Econometric Reviews
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713597248

Provincial Conditional Income Convergence in China, 1953-1997: A Panel Data Approach

Melvyn Weeks [a]; James Yudong Yao [a]
[a] Faculty of Economics and Politics, University of Cambridge, Cambridge, UK

Online publication date: 27 February 2003

To cite this Article Weeks, Melvyn and Yao, James Yudong(2003) 'Provincial Conditional Income Convergence in China, 1953-1997: A Panel Data Approach', Econometric Reviews, 22: 1, 59 — 77
To link to this Article: DOI: 10.1081/ETC-120017974
URL: http://dx.doi.org/10.1081/ETC-120017974

ECONOMETRIC REVIEWS
Vol. 22, No. 1, pp. 59–77, 2003

Provincial Conditional Income Convergence in China, 1953–1997: A Panel Data Approach

Melvyn Weeks* **and James Yudong Yao**

Faculty of Economics and Politics, University of Cambridge, Cambridge, UK

ABSTRACT

This paper examines the tendency towards income convergence among China's main provinces during the two periods: the pre-reform period 1953–1977 and the reform period 1978–1997 using the framework of the Solow growth model. The panel data method accounts for not only province-specific initial technology level but also the heterogeneity of the technological progress rate between the fast-growing coastal and interior provinces. Estimation problems of weak instruments and endogeneity are addressed by the use of a system generalized method of moments (GMM) estimator. The main empirical finding is that there is a system-wide income divergence during the reform period because the coastal provinces do not share a common technology progress rate with the interior provinces.

Key Words: Provincial convergence; China; Panel data; GMM estimators.

JEL Classification: O40; O41; O53; C14; H4.

1 INTRODUCTION

China's accelerated growth rate during the reform period 1978–1997 has reinforced concerns about how to cope with continued growth whilst maintaining balanced regional

*Correspondence: Melvyn Weeks, Faculty of Economics and Politics, University of Cambridge, Cambridge, UK; E-mail: melvyn.weeks@econ.cam.ac.uk.

DOI: 10.1081/ETC-120017974 0747-4938 (Print); 1532-4168 (Online)

www.dekker.com

income inequality.[a] In this paper we investigate the tendency towards income convergence across the provinces of China during both the pre-reform period 1953–1977 and the reform period 1978–1997.[b] The Chinese case is interesting for several reasons. First, in a recent paper Sala-i-Martin (2002) notes that the substantial increase in growth rates during the reform period had largely determined the observed decline in global income inequality. Therefore, since China is the most populous country in the world and displays vast geographical disparities in the resource base, living standards and other determinants of income growth, an interesting question is whether these changes have coincided with changes in income inequality *within* China. Second, China has been subject to two contrasting policy regimes since the establishment of the Peoples Republic of China in 1949. Before the reforms of 1978 China was a closed economy under centralized planning. In 1978 China adopted economic reforms and the open-door policy, and as a result has experienced spectacular growth rates, enabling per capita incomes to almost quadruple during the last twenty years. Finally, historical experience suggests that few countries have succeeded in maintaining political stability under conditions of severe income disparity. China's own history is full of uprisings, rebellions, and revolutions sparked by economic injustice. As such the extent of regional income inequality is of considerable interest as it bears directly on the sustainability of economic reform.

There have been three main studies on China's provincial income convergence using a so-called conditional convergence approach:[c] Jian, Sachs and Warner (1996), Chen and Fleisher (1996), and Raiser (1998). All studies have utilized the Solow growth model to examine income convergence. The study by Jian et al. (1996), using the cross-sectional approach, examines the convergence of GDP per capita across China's provinces[d] over the period 1952–1993, finding that real income convergence has been a relatively recent phenomenon, emerging strongly only since the reform period began in 1978. Chen and Fleisher (1996) also use the cross-sectional method finding evidence of both unconditional and conditional convergence of per capita income from 1978 to 1993. An estimated unconditional convergence speed of 0.9% per year implies that it would take 77.3 years to eliminate half of the gap in 1978. The conditional convergence speed (conditional on physical investment share, employment growth, human-capital investment, foreign direct investment and coastal location) is estimated to be 5.7% per year. This is considerably higher than the figure of 2% per year which is a relatively robust result from a number of *cross-region* studies [for example, Sala-i-Martin (1996), and Mankiw et al. (1992)—hereafter MRW]. A recent study by Raiser (1998) test both unconditional and conditional convergence using both a cross-sectional and a static panel data model during the reform

[a]This paper only focuses on the mainland China, and thereby excludes Hong Kong, Maco, and Taiwan.

[b]Inter-provincial income inequality is one of many important dimensions of income inequality. Of these various dimensions, individual, rural–urban and inter-provincial inequality have aroused the most concern in China during the reform period.

[c]Other approaches include the dynamic income distribution approach (including σ-convergence — see Friedman, (1992)), explores the time-series properties of the cross-economy variance of the logarithm of per capita income. Quah (1993) advocates the use of a Markov transition matrix to examine the evolution of income distribution over time, with a particular focus on intra-distribution mobility.

[d]For the pre-reform period GDP data is available for only 15 provinces.

period 1978–1992. He confirms previous findings that the speed of the convergence falls over the course of economic reforms, with estimated convergence rates ranging from 0.8% to 4.2% per year for various sub-periods. Overall, these studies suggest that there is no obvious convergence during the pre-reform period, with some consensus regarding conditional convergence during the reform period.

The present study represents a significant contribution in a number of important aspects. First, there are two principal sources of bias in previous cross-sectional studies: unobserved province-specific heterogeneity in initial technology levels and endogenous explanatory variables. In particular, previous cross-sectional studies have assumed a homogeneous aggregate production function across provinces and in doing so ignore the problem of heterogeneity in initial technology levels. This has considerable implications with regards the estimation of unbiased convergence rates. The problem of potential endogeneity of right-hand-side variables such as the investment rate is also neglected. By utilizing both cross-sectional and time series variability, the panel data approach is seen as a promising alternative. In this study, we use a first differenced system generalized method of moments estimator system (GMM) which allows us to eliminate unobserved country-specific initial technology effects and correct for endogeneity.

Furthermore, previous cross-sectional studies have paid scant attention to the problem of heterogeneity in the technology progress rates among subgroups of provinces, and thereby incur a significant risk of misinterpreting the results. There are three possible sources of heterogeneity between the coastal and interior provinces: (1) the initial technology level; (2) the technology progress rate; and (3) the steady state income level, i.e. the investment rate and population growth rate. Within the confines of a cross-sectional study it is not possible to identify the precise source of this heterogeneity, and thereby differentiate between a number of very different scenarios. For example, if it were possible to conclude that there is heterogeneity in the technology progress rate across provinces, this would imply a system-wide income divergence. Using a panel data approach we are able to distinguish between different sources of heterogeneity between the subgroups of the provinces in an explicit way.

Finally, this study uses a more recent, extensive and reliable data source, namely the recently-released Hsueh and Li (1999) National Income (NI) data set with new province-level GDP measures, spanning 45 years from 1952 to 1995. Province-level GDP and investment deflators are available in the Hsueh–Li data set thereby facilitating the comparison of provisional incomes over the pre and post reform period.

This paper is organized as follows. In Section 2, we examine the characteristics of the Chinese statistical reporting system, pre and post reform, highlighting the nature of the data used in this study relative to previous studies. In Section 3, we motivate the ensuing analysis by presenting a brief graphical overview of the relative growth paths of China's provinces over the period 1952–1995. Section 4 presents an overview of the Solow neoclassical growth model, in conjunction with a brief review of the existing panel data literature as it relates to testing for income convergence.[e] An extended GMM estimator is introduced in conjunction with the problem of weak instruments. Section 5 contains the empirical results and Section 6 concludes.

[e]In an earlier version of this paper, we also present results of an application of Barro type growth regressions to China province level data. See Weeks and Yao (2000).

2 THE CHINESE STATISTICAL REPORTING SYSTEM: PRE AND POST REFORM

Since the adoption of the comprehensive reform policy in 1978, China's statistical system has followed the reform wave. Starting from 1985, the state statistical bureau (SSB) has received financial aid from both the World Bank and the Asian Development Bank towards the costs of improving the national income accounts system.[f]

The Chinese statistical reporting system is organized within a hierarchical framework, from the top level, SSB, down to the provincial and county level. This organizational structure forms a reporting system for the grass-roots units to submit statistical data to the statistical authorities. During the pre-reform period of 1952–1977, the Chinese statistical system adopted the system of MPS which is tailored to meet the needs of the central planning economy. The main aggregate indicators are the value of total output and NI. National income is calculated as value-added and comparable with GDP in the SNA adopted by the market-economy countries. The main difference between GDP and NI accounts is that the latter do not account for the value-added of the service sector. Until 1993 NI[g] had been the single most important economic indicator in the national and provincial accounts in China, and had occupied a position analogous to that of GDP in market economies. Data on NI are available at both the national and provincial levels throughout the period 1952–1992. However, GDP data for more than half of China's provinces is only available after 1978, resulting in difficulties when comparing performance between the pre-reform and the reform period.

There are three principal shortcomings with the SNA. First, there is no provincial GDP data for about half of China's provinces during the pre-reform period. As a result, previous studies on China's regional economy have used national income data. Second, there are no provincial GDP deflators and the provincial retail price index is used to deflate NI for each province. Finally, there is no national and provincial investment deflators until 1991. With the support from SSB, Hsueh and Li (1999) have published the most complete set of Chinese national and provincial income accounts. The Hsueh–Li data set provides information for the service sector omitted in the material product balances and thus is directly comparable with those of other developed economies.

Furthermore, provincial level GDP, GDP deflators, total investment, and investment deflators for both the reform and pre-reform periods, is also available. In this study, we use provincial GDP data from the Hsueh–Li NI data set, covering the period 1952–1995. Provincial GDP data and investment data for 1996 and 1997 is drawn from China Statistics Yearbook, 1997.

Our data covers a 45 year period (1953–1997) and includes 28 provinces (see Table 1). The two exclusions are Hainan, a newly established province and Tibet, which does not have data until 1987. Nominal provincial GDP data is deflated using provincial GDP

[f]This aid has been used for the estimation of GDP and its components in the system of national accounts (SNA), and specifically to fund the collection of service sector data which is excluded from material product balances (MPS). System of national accounts were completely implemented for the entire economy in 1992.

[g]National Income (NI) is net material product, which excludes depreciation of capital and the value added of the service sector. It includes value added for the agriculture, industry, construction, transport, communication, and commerce sectors. NI differs from national income in the market economy in the coverage of the service sector.

Table 1. China's provinces and geographic location.

Province	Location	Province	Location
Beijing	Interior	Henan	Interior
Tianjing	Coast	Hubei	Interior
Hebei	Coast	Hunan	Interior
Shanxi	Interior	Guangdong	Coast
Inner Mongolia	Interior	Guangxi	Interior
Liaoning	Coast	Hainan	Interior
Jilin	Interior	Sichuan	Interior
Heilongjiang	Interior	Guizhou	Interior
Shanghai	Coast	Yunnan	Interior
Jiangsu	Coast	Tibet	Interior
Zhejiang	Coast	Shaanxi	Interior
Anhui	Interior	Gansu	Interior
Fujian	Coast	Qinghai	Interior
Jiangxi	Interior	Ningxia	Interior
Shandong	Coast	Xinjiang	Interior

deflators. Real investment/GDP ratio is defined as the total investment within one year at 1995 constant prices.[h] Because of the difficulty in obtaining data on capital depreciation, we assume that it is invariant across provinces. This present paper maintains the assumption of Raiser (1998) that the rate of technological progress and capital depreciation is equal to 0.07 and constant across China's provinces. Following Islam (1995), we use five-year time intervals for the two periods: 1953–1978 and 1978–1997. By adopting this approach our results are less likely to be influenced by business cycle fluctuations.[i]

3 A GRAPHICAL OVERVIEW

Below we provide a graphical analysis of the provincial growth process during the pre-reform (1952–1977) and reform periods (1978–1997). Our intention is to present the general trends toward income convergence[j] or divergence among the mainland China's 28 provinces. We first categorise the mainland provinces on the basis of coastal (9 provinces) and the interior provinces (19 provinces). One reason for adopting this classification is that there is a significant difference in growth rates between the coastal provinces and interior provinces, in part attributable to regional policy during the reform period which has emphasized the development of the coastal region. In Table 1, we list all the provinces and indicate location in terms of the coastal/interior classification. Figure 1 shows that the

[h]Deflators for both GDP and investment take the prices of 1995 as 100.

[i]For 1952–1978 there are five sub-periods: 1953–1957, 1958–1962, 1963–1967, 1968–1972, and 1973–1977. For 1978–1997 there are four: 1978–1982, 1983–1987, 1988–1992, and 1993–1997.

[j]This analysis considers convergence as the reduction of inter-province income differences over time.

income gap in terms of log GDP per capita between coastal and interior provinces increases slightly after 1978. A problem with this classification of provinces is that there exists considerable heterogeneity *within* both the coastal and interior provinces. For example, not all coastal provinces outperform the interior provinces in terms of the long-run growth performance. In fact only the five fastest growing provinces (Guangdong, Fujian, Jiangsu, Shandong, and Zhejiang), have outstanding growth performance relative to the interior provinces. In addition, the annual average growth rates of three coastal provinces (Tianjiang, Liaoning, and Shanghai) are less than the national average (see Table 2). Figure 2 shows that the average per capita income of the five fastest growing coastal provinces[k] is rapidly approaching that of Shanghai. In contrast, two provinces, Heilongjiang, the heavy industrial base in North-East of China, and Qinghai, an inland province in North-West of China, have been obviously falling behind. Figure 3 compares the remaining coastal provinces (Hebei, Liaoning, Tianjing, and Shanghai) with the interior provinces excluding Heilongjiang and Qinghai.

Subsequently, we divide the 9 coastal provinces into the richest (Shanghai), the average group and the poorest (Hebei). Figure 4 demonstrates that the income gap between the richest coastal province (Shanghai) and the poorest coastal (Hebei) is relatively constant. Similarly, we divide the 19 interior provinces into the richest (Beijing), the average group and the poorest (Guizhou). Figure 5 shows that the income gap between the richest interior province (Beijing) and the poorest (Guizhou) has increased slightly since 1980s.

By focussing upon the time-series profile of the cross-section of log per capita GDP for *all* provinces we can graphically examine whether there is a common equilibrium across provinces. In Figure 6, we plot the standard deviation of log per capita GDP (σ_{LPT}) across the 28 provinces for the period 1952–1997. Omitting a large increase in this statistic between 1958–1959 and a large decline in 1961, we observe a general increase in σ_{LPT} until the mid 1970s, a period which roughly coincides with the Culture Revolution. Following the process of trade liberalization in the 1970s, and especially post 1978, we observe a clear tendency towards σ-convergence over a period longer than a decade. However, since 1990 there has been a clear tendency towards σ-divergence, such that after the trade liberalization in 1978 we observe what might be termed a J-curve of σ-con--convergence.

One possible explanation for this pattern, and consistent with the pattern of inter-provincial growth difference in China post 1978 is the existence of non-parallel growth paths between China's coastal provinces and interior provinces after 1978, due to different technological growth rates. Coastal provinces were initially poorer than many interior provinces at the beginning of the reform period, and subsequently overtook a number of initially rich provinces. For example, since 1978, the five dragons have grown much faster than Heilongjiang and Qinghai. In the empirical analysis, we exploit both the time-series and cross-section dimension of our provincial data to investigate whether there are significant differences in both the rate of technological process and the initial level of technology.

[k]These provinces, often referred to as the "five dragons", have grown at more than 10% each year since 1978.

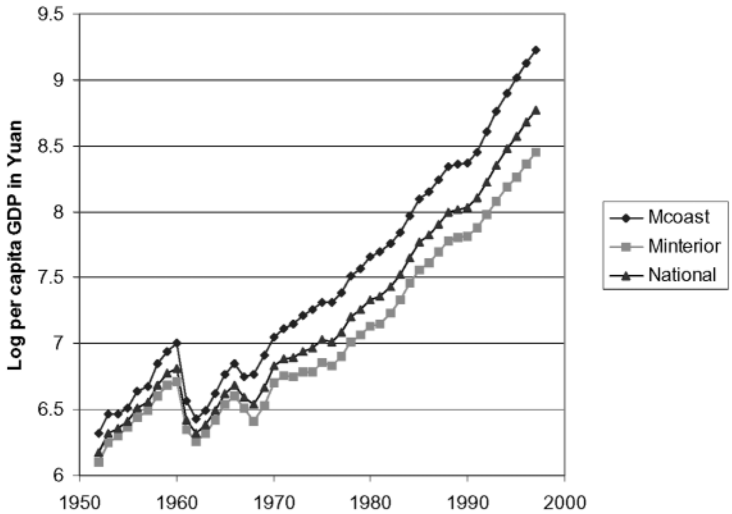

Figure 1. Log per capita GDP of national, coastal and interior provinces 1952–1997.

4 THE SOLOW GROWTH FRAMEWORK

Despite its age the Solow growth model continues to provide the theoretical basis for a large number of the cross-sectional studies of income convergence (for example, Barro and Sala-i-Martin, (1991); MRW). More recently, studies by Islam (1995), Caselli et al. (1996), hereafter CEL, Lee et al. (1997, LPS), and Nerlove (1999), have utilised both cross-section and time series observations to test income convergence and estimate the convergence rate. Using standard notation we assume a Cobb-Douglas production function with output (Y) and three inputs, capital (K), labor (L) and labor augmenting technological progress (A).[1] Assuming constant returns to scale we write

$$Y(t) = K(t)^{\alpha}[A(t)L(t)]^{1-\alpha}, \tag{1}$$

where $0 < \alpha < 1$. Labor force and technology grow at the following constant and exogenous rates

$$L(t) = L(0)e^{nt} \tag{2}$$
$$A(t) = A(0)e^{gt}, \tag{3}$$

[1]The exposition of the Solow model is mainly based on MRW and Islam (1995).

Table 2. Average annual growth rates of per capita GDP of China's provinces.

Province	Pre-reform period 1952–1978	Reform period 1978–1997	Percent change
Beijing	8.57	7.91	−7.70
Tianjing	6.07	8.53	40.53
Hebei	4.63	9.47	104.54
Shanxi	4.73	8.16	72.52
Inner Mongolia	3.24	8.57	164.51
Liaoning	7.4	7.88	6.49
Jilin	3.42	8.93	161.11
Heilongjiang	3.73	6.70	79.62
Shanghai	7.09	8.35	17.77
Jiangsu	2.97	12.33	315.15
Zhejiang	3.7	13.27	258.65
Anhui	2.46	9.22	274.80
Fujian	4.18	12.64	202.39
Jiangxi	2.47	9.36	278.95
Shandong	5.04	10.83	114.88
Henan	3.22	9.70	201.24
Hubei	4.41	9.64	118.59
Hunan	3.85	8.21	113.25
Guangdong	3.94	11.51	192.13
Guangxi	4.58	8.23	79.69
Hainan	N/A	N/A	
Sichuan	3.9	9.68	148.20
Guizhou	3.37	8.22	143.92
Yunnan	3.83	8.99	134.73
Tibet	N/A	N/A	
Shaanxi	5.74	8.37	45.82
Gansu	3.97	7.62	91.94
Qinghai	6.03	5.88	−2.49
Ningxia	6.77	7.21	6.50
Xinjiang	2.68	8.99	235.45
Average (standard error)	4.50 (1.567)	9.09 (1.722)	

where n is the growth rate of the labor force, g is the rate of technological progress, $L(0)$ is the initial state of the labor force, and $A(0)$ is the initial state of technology. We write an autoregressive form of the growth model as

$$\begin{aligned}\ln y(t_2) &= \zeta \ln y(t_1) + (1-\zeta)\ln A(0) + g(t_2 - \zeta t_1) \\ &\quad + (1-\zeta)\frac{\alpha}{1-\alpha}\ln(s) - (1-\zeta)\frac{\alpha}{1-\alpha}\ln(n+g+\delta) \qquad (4)\end{aligned}$$

where $y(t) = Y(t)/L(t)$ stands for per capita output, and $\zeta = e^{-\lambda}(t_2 - t_1)$, with $\lambda = (n + g + \delta)(1 - d)$. The Solow model in Eq. (4) focuses upon the transitional growth dynamics of one economy to its steady state income path and represents a general dynamic

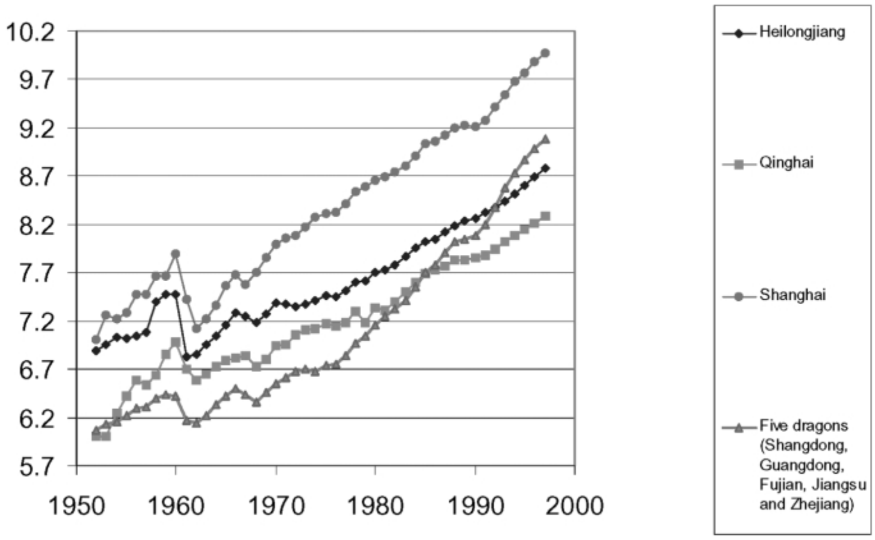

Figure 2. Log per capita GDP: a comparison of the five dragons, Heilongjiang and Qinghai with Shanghai.

framework within which to examine income convergence. Note that the intercept in (4) is additive in two constant terms: $(1-\zeta)\ln A(0)$ and $g(t_2-\zeta t_1)$. However, with multiple observations per cross-sectional unit it is possible, through, respectively, the introduction of province-specific and time-specific effects, to relax the assumption of strict parametric homogeneity of both $\ln A(0)$, the initial technology state, and g, the technological progress rate.

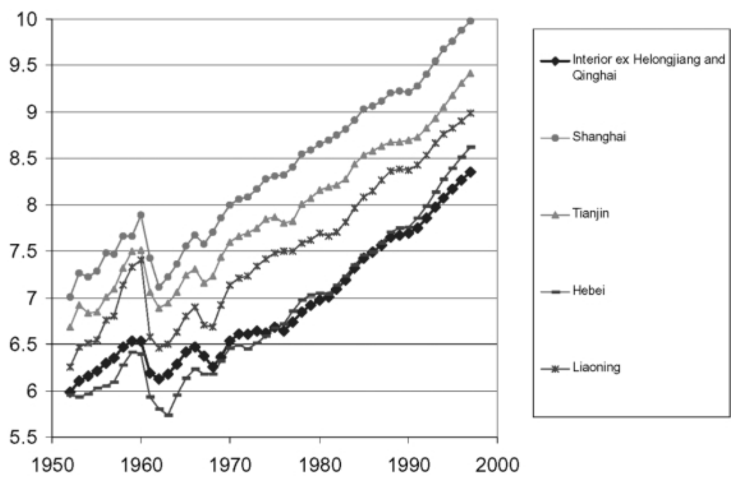

Figure 3. Log per capita GDP of four coastal provinces (Hebei, Liaoning, Tianjing, and Shanghai) and 17 interior provinces excluding Heilongjian and Qinghai.

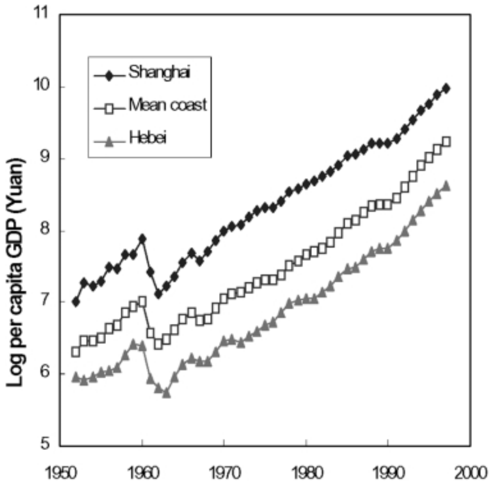

Figure 4. Log per capita GDP of the richest (Shanghai), the poorest (Hebei) and mean of coastal provinces.

Using obvious notation we may, adding a disturbance term, write (4) in panel data form

$$y_{it} = by_{it-1} + \boldsymbol{\theta}'\mathbf{x}_{it} + T_t + \eta_i + v_{it}, \tag{5}$$

where $\mathbf{x}_{it} = [\ln(s_{it}),\ \ln(n_{it} + g + \delta)]'$, $\boldsymbol{\theta} = [(1-\zeta)\alpha/(1-\alpha), -(1-\zeta)\alpha/(1-\alpha)]'$, $\eta_i = (1-\zeta)\ln A(0)$, $T_t = g(t_2 - \zeta t_1)$ and $y_{it} = \ln y(t_2)$. We interpret the effects η_i as a composite of unobservable province-specific factors, which include initial technology differences. Similarly, T_t captures the time-specific effects which includes the rate of technological change.

By allowing for differences in the initial state of technology $A(0)$ we thereby allow economies to have distinct but parallel steady state income paths. For example, Islam (1995) and CEL (1996) allow the aggregate production function to differ across countries with respect to initial technology state $A(0)$ while the homogeneity of g is maintained. Conditional upon a homogeneous growth rate of technology, we can say that the income gap among the economies is stable due to the existence of parallel steady-state growth paths. In this respect, convergence may be interpreted as the speed with which economies approach parallel long-run growth paths.

The question as to whether or not economies have the same technology progress rate is also of considerable empirical interest. LPS (1997) demonstrate that if the assumption that the technological progress rate g is the same across all geographical units is invalid, then the effect of imposing a common g biases the estimate of ζ toward 1.[m] Lee et al.

[m]LPS (1997) demonstrate the existence of pervasive heterogeneity in g_i in the Summers–Heston data.

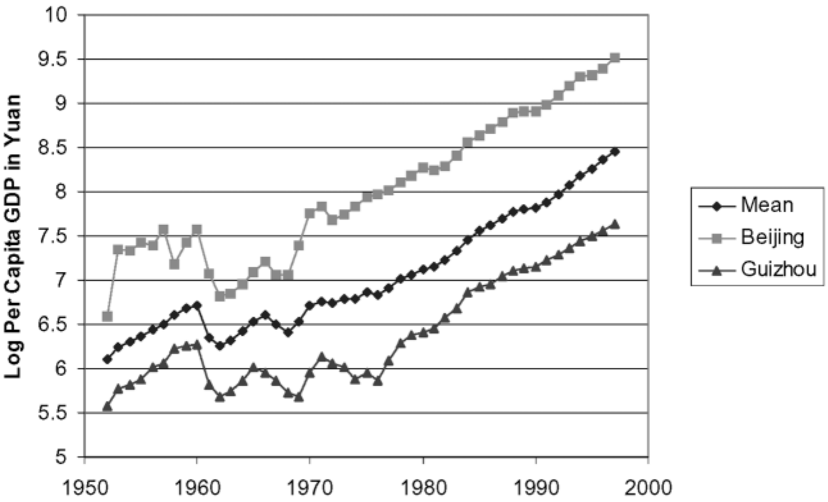

Figure 5. Log per capita GDP of the richest (Beijing), the poorest (Guizhou) and mean of interior provinces of China 1952–1997.

(1998) suggest the use of the panel data approach to allow countries to differ not only with regard to $A(0)$ but also with respect to g. If g does vary across economies long-run growth paths are not parallel and the system of economies are diverging. As far as economic implications for income inequality is concerned, the existence of heterogeneity in technology growth rates completely alters the notion of (conditional or unconditional) convergence. As Lee et al. (1998) note, such a finding provides no insight into a comparison of the evolution of the distribution of cross-country outputs.

Although an assumption of homogeneity of the rate of technological progress across provinces during the pre-reform period is tenable,[n] this is unlikely to be the case for the reform period. After 1978 China has adopted an open door policy such that access to the ocean, and thereby to the world market, has undoubtedly afforded real advantages to the coastal provinces. In the context of a fragmented domestic economy and restrictive interregional trade (see, for example, Young (2000)), the interior provinces may not be able to share the same technical knowledge as the coastal provinces.

In particular, we might conjecture that the technology progress rate of coastal provinces is different from that of the interior provinces. This hypothesis can be tested empirically by the using a composite dummy constructed by taking the product of a time and coastal dummy. We do this by rewriting (5) as

$$y_{i,t} = by_{it-1} + \boldsymbol{\theta}\mathbf{x}_{it} + D_i T_t + T_t + \eta_i + v_{it}, \tag{6}$$

[n]During the pre-reform period China was extremely isolated from the outside world such that geographical location had little bearing in accessing technical knowledge.

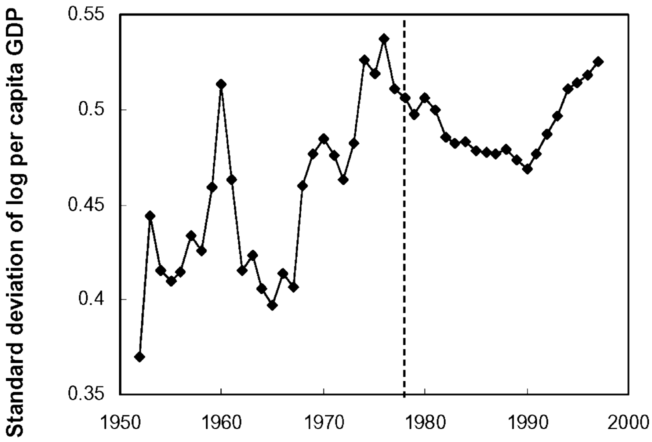

Figure 6. Annual dispersion in GDP per capita among 28 provinces for 1952–1997.

where $D_i = 1$ if the ith province belongs to the coastal region. Note that within each region (coastal and interior) there is a maintained assumption that the rate of technological progress is homogeneous.[o]

4.1 The System Generalized Method of Moments Estimator and the Problem of Weak Instruments

Estimates of the convergence speed parameter based upon panel data studies have been, in general, considerably higher than the 2% of the cross-sectional studies. For example, Islam (1995) using the Summers–Heston data finds annual convergence rates between 3.8% and 9.1%, whereas CEL using the first-difference GMM (DIFF-GMM) estimator finds a convergence rate of 10%. However, estimation problems inherent in the use of panel data estimators used have been largely ignored.[p] In this paper, we focus upon the problems manifest in the use of the first-difference GMM estimator, when the true value of the autoregressive parameter, ζ, is close to unity i.e. y_{it} is persistent and nearly nonstationary.[q] Thus, by focussing upon the relative performance of a number of GMM estimators we have excluded maximum likelihood (ML) estimators. Although it is obvious that ML generates a set of implicit moments subsequent upon specification of a complete density, the requirement of a full parametric specification has resulted in a number of problems for this estimator. In this particular context, the inconsistency of ML in dynamic

[o]The significance of the dummy would imply that the coastal region has twice the technological progress rate of the interior region. While this is admittedly arbitrary, we believe that it represents an improvement over the assumption that the two regions share the same technological growth.

[p]A number of notable exceptions include Nerlove (1999) who examines the sensitivity of the convergence rate to the econometric method used. Noteworthy, here is the use of ML estimation unconditional on initial observations. See also Hsiao et al. (2002).

[q]See Nerlove (1999).

panels stemming from the problem of omitted individual heterogeneity and the initial conditions problem is well known. Thus, whereas GMM can be applied as soon as a sufficient number of (conditional) moments are specified, ML requires distributional assumption for the initial conditions. Nonetheless, a recent paper by Hsiao et al. (2002) has made a significant contribution to this debate, demonstrating that for short panels ML dominates GMM.

The System GMM estimator developed by Blundell and Bond (1998) represents a significant improvement over the first difference GMM estimator proposed by CEL. Given that annual log per capita GDP (or five-year averages of log per capita GDP), is likely to be persistent, weak correlations exist between the growth rate of log per capita GDP and the lagged log per capita GDP levels. This results in what is referred to as a *weak instruments* problem in the context of the first-difference GMM estimator. Using Monte Carlo simulations Blundell and Bond (1998) demonstrate that this problem can result in large finite-sample biases when using the first-difference GMM estimator to estimate autoregressive models for moderately persistent series from relatively short panels. The authors show that the biases can be dramatically reduced by incorporating more informative moment conditions that are valid under quite reasonable stationarity restrictions on the initial condition process. Essentially the System GMM estimator represents the use of lagged first-differences as instruments for equations in levels, in addition to the usual lagged levels as instruments for equations in first-differences. In addition, the finite-sample performance of the System GMM can be tested by the identification of an estimation range for the convergence speed provided by the OLS and within-group estimator.

As a way of correcting for this bias Blundell and Bond (1998) note that if the initial conditions y_{i1} satisfy the stationarity restriction $E[\Delta y_{i2}\eta_i] = 0$, then suitably lagged values of Δy_{it-s} as well as $\Delta x_{i,t-s}$ are available as instruments for the levels equations. The resulting System GMM estimator combining equations in levels with equations in first-differences, is shown to provide dramatic gains both in asymptotic efficiency and in finite sample properties, relative to the first-difference GMM estimator [see Arellano and Bond (1991)]. Both sets of moment conditions can be exploited as a linear GMM estimator in a system context.

To evaluate the finite sample performance of System-GMM estimator in this particular application we establish a bound for the autoregressive parameter. Knowledge of the direction of the bias in the OLS and within-groups estimator in models with fixed T is used to establish an approximate upper and lower bound for b in the growth regressions. As Hsiao (1986) shows, omitting unobserved time invariant country effects in a dynamic panel data model will cause OLS levels estimates to be biased upwards and inconsistent, given the positive correlation between the lagged dependent variable y_{it-1} and the permanent effects η_i. On the other hand, the within-group estimator produces a downward bias with the extent of attenuation increasing when exogenous covariates are added. Sevestre and Trognon (1996) demonstrate that, for the purely autoregressive case (i.e., $\boldsymbol{\theta} = \mathbf{0}$) and within a class of estimators including the mean group estimator and the Generalized Least Squares estimator, the within group and OLS estimator can provide a tighter bound around ζ. Nerlove (1999) empirically confirms that the Sevestre–Trognon bound generally holds except for one reversal in the case of the first-difference model.

5 EMPIRICAL RESULTS

5.1 Panel Data Test Conditional on Homogeneity in Technological Progress Rate

Table 3 reports results for the growth regressions for the pre-reform period based on Eq. (5), and assuming the homogeneous technology progress rates across the provinces.[r] A positive coefficient less than 1 on initial GDP is interpreted as conditional convergence. Columns 1 and 2 report, respectively, the results of the OLS levels and the within groups (WG) estimator. These two estimators provide, respectively, the upper and lower bounds for the GMM estimation. Since the OLS estimator of b is greater than unity this implies that provincial income is highly persistent. The implied speed of convergence using the results of the WG estimator in column 2, 19.37%, is significantly different from the divergence implied by the OLS estimation.

In column 3, we present parameter estimates using the DIFF-GMM estimator, assuming that initial income, investment, together with population growth, are endogenous. The coefficient on the lagged dependent variable is statistically significant and exceeds the upper bound provided by the within groups estimator. Given that $\ln y_{i,t}$ is highly persistent according to the OLS estimation in column 1, it is likely that the poor performance of the DIFF-GMM estimator is due to the weakness of the instrument set. An application of the Sargan test suggests that the instrumental variables used in the DIFF-GMM estimator are not valid.

Since the DIFF-GMM estimator appears to suffer from the weak instruments problem we use a system GMM estimator as an alternative. The results are reported in column 4. The coefficient on the lagged dependent variable from the system-GMM estimator falls between the upper and lower bound (0.3797–1.0248), and therefore is more likely to be unbiased. In addition, the estimates of the population growth rate and investment ratio are more precise than those obtained from first differenced GMM estimator. An application of the Sargan test (p value $= 0.416$) strongly suggests that the instrumental variables used in the system GMM are valid. Thus, based upon this evidence the system GMM is the preferred estimator for the Solow growth regression during the pre-reform period. The estimated speed of convergence is ~0.41% per year and extremely slow. The estimated effect of the investment ratio is negative and significant in the system GMM regression. During the pre-reform period all provincial investment was controlled by the state and made through China's state-own enterprises. In this respect the negative sign may be interpreted in the light of soft budget constraints,[s] which represented a major incentive problem of the state-owned enterprises during the central planning period.

[r] All reported standard errors are corrected for heteroskedasticity. The parameter estimates and standard errors reported from GMM estimation are one-step estimators. All regressions except the first-difference GMM regressions include time dummies and they are found to be jointly significant in every regression. In order to conserve space the time dummy estimates are not reported in the tables.

[s] Soft budget constraints are a key characteristic of socialist economies and remain an important concern in transition economies. Following Kornai (1980), a local government or an enterprise is said to have a soft budget constraint when it expects to be bailed out when faced with financial difficulties. This creates an obvious incentive problem.

Table 3. Panel data tests for conditional convergence of the pre-reform period 1953–1977.

	(1) OLS	(2) WG	(3) DIFF-GMM	(4) SYS-GMM
$\ln(y_{t-1})$	1.0248	0.3797	1.0457	0.9795
	(0.0305)	(0.1277)	(0.1213)	(0.0543)
$\ln(n+g+\delta)$	−0.1483	−0.0283	−0.3558	0.0666
	(0.0780)	(0.0771)	(0.1343)	(0.1298)
$\ln(I/\text{GDP})$	0.0134	−0.1027	0.3242	−0.1724
	(0.0281)	(0.0550)	(0.0956)	(0.0621)
Constant	−0.3220	−0.0380	N/A	0.2570
	(0.2904)	(0.0346)	(N/A)	(0.3927)
Implied λ	N/A	19.37%	N/A	0.414%
Sargan Test (p value)			0.033	0.416

Note: Standard errors in brackets. The figure reported for the Sargan test is the p value of the null hypothesis of valid instruments.

Table 4 reports growth regressions for the reform period. As before the system GMM estimator is preferred to the DIFF-GMM estimator. First, whereas the convergence coefficients of $\ln(y_{t-1})$ for the DIFF-GMM estimator (1.0299) falls outside of the lower-upper bound (0.9043–0.9927), the system GMM estimate falls within this bound. Second, the OLS estimate of the autoregressive parameter shows that provincial income is highly persistent. The implied rate of convergence calculating using the system GMM estimator is 2.23% per year. An application of the Sargan test suggests

Table 4. Panel data tests for conditional convergence of the reform period 1978–1997.

	(1) OLS	(2) WG	(3) DIFF-GMM	(4) SYS-GMM
$\ln(y_{t-1})$	0.9927	0.9043	1.0299	0.8944
	(0.0272)	(0.1765)	(0.0264)	(0.0522)
$\ln(n+g+\delta)$	−0.4024	−0.5676	−1.1250	−0.1657
	(0.2451)	(0.2941)	(0.2075)	(0.5964)
$\ln(I/\text{GDP})$	−0.0060	0.0866	0.1411	0.1279
	(0.0591)	(0.0770)	(0.0758)	(0.1404)
Constant	−0.5224	−0.0422	N/A	0.9322
	(0.6031)	(0.0718)		(1.6535)
Implied λ	0.15%	2.01%	1.11%	2.23%
Sargan Test (p value)			0.769	0.258

that the instrumental variables used in both the DIFF-GMM system GMM estimator are significant.

The coefficient of investment has, with the exception of OLS, a positive sign across all estimators, although they are insignificant. In contrast to the pre-reform period, the positive investment coefficient may be due to the improvement in investment efficiency following the changes in China's investment ownership structure after 1978, with increasing shares of private investment and FDI. The process of increasing market competition and fiscal decentralization has resulted in a hardening of the budget constraints of state-owned enterprises (see Qian and Roland (1998)). Nevertheless, the general insignificance of the coefficients of investment rates for the reform period 1978–1997 may imply that inter-provincial differences in productivity instead of capital accumulation are likely to play an important role in explaining differences in provincial income. The coefficient on the population growth rate has the expected sign in all regressions.

5.2 A Test for Heterogeneity in the Rate of Technological Progress

Whether the coastal provinces have the same rate of technological progress as the interior provinces is a critical concern for our study. Table 5 reports the system GMM estimates using Eq. (6).[t] For the pre-reform period we cannot reject the null hypothesis that there is no difference in the rate of technological progress across interior and coastal provinces (p value $= 0.303$). The implied rate of convergence is 0.879% per year, with a half-life of 77 years. This finding, namely that by imposing homogeneity in the rate of technological progress the estimate of ζ is pushed towards one, and the measured speed of convergence is reduced, is consistent with the results obtained by LPS (1997). Although this estimate is higher than the estimated convergence rate using (5), it is still very slow. For the reform period the composite dummy is highly significant with a p value of less significantly less than 0.001. This finding implies a significant difference in the rate of technological progress across the coastal and interior provinces. An immediate implication from the Solow growth model is that the group of the long-run growth paths of the coastal provinces is not parallel with that of the interior provinces. As such the finding of conditional convergence ($\zeta = 0.8467 < 1$) implies that the coastal and interior provinces are approaching their own parallel steady state paths at the same convergence speed (3.328% per year; the half-life is 22 years), and thus form two distinct convergence clubs.

The investment rate has a negative sign for the pre-reform period, and may be explained in part by the existence of a central planning regime and the pure state investment structure. For the reform period, it has a positive sign which may be interpreted in the light of increasing private investment and FDI. Nevertheless, the population growth and investment rate are not significant for both periods.

[t]As before, the system GMM estimator is preferred in the growth regressions for both the pre-reform and reform period. To conserve space, we do not report the results of OLS, within group and the first-difference GMM estimator.

Table 5. Panel data tests for conditional convergence with different technology progress rates between the coastal and interior provinces.

	Pre-reform period 1953–1977 (SYS-GMM)	Reform period 1978–1997 (SYS-GMM)
$\ln(y_{t-1})$	0.9570	0.8467
	(0.0496)	(0.0303)
$\ln(n+g+\delta)$	0.0727	−0.2906
	(0.1325)	(0.4809)
$\ln(I/\mathrm{GDP})$	−0.1735	0.0123
	(0.0769)	(0.1183)
Implied λ	0.879%	3.328%
Wald test	0.303	0.000
Sargan Test	0.541	0.163

Note: The figure reported for the Wald test is the p value of the null hypothesis of joint insignificance of the coast dummy interacted with time dummy. Also see notes in Table 3.

6 CONCLUSION

This paper extends the analysis of previous studies on China's provincial income convergence by using the System-GMM estimator to examine provincial income convergence during the pre-reform period 1953–1977 and the reform period 1978–1997. Utilising results from an application of OLS and WG estimators, a system GMM estimator is shown to be the preferred estimation method, and is more likely to produce consistent and more efficient estimates than the DIFF-GMM estimation used by GEL (1996).

Since the beginning of the reform period the growth performance of the coastal provinces' has been much more remarkable than the interior provinces of China. Based on the empirical specification of LPS (1998), we allow for heterogeneity in technology growth rate between the coastal and interior provinces by using a coastal dummy interacted with the time dummy. Whereas, we find a lack of heterogeneity between coastal and interior provinces for the pre-reform period, heterogeneity is found for the post-reform period. This implies that provincial incomes as a system were converging during the pre-reform period but are diverging during the reform period. We are able to conclude that the rapid economic growth of China's provincial economies over the reform period is at the price of the increasing interprovincial income inequality.

ACKNOWLEDGMENT

Support from the Economic and Social Research Council under grant L138251008 is gratefully acknowledged.

REFERENCES

Arellano, M., Bond, S. (1991). Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. *Rev. Econ. Stud.* 58(2):277–297.

Arellano, M., Bover, O. (1995). Another look at the instrumental variable estimation of error-components models. *J. Econometrics* 68(1):29–51.

Barro, R. J., Sala-i-Martin, X. (1991). Convergence across states and regions. *Brookings Papers on Economic Activity* 0(1):107–158.

Barro, R.-J., Sala-i-Martin, X. (1992). Convergence. *J. Polit. Econ.* 100(2):223–251.

Barro, R.-J., Sala-i-Martin, X. (1995) *Economic Growth. Advanced Series in Economics.* Vol. 539. New York; London and Montreal: McGraw-Hill, xviii pp.

Baumol, W.-J. (1986). Productivity growth, convergence, and welfare: what the long-run data show. *Am. Econ. Rev.* 76(5):1072–1085.

Baumol, W.-J., Wolff, E.-N. (1988). Productivity growth, convergence, and welfare: reply. *Am. Econ. Rev.* 78(5):1155–1159.

Ben, D., Dan, Loewy, M. B. (1997). Free trade, growth and convergence. NBER Working Paper No. 6095.

Bernard, A. B., Durlauf, S. N. (1996). Interpreting tests of the convergence hypothesis. *J. Econometrics* 71:161–173.

Blundell, R., Bond, S. (1998). Initial conditions and moment restrictions in dynamic panel data models. *J. Econometrics* 87(1):115–143.

Caselli, F., Esquivel, G., Lefort, F. (1996). Reopening the convergence debate: a new look at cross country growth empirics. *J. Econ. Growth* 1(3):363–389.

China Statistics Yearbook, various issues.

Chen, J., Fleisher, B.-M. (1996). Regional income inequality and economic growth in China. *J. Comp. Econ.* 22(2):141–164.

Cho, D. (1996). An alternative interpretation of conditional convergence results, *J. Money, Credit Bank.* Part1, 28(4): 669–681.

Durlauf, S., Quah, D. T. (1998). The new empirics of economic growth. Working Paper 6422, National Bureau of Economic Research.

Friedman, M. (1992). Do old fallacies ever die? *J. Econ. Lit.* 30(4): 2129–2132.

Hsiao, C. (1986). *Analysis of Panel Data*. Econometric Society Monographs, no. 11, Cambridge; New York and Sydney: Cambridge University Press.

Hsiao, C., Pesaran, H., Tahmiscioglu, K. A. (2002). Maximum likelihood estimation of fixed effects dynamic panel data models covering short time periods, forthcoming in *J. Econometrics.*

Hsueh, T., Li, Q. (1999). *China's National Income*. Boulder and Oxford: Westview Press.

Hu, Z., Khan, M. (2000), Why is China growing so fast? *Econ. Issues* 8, International Monetary Fund, Washington, D.C.

Islam, N. (1995). Growth empirics: a panel data approach. *Q. J. Econ.* 110(4):1127–1170.

Jian, T., Sachs, J.-D., Warner, A.-M. (1996). Trends in regional inequality in China. National Bureau of Economic Research Working Paper: 5412.

Judson, R.-A., Owen, A.-L. (1997) Estimating dynamic panel data models: a practical guide for macroeconomists, board of governors of the federal reserve system. Finance and Economics Discussion Paper Series: 1997/03.

Kiviet, J.-F. (1995). On bias, inconsistency, and efficiency of various estimators in dynamic panel data models. *J. Econometrics* 68(1):53–78.

Kornai, J. (1980). *Economics of Shortage*. Amsterdam: North Holland.

Lee, K., Pesaran, M. H., Smith, R. (1997). Growth and convergence in a multi-country empirical stochastic Solow model. *J. of Applied Econometrics* 12(4):357–392.

Lee, K., Pesaran, M. H., Smith, R. (1998). Growth empirics: a panel data approach—a comment. *Q. J. Econ.* 113(1):319–323.

Mankiw, N. G. (1995). The growth of nations. *Brookings Pap. Eco. Ac.* (1):275–310.

Mankiw, N. G., Romer, D., Weil, D.-N. (1992). A contribution to the empirics of economic growth. *Q. J. Econ.* 107(2):407–437.

Naughton, B. (1996). China's emergence and prospects as a trading nation. *Brookings Pap. Eco. Ac.* 0(2):273–337.

Nerlove, M. (1999). Properties of alternative estimators of dynamic panel models: an empirical analysis of cross-country data for the study of economic growth. In: Hsiao, C., Lahiri, K., Lee, L. F., Pesaran, M. H., eds. *Analysis of Panels and Limited Dependent Variable Models.* Cambridge University Press, pp. 136–170.

Nickell, S. (1981). Biases in dynamic models with fixed effects. *Econometrica* 49:1417–1426.

Qian, Y., Roland, G. (1998). Federalism and the soft budget constraint. *American Economic Review* 88(5):1143–1162.

Quah, D. (1993). Empirical cross-section dynamics in economic growth. *Eur. Econ. Rev.* 37(2/3):426–434.

Quah, D. (1993). Galton's fallacy and tests of the convergence hypothesis. *Scand. J. Econ.* 95(4):427–443.

Raiser, M. (1998). Subsidising inequality: economic reforms, fiscal transfers and convergence across Chinese provinces. *J. Dev. Stud.* 34(3):1–26.

Ravallion, Jalan. (1996). Growth divergence due to spatial externalities. *Econ. Lett.* 53:227–232.

Sala-i-Martin, X. (1994). Regional cohesion: evidence and theories of regional growth and convergence. Centre for Economic Policy Research, Discussion Paper 1075.

Sala-i-Martin, X. (1996). Regional cohesion: evidence and theories of regional growth and convergence. *Eur. Econ. Rev.* 40(6):1325–1352.

Sala-i-Martin, X. (2002). The disturbing 'Rise' of global income inequality. *Mimeo.* Columbia University.

Sevestre, P., Trognon, A. (1996). Dynamic linear models. Matyas, L., Sevestre, P., eds. In *The Econometrics of Panel Data: A Handbook of the Theory with Applications.* 2nd ed. Advanced Studies in Theoretical and Applied Econometrics, Vol 33. Dordrecht; Boston and London: Kluwer Academic, pp. 120–144.

Solow, R. M. (1956). A contribution to the theory of economic growth. *Q. J. Econ.* 70:65–94.

Summers, R., Alan, H. (1991). The Penn world table (Mark 5.0): an expanded set of international comparisons, 1950–1988. *Q. J. Econ.* 106(2):327–368.

Temple, J. (1999). The new growth evidence. *J. Econ. Lit.* 37(1):112–156.

Weeks, M., Yao, J.-Y. (2000). Provincial income convergence in China, 1953–1997: a panel data approach. Working Paper No. 0010, Department of Applied Economics, University of Cambridge.

Young, A. (2000). The razor's edge: distortions and incremental reform in the People's Republic of China. *Mimeo*. Graduate School of Business, University of Chicago.