (6)$$

where c=C/N.

Total social utility in each period is weighted by the size of population and the rate of time preference, ρ, in each period. Thus, social utility is maximised by adding social utility over all future period.

$$u = \int_0^\infty u(c)^{-(\rho-n)t} dt \qquad (7)$$

The optimal growth path is then to maximise the above equation subject to the capital accumulation growth path. The current value Hamiltonian is

$$H = u(c) + m[f(\hat{k}) - \hat{c} - (\delta + n + x)\hat{k}] \qquad (8)$$

The maximum principle requires

$$\frac{\partial H}{\partial c} = u'(c) - m = 0 \qquad (9)$$

$$\frac{\partial H}{\partial m} = f(\hat{k}) - \hat{c} - (\delta + n + x)\hat{k} = \dot{\hat{k}} \qquad (10)$$

$$\frac{\partial H}{\partial k} = m[f'(\hat{k}) - (\delta + n + x)] - (\rho - n)m = -\dot{m} \qquad (11)$$

Differentiate equation (9) with respect to time

$$u''(c)\dot{c} = \dot{m} \qquad (12)$$

Use equations (7) and (10) to get rid of m and $\dot{m}$ in equation (11).

$$\dot{c} = \frac{u'(x)}{u''(x)}[f'(\hat{k}) - (\delta + x + \rho)] \qquad (13)$$

$$\dot{\hat{k}} = f(\hat{k}) - \hat{c} - (\delta + n + x)\hat{k} \qquad (14)$$

The above equation can be linearised using Taylor expansion theorem. But the characteristic roots cannot be compared unless special functional forms are assumed for u(c) and f(k).

Following Barro et al (1995), the utility function takes the form

$$u(c) = \frac{c^{1-\theta} - 1}{1-\theta} \qquad (15)$$

Since u'(c)=c$^{-\theta}$ and u''(c)=-θc, equation (14) and (13) become

$$\dot{c} = \frac{c}{\theta}[f'(k) - (\delta + x + r)] \qquad (16)$$

Check that equation (15) is given by

$$\dot{\hat{k}} = f(\hat{k}) - \hat{c} - (\delta + n + x)\hat{k} \qquad (14)$$

and

$$\dot{c} = \frac{u'(x)}{u''(x)}[f'(\hat{k}) - (\delta + x + \rho)] \qquad (13)$$

Equations (14) and (16) provide the steady state growth paths for k and c. In the steady state, y, k, and c grow at the rate of x. To show the stability of the model, we can linearise in the zone of steady state equilibrium ($\bar{c}, \bar{k}$). This yields

$$\begin{bmatrix} \dot{k} \\ \dot{c} \end{bmatrix} = \begin{bmatrix} \psi & -1 \\ \frac{c}{\theta} f'(k) & 0 \end{bmatrix} \begin{bmatrix} k & -\bar{k} \\ c & -\bar{c} \end{bmatrix} \qquad (17)$$

where ψ=ρ-n-(1-θ)x

which is regarded as positive and in the steady state

$f'(k)=\delta+\rho+(1+\theta)x$.

Thus the last term in the 2×2 matrix is zero. The system shows saddle path stability because the trace and determinants of A are positive and negative respectively, i.e.,

$Tr(A)=\psi>0$

$$Det(A)=-(c/\theta)f'(k)<0 \qquad (18)$$

The stable root, β, is given by

$\beta=-Tr(A)+\{Tr(A)^2-4Det(A)\}^{1/2}$

given a Cobb-Douglas (CD) production function, i.e.,

$\hat{y}=f(\hat{k})=A\hat{k}^{\alpha}$

This yields

$$\beta=\frac{1}{2}\{\psi^2+4(\frac{1-\alpha}{\theta})(\rho+\delta+\theta x)[\frac{\rho+\delta+\theta x}{\alpha}-(n+\delta+x)]\}^{1/2}-\frac{\psi}{2} \qquad (19)$$

Note with CDPF, the dynamic time paths of y and k are identical. Hence, in discrete time, the solution for $\log[\hat{y}(t)]$ is

$$\log[y(t)]=\log[y(0)e^{-\beta t}+\log(\bar{y})(1-e^{-\beta t}) \qquad (20)$$

The greater the value of β, the greater the responsiveness of the average growth rate to the gap between $\log(\bar{y})$, long run equilibrium level, and the initial level of income, i.e., log[y(0)]. The model implies conditional convergence in that for given values of x and $\bar{y}$. The growth rate is higher the lower is log[y(0)].

For empirical estimation, we follow

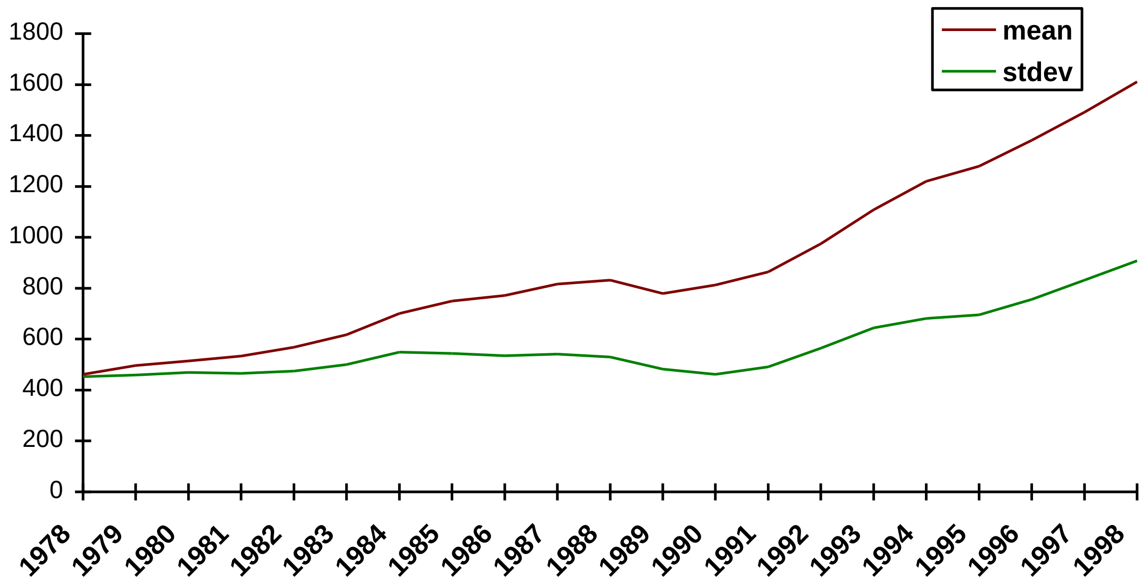
$$\log(\frac{y_{it_0+T}}{y_{it_0}})=\theta-(1-e^{-\beta t})\log(y_{it_0})+u_{i,t_0,t_{0+T}} \qquad (21)$$

where $\theta=x+[(1-e^{-\beta t})][\log(\bar{y})+xt_0]$, $u_{i,t0,t0+T}$ is the error term and i is regions. The coefficient on $\log(y_{it0})$ in Equation (21) falls as T rises, for a given β.

3 Empirical specification and results

In this paper, we are mainly concerned with the movement of the provincial real GDP per capita between 1978 and 1998. Figure 1 shows that the national mean real GDP per capita has increased sharply from 462.12 Chinese Yuan in 1978 to 1610.72 Yuan in 1998 and its standard deviation has remained fairly constant during 1978-1989, though it has been increasing since 1990. Here, we should not ignore the impact of structural change as the standard deviation indicates an increase in the dispersion of real GDP per capita across provinces over time. We divide the whole period, 1978-1998 under two sub-periods, 1978-1989 and 1990-1998, to see the nature of structural change over time.

Figure 1 Mean and standard deviation of Chinese provincial real GDP per capita over 1978-1998



We now consider whether the Chinese data support the prediction about convergence of the theoretical model of the previous section. On the basis of large homogeneity across Chinese economies, we expect convergence of real GDP per capita in the long run. However, in the short run, there could be forces working either on convergence or divergence. After the introduction of market reforms in 1978, the first significant changes were observed in the rural areas. By 1985, the commune system was completely dismantled and the Household Responsibility System was implemented. These changes mainly resulted in a dramatic increase in farmers' income across the country. We expect convergence in terms of real GDP per capita in the sub-period of 1978-1989. After 1985 the pace of agricultural productivity improvement slowed markedly as if the one-shot gains to agricultural reforms had been reaped. Meanwhile, the Chinese economy was opened for trade and foreign direct investment gradually. By 1990, provinces with a coastline benefited greatly from openness. Even if China had been open completely, the inland provinces would have not attracted much foreign trade and direct investment due to their geographical disadvantages. Hence we expect a divergence in terms of relative GDP per capita across provinces in the second sub-period of 1990-1998.

To test our hypotheses about convergence, we use the specifications derived from the previous section. Equation (22) implies the test for unconditional convergence while equation (23) specifies the conditional convergence. Basically equation (22) is imposed a restriction that there are no differences in preference, technology and steady states. In equation (23) some variables are included to control for the differences in preference and technology and hence in steady states. The empirical models for the estimation at a given time are thus

$$Y_{i,t0+T}-Y_{i,t0}=a+b_0Y_{i,t0}+v_{it} \qquad (22)$$

and

$$Y_{i,t0+T}-Y_{i,t0}=a+b_0Y_{i,t0}+b_1TRADE_{it}+b_2AGRI_{it}+b_3HC_{it}+v_{it} \qquad (23)$$

where T= number of years in the period and i = 1, 2, ..., and 30 provinces. And *a* and

b_0, b_1, b_2 and b_3 are the parameters to be estimated. As usual, $b_0 < 0$ is a necessary, although as Bernard and Durlauf (1991) have shown, but not a sufficient condition for convergence.

The dependent variable is the difference in natural logarithm of real GDP per capita relative to national mean between the beginning and end years in the period. $Y_{i,t0}$ on the right-hand side is the natural logarithm of provincial real GDP per capita relative to national mean of the beginning year in each period under study. This specification looks at deviations from national mean and thus investigates convergence between provinces[1].

The model considers three other explanatory variables, which are expected to control for the differences in preference, technology and steady states. The inclusion of the variables will be justified later in the study. These variables are demeaned before estimation for the purpose of removing some of the correlations that may exist across the error terms (see Lee, Pesaran and Smith, 1997). TRADE is the difference between natural logarithms of the provincial and national ratio of trade value to GDP at current price, averaged over each period. Similarly, AGRI is the difference between natural logarithms of provincial and national average percentage of GDP that is produced by agricultural sector. Because of data constraints, the literature has often attempted to proxy the variables relevant to growth estimation by those that are directly observable. For example, although human capital stocks are necessary to estimate the growth equations, the literature has usually used enrolment rates as a proxy for human capital accumulation. To be compatible to the previous studies, the final explanatory variable in our growth equation is a proxy for the ratio of human capital investment to GDP. We use the difference between natural logarithms of provincial and national

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[1] Barro and Sala-i-Martin's (1992) specification looks at deviations from sectional means and thus examines convergence within sections rather than strictly convergence between sections. In other words, they investigate convergence to a section's own steady state.

percentage of working-age population that is enrolled in secondary schools. This variable is averaged over time too.

In this study we carry out the estimation by the conventional methodology on convergence, the single cross-sectional regression, and the estimation results are compared with those derived by the panel data analysis and seemingly unrelated regression.

The single cross-province regression works on variables averaged over the whole period. Dividing the whole period of study into several shorter time spans and hence having more data points for each province derives a panel data framework. But what is the appropriate length of such time spans? Chen and Fleisher (1996) consider time spans of just one year, which is technically feasible given that the underlying data set provides annual data.

However, for several reasons it seems that yearly time spans are too short to be appropriate for studying growth process. First, short-term disturbances may loom large in such brief time spans. Secondly, the theory underlying this study relates to long-run growth, and the precise timing between growth and its determinants, regressors in the investigation of conditional convergence in our case, is not well specified at the high frequency. Relationships at the annual frequency could be dominated by mistiming and hence measurement error. These conditions suggest a focus on the determination of growth rates over fairly long intervals.

Following Knight, Loayza and Villanueva (1993) and Islam (1995), we work with regular non-overlapping interval of five years in the study. We break up the entire period 1978-1998 into four non-overlapping sub-periods, 1978-1982, 1983-1987, 1988-1992 and 1993-1998. On the one hand, a period of five years (T=4) is more appropriate than an interval of a year for the study on growth. On the other hand, we have four data (time) points for each province. With this set-up, the v_{it}'s are now five calendar year apart and hence may be thought to be less influenced by business cycle fluctuations and less likely to be serially correlated than they would be in a yearly data set-up.

The growth equation for the panel data analysis is

$$Y_{i,t0+T}-Y_{i,t0}=a_0+b_0Y_{i,t0}+u_i+v_{i,t}$$

$$i=1,2,...30 \text{ and } t=1,2,3,4 \qquad (24)$$

where all the symbols are already defined except u_i which represents the joint effect of all omitted time-invariant province-specific variables, and v_{it} which represents a classical disturbance term for minor omitted variables, random shocks and measurement error. In this study we use data to provide guidance on the choice between the fixed-effect and random-effect models.

3.1 Estimation results on unconditional convergence

Table 1 Estimates of the growth model ()

	1978-1998		1978-1989		1990-1998	
	Cross-section	Random effect	Cross-section	SURE	Cross-section	SURE
Constant	-0.259	-0.056	-0.152	-0.151	0.848	-0.717
	(-2.013)	(-2.042)	(-2.463)	(-2.586)	(0.097)	(-0.853)
Y_{it0}	-0.338	-0.087	-0.2398	-0.238	0.037	-0.0635
	(-3.064)	(-3.312)	(-4.522)	(-4.789)	(0.378)	(-0.686)
Implied λ	0.0206	0.023	0.0249	0.0247		0.158
Obs.	30	120	30	30	30	30
R^2	0.25	0.09	0.42	0.42	0.005	0
Hausman Test		$\chi^2(1)=3.703$				

Note: Values in the bracket are t-ratios.

Y_{it0} = natural logarithm of provincial real GDP per worker relate to national mean of the beginning year, for instance, 1978 for cross-section regression and 1978, 1983, 1988 and 1993 for random effect model and SURE

Our regression results for the whole period, 1978-1998, by the single cross-province regression and panel data analysis are presented in columns 2 and 3 of Table 1. An unconditional convergence is observed because the coefficient on the initial level of relative GDP per capita, y_{t0}, is negative and statistically significant by both methods.

According to the single cross-province regression over 1978-1998, provinces with lower initial levels of relative GDP per capita tend to grow 0.338 percent faster than rich ones. Given that $T=20$ from 1978 to 1998, the implied value of the rate of convergence is 0.0206 from $-(1-e^{-\lambda T})=-0.338$. Given that $\lambda=0.0206$, the time for an economy to move halfway to national steady state[2] is 34 years from the half-life formula, $t=\ln2/\lambda$. These results indicate that 2.06 percent of the gap in the levels of income between poor and rich provinces vanishes in a year if their steady states are identical and it will take 34 years for the provinces to move halfway to national steady state.

This unconditional convergence was also shown to exist across US states, Japanese prefectures and European regions. (Barro and Sala-i-Martin, 1991). Our estimated rate of absolute convergence[3], 0.0206, is slightly higher than the rate, 0.0167, estimated by Mankiw, Romer and Weil (1992) for 22 OECD countries over 1960-1985. It can be justified by the fact that Chinese regional economies are more homogeneous than the OECD countries. Factors of production are more mobile between Chinese provinces and such mobility tends to equalise the capital-labour ratios and thereby per capita income more quickly across provinces.

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[2] Or it is interpreted as the time for half the initial gap to be eliminated.

[3] We are unable to compare the rates of absolute convergence among the studies on China. Jian, Sachs and Warner (1996) do not estimate the rate of absolute convergence while Chen and Fleisher (1996) do not observe any absolute convergence across provinces.

The investigation of unconditional convergence requires a restrictive assumption that there is no difference in preference, technology and steady state across provinces. Econometric techniques of a panel data analysis could slightly relax this restriction as it takes province-specific effects into consideration. In this study, Hausman test yields a statistic of 3.703, which is Chi-squares distributed with degree of freedom equal to one. This means that we cannot reject the null hypothesis that province-specific effects are not correlated with the regressor included in the model. Under the null hypothesis of no correlation, both fixed and random effect models are consistent, but the former is less efficient. Thus our discussion below will focus on the results of the random effect model.

The results of the random effect model, presented in column 3 of Table 1, are consistent with those derived by the single cross-province regression. There is an absolute convergence because the coefficient on the initial levels of real relative GDP per capita is negative and significant. Provinces with lower initial levels of relative GDP per capita tend to grow 0.087 percent faster than rich ones. On the basis of $-(1-e^{-\lambda T})=-0.087$ and T=4, the estimated value for the speed of convergence is 0.028. It implies that 2.28 percent of the gap of initial levels of real relative GDP per capita between the rich and the poor vanishes in a year if their steady states are identical. And it will take 30.46 years (t=ln2/0.0228) for an economy to move halfway to national steady state. The estimate that it will take 30.46 years for an economy to move halfway to national steady state is quite close to that (33.65 years) estimated by the single cross-province regression earlier.

As the standard deviation of real GDP per capita shows the impact of structural changes, we like to see if there is a difference in the tendency of convergence between the sub-periods. Estimation results for sub-periods by the single cross-province regression are reported in columns 4 and 6. During 1978-1989, we find an unconditional convergence across Chinese provinces and provinces with lower initial levels of relative GDP per capita tend to grow 0.239 percent faster than the rich ones. The estimated speed of convergence is 0.0249 on the basis of $-(1-e^{-\lambda T})=-0.2398$ and T=11. It implies that 2.49 percent of the gap of initial levels of real relative GDP per capita between the rich and the poor vanishes in a year and it will take 27.81 years (t=ln2/0.0249) for an economy to move halfway to national steady state. However, during 1990-1998, it is not evident that there is any tendency of unconditional convergence across Chinese provinces, as the coefficient on initial level of real relative GDP per capita is positive and statistically insignificant.

To see the robustness of the results for the sub-periods, we apply the seemingly unrelated regression (SURE). Basically we estimate a multivariate regression system with as many regressions as sub-periods on the basis of the assumption that the disturbances are correlated between sub-periods. The disturbances in the equations could certainly include factors that are common to all sub-periods as well as factors that are specific to a particular sub-period. Under this assumption, the efficient estimator is generalised least squares . Results by SURE are reported in columns 5 and 7 and they are consistent with the findings based on the single cross-province regression.

The tendency to converge at a relatively high rate during 1978-1989 could be explained by the fact that Chinese provincial economies departed greatly from their steady states during the Cultural Revolution, which is a period immediately before 1978-1989. The slower speed of convergence during the whole period 1978-1998 can be explained by the dilution effect of divergence during the second sub-period on the general tendency of the whole period. The absence of unconditional convergence during the second period supports our expectation that the unbalanced openness across provinces leads to differences in preference and technology.

3.2 Results on conditional convergence

This section examines the effect of dropping the restriction that there is no difference in preference, technology and steady state across provinces and hence permits analysis of structural differences in the economies. To control for the difference in preference, technology and steady state, TRADE, AGRI and HC are included. TRADE is included under assumption that the higher degree of integration with the world market, the higher the level of technology. Provinces with more exports and imports could have used their resources more efficiently and imitated better foreign advanced technology.

AGRI is included to allow for the differing composition of economic activities within Chinese provinces. Literature on economic development has long assumed that different components of economic activities have different levels of technology (see Ghatak, 1995). Thus provinces with higher percentage of GDP by agriculture are expected to have lower level of technology.

HC is included on the ground that education and knowledge accumulation boosts output growth rate.

Table 2 Estimates of the Growth equation ()

	1978-1998		1978-1989		1990-1998	
	cross-province	Fixed-effect	Cross-province	SURE	cross-province	SURE
Constant	-0.938		-0.358	0.452	-0.278	0.266
	(-3.47)		(2.136)	(53.588)	(1.066)	(23.234)
Y_{it0}	-1.123	-0.24	-0.486	0.25	-0.4	0.196
	(-4.710)	(-3.708)	(-3.152)	(27.059)	(-1.341)	(12.225)
TRADE	0.354	-0.025	0.102	0.045	0.18	0.181
	(5.58)	(-0.0199)	(2.818)	(8.1)	(2.623)	(21.898)
AGRI	-0.412	-0.18	-0.118	0.497	-0.126	0.341
	(-1.861)	(-2.587)	(-0.925)	(96.059)	(-0.591)	(46.587)
HC	0.291	-0.066	0.149	0.209	0.182	0.283
	(2.534)	(-1.1)	(2.509)	(22.836)	(1.306)	(17.565)
Implied λ		0.0686	0.0605		0.064	
Adj R^2	0.66	0.42	0.55	0.98	0.13	1
Obs.	30	120	30	30	30	30
Hausman test		$\chi^2(4)=25.87$				

Note: Values in the bracket are t-ratios.

Y_{it0} = natural logarithm of provincial real GDP per worker relative to national mean of the beginning year, for instance, 1978, 1978 and 1990 for 1978-1998, 1978-1989 and 1990-1998 cross-section regression and SURE respectively and 1978, 1983, 1988 and 1993 for fixed-effect model

TRADE = difference in natural logarithms of the provincial and national ratio of imports and exports to GDP over each period for cross-section regression and SURE and over 1978-1982, 1983-1987, 1988-1992 and 1993-1998 for fixed-effect model

AGRI = difference in natural logarithms of the provincial and national average percentage of GDP that is produced by agriculture over each period for cross-section regression and SURE and over 1978-1982, 1983-1987, 1988-1992 and 1993-1998 for fixed-effect model

HC = difference in natural logarithms of provincial and national secondary school enrolment rates averaged over each period for cross-section regression and SURE and over 1978-1982, 1983-1987, 1988-1992 and 1993-1998 for fixed-effect model

Once the variables are controlled, the absolute value of the coefficient on the initial level of income is increased and the fit of the regression is improved. It shows that if economies did not vary in the degree of integration with world market, components of economic activities and their investment in human capital, there would have been a stronger tendency for poor economies to grow faster than rich ones. Controlling for other variables, provinces with lower initial levels of real GDP per worker tend to grow 1.123 percentage point faster than rich ones.

The signs of the coefficients on the explanatory variables are correct although the coefficient on percentage of agriculture is statistically insignificant. The openness and human capital investment are positively and significantly related to the subsequent economic growth rates. Provinces with higher degree of integration with world market and human capital investment tend to grow, respectively, 0.354 and 0.291 percentage points faster than those with lower ratios.

Panel data analysis also shows that controlling for other variables, the tendency to converge is stronger. Conditionally, poor provinces will grow 0.24 percentage faster than rich ones. The speed of convergence is 6.86 percent and it will take about 10.1 years for the economies to eliminate half of the initial gap. This speed of convergence is not surprising. Knight, Loayza and Villanueva (1993) and Islam (1995) use the similar method but different conditional variables. Knight, Loayza and Villanueva

(1993) estimates that the speed of convergence is 6.26 percent for 98 countries including developing ones over 1960-1985. Islam (1995) estimates that the speed of convergence for 22 OECD countries that are more homogenous over the same period is 9.26 percent. Islam (1995) argues that the high speed of convergence is consistent with the prediction of the Solow-Cass-Koopmans model since an open economy version of the growth model predicts speedy convergence.

However, openness and human capital are insignificantly and negatively correlated with subsequent growth. Both Knight et al (1993) and Islam (1995) also find a negative correlation between human capital investment and the subsequent growth rates. In the panel data analysis, we use not only the cross-province differences in the relation between openness and growth and education and growth but also the effect of changes in openness and education over time in each province. The temporal relationship between growth and education has been negative[4] over the years and the negative temporal relationship is strong enough to outweigh the positive cross-province relationship. However, there is no negative temporal relationship between openness and growth over time in this case. The insignificant coefficient of openness indicates that openness may not be an appropriate variable to control for the difference in technology or preference.

By the single cross-province regression, the speed of convergence is enhanced for the sub-period of 1978-1989 while it is not evident that there is any conditional convergence across provinces during 1990-1998. SUR estimation does not support any conditional convergence at all.

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[4] While output growth increased steadily, secondary school enrolment rates fell over time due to the fact that compulsory family planning scheme has taken its effects.

4 Conclusion

This section has investigated empirically the pattern of China's economic growth over 1978-1998. It is evident that there is a tendency to converge in real GDP per capita relative to national mean across provinces unconditionally during 1978-1998. While there is an absolute convergence during 1978-1989, there is a tendency to diverge during 1990-1998. The findings are broadly supported regardless of the methods that we have used.

Conditional on openness, component of economic activities and human capital investment, the speed of convergence is faster over 1978-1998 and 1978-1989. This investigation is an improvement in terms of completeness and consistency in comparison with previous studies on China. For instance, Chen and Fleisher (1996) estimate the unconditional convergence by cross-sectional regression, which yields 77.3 years for a province to move half way to its steady state. They do not report the estimation results on unconditional convergence by the panel of yearly data over 1978-1993. On the other hand, they estimate that it will take the Chinese provinces 12.4 years to move half way to their steady state by the single cross-province regression but 44.4 years by the panel data analysis.

The advantage of our methodology for studying convergence is that it is derived from the neo-classical growth model. It also takes into account some variables which are regarded as important in the new growth theory. Thus this paper has not only examined whether there is a tendency to converge in relative GDP per capita across provinces, but also investigated the effects of openness, component of economic activities and human capital investment in the growth process of China over the reform period 1978-1998. As predicted by the model, growth rates of income per capita were higher in provinces with higher degree of openness and more investment in human capital.

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