Economic Reform, Growth and Convergence in China

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Abstract

In this paper, we propose a new concept of convergence which is based on the metric entropy measure recently proposed by Granger et al. (2004) to investigate economic convergence in China. This entropy measure compares whole distributions of growth rates across individual provinces. Separately, based on this same entropy measure, we also implement cluster analysis to identify any convergence clubs. Our four main conclusions are: (1) while we certainly reject the null hypothesis that there exists a nation-wide convergence, we do find that there exist convergence clubs for both the pre- and post-reform periods, (2) we find a number of very small convergence clubs. In particular, there are seven and five convergence clubs for the pre- and post-reform periods, respectively. (3) in comparing the number and size of convergence clubs for both the pre- and post-reform periods, it could be argued that the extent of convergence is more prevalent during the post-reform period than during the pre-reform period, (4) convergence groups cannot be characterized by such unique features as region or the extent of policy preference level that are commonly used in the literature.

JEL: C13, C21, C22, C23, C33, D30, E13, F43, Q30, Q41.

Keywords: convergence, growth, entropy, China, cluster analysis

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1 Introduction

Recent years have seen a rapid growth in GDP in China. In particular, beginning with the government instituted economic reforms of the late 1970s, the Chinese economy realized a growth rate of 8.8% per annum between the years 1978 – 1997. However, despite rapid growth in the country as a whole, many studies (e.g., Xu and Zou, 2000) have found that at the subnational level, the income disparity has been increasing across provinces. The increased disparity is primarily due to two factors, though other factors are at play: advantageous location, and government's preferential policy (Demurger *et al.* 2002). Although the Chinese government expected that the economic growth would promote economic equity through the spillover effects from some developed areas to other areas that lagged behind, this expectation was not realized. As the economic reforms evolve, income disparity seems to be increasing (see Heshmati 2004 and Kanbur and Zhang 2003 for excellent review of income inequality in China). Income disparity has become a major social concern to both policymakers and economists. As a result, the Chinese government started to invest more in the western areas, which are generally considered to be the least developed, in the hope of balancing development and reducing income inequality in China. The main questions being asked include: Is there any "growth convergence" nation-wide, either before or after economic reforms? If not, does there exist any group or club convergence? If so, how many groups or clubs exist, who are the members within each group, and can these groups be uniquely characterized by such features as geographical locations (regional convergence)?

Given the previous unavailability of quality data, there have been only a few empirical studies on the growth convergence in China to date. These studies have documented different extent of convergence during the post-reform period. Jian *et al.* (1996) find that while there is no significant evidence of convergence during the pre-reform period – and even significant divergence during the Cultural Revolution (1966 -1977) – there is a significant evidence of *absolute* convergence during the post-reform period.[1] Chen and Fleisher (1996) document a *conditional* convergence after adjusting for differences in such variables as physical investment share, employment growth, and coastal location[2]. Li *et al.* (1998), while extending Chen and Fleisher (1996) to control for time-invariant province-specific effects using panel data, find similar results. Dayal-Gulati and Husain (2000) also find that different regions are converging toward different steady states of income. Conversely, using a system GMM estimator to address potential weak instruments and

[1] *Absolute* convergence means that the provinces with lower initial level of per capita GDP have, on average, a faster growth rate than those provinces with higher initial level of per capita GDP.

[2] *Conditional* convergence means that the provinces with lower initial level of per capita GDP still have, on average, a faster growth rate than those provinces with higher initial level of per capita GDP after conditioning on a set of such variables as geographic locations, investment ratios and human capital characteristics.

endogeneity problem, Weeks and Yao (2003) find that there is a nation-wide *divergence* during the post-reform priod, and that coastal and interior provinces converge to their own steady states; while Pedroni and Yao (2005) agree that there is a nation-wide divergence, but do not find regional convergence. In fact, they find that *divergence* is also pervasive within regional and political groups. In the end, the current literature remains inconclusive with regards to convergence both within the country and within the regional groups, and difference in the convergence behavior for both the pre- and post-reform periods.

This ambiguity seems related to three key points. First, the above studies are based on different data sets. For example, while Dayal-Gulati and Husain (2000) compile data mainly from *China Statistical Year Book*. Weeks and Yao (2003) and Pedroni and Yao (2005) base their analysis mostly on Hsuech and Li (1999) data, which is more consistent and comparable. Additionally, owing to lack of consistent and reliable data during the pre-reform period, most studies are silent about the difference in convergence behaviors between the pre- and post-reform. Jian *et al.* (1996), Weeks and Yao (2003) and Pedroni and Yao (2005) are rare exceptions. Second, most of the studies rely on a conventional parametric regression, typically with GDP growth as dependent variable and initial level of per capita GDP as an independent variable. If the coefficient of the initial level of per capita GDP is significantly negative there is so-called β convergence. Such a narrow definition is criticized by Quah (1993, 1997) and Maasoumi et al (2006) since this type of analysis only focuses on the conditional mean of the distribution and ignores other important information of the distribution. Finally, in prior studies, identification of convergence clubs depends more or less on the pre-classification of the clubs. For example, Weeks and Yao (2003) test the joint significance of the interaction terms between costal location dummy and time trend to investigate the within group convergence. Interpretation of this approach requires care. If the coefficients of the coastal dummy and its interactions with other variables are significant, we may only conclude these two groups are different, and we cannot rule out the possibility that different convergence groups exist within the coastal or interior group. Indeed, Pedroni and Yao (2005) experiment with different classifications of regional subgroupings and find that the results are sensitive to the inclusion or exclusion of certain provinces in the group of interior or policy-preferential provinces. More importantly, this method does not reveal changes in the club membership. If convergence within a pre-classified group doesn't exist, this method cannot reveal why the members are diverging and which member(s) are moving away to another group from others in the original group, let alone answering how far away they are moving from the original group.

In this paper, we seek to add to this literature in several important ways that respond to the limitations discussed above. First, folowing Maasoumi et al (2006), we propose a new concept of convergence based on the similarity of the distributions of growth rates across provinces. The similarity is measured by the normalization of the Bahattacharya-Matusita-Hellinger Entropy measure proposed in Granger *et al.*

(2004). This entropy measure goes beyond the first and second moments of the distributions and is able to summarize the information of the *whole* distribution. Since it is also a "metric" measure of the "distance" between two distributions (as contrasted with "divergence") our method provides a detailed picture of the changes in the distance of the distributions of growth rates between any provinces. By comparing the changes in the distance of the distribution of provincial growth rates for the pre- and post-reform periods, we are able to see how economic reform affects the dynamic behaviors of economic growth for each province. Second, based on the entropy measure, we implement a cluster analysis in order to identify convergence clubs within any historical time period. Such analysis allows us to find convergence groups that may be arbitrally small, and avoiding potential pre-classification errors. In addition, by comparing the results from the pre- and post-reform periods, we are able to discover a clearer picture of how the cluster membership changes, why certain members move away from the original cluster, and the extent of the change. We investigate the convergece hypothesis for both the pre- and post reform periods. Following the literature, we employ the year 1978 as the cut-off point, which is the date that economic reforms in China were officially announced. Dividing our sample into two subperiods explicitly allows for a change in the number and membership of convergence clubs, and hence, allows us to answer the following question: did economic reforms lead to economic divergence/convergence in China?

Our results are striking, yielding four conclusions: (1) while we certainly reject the null hypothesis that there exists a nation-wide convergence, we do find the existence of convergence clubs for both the pre- and post-reform periods, (2) the number of convergence clubs is rather small. In particular, there are seven and five convergence clubs for the pre- and post-reform periods, respectively. These results are consistent with Hobijn and Franses (2000) and Corrado *et al* (2005); the former investigates convergence across 115 countries finding 63 asymptotically perfect convergence clubs, and the latter studies the regional convergence in Europe finding more than twenty convergence clubs in all the sectors, with most clubs having only two or three members, (3) in comparing the number and size of convergence clubs for both the pre- and post-reform periods, it could be argued that the extent of convergence is more prevalent during post-reform period than during the pre-reform period, (4) convergence groups cannot be characterized by such unique features as region or the extent of policy preference level that are commonly used in the literature. The final result is consonant with Pedroni and Yao (2005) as well as Hobijn and Franses (2000) and Corrado *et al.* (2005).

The remainder of the paper is organized as follows. Section 2 details the empirical methodology. Sections 3 and 4 discuss the data and results, respectively. Section 5 concludes.

2 Empirical Methodology

2.1 Entropy Measures of Distributional Distance

In our analysis, we define convergence as the similarity of the distributions of growth rates of two provinces. More formally, two provinces are converging if

$$H_0 : f_1 = f_2$$

where f_1 (f_2) is the marginal density of the growth rates over time for region 1 (2) in our analysis. While one simple and convenient way to test the null hypothesis is to test for equality of either mean or variance of the two distributions, this method ignores a large amount of information of the distributions. One solution to this shortcoming is to find a measure that is able to summarize the information in the *whole* distribution. Many commonly used information-based entropy measures such as Shannon's *mutual information* function (see Granger and Lin 1994) are available for this purpose. However, Shannon's entropy measure as well as other entropy measures are not *metric*; these measures violate the triangularity rule. Hence, they measure only *divergence* instead of *distance* between two distributions, which will be espeically problematic when implementing a clustering analysis, or when we wish to go beyond a test of hypothesis of equality. We will discuss this in further detail shortly.

Following arguments in Granger et al. (2004) and Maasoumi and Racine (2002), we utilize a *metric entropy* measure S_ρ which provides a formally quantified distance between distributions of variables (in our case, growth rates). This entropy is a normalization of the Bhattacharya-Matusita-Hellinger measure of distance. It is given by

$$S_\rho = \frac{1}{2}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\left(f_1^{\frac{1}{2}} - f_2^{\frac{1}{2}}\right)^2 dxdy$$

Importantly, our null hypothesis can be refomulated as the null hypothesis that $S_\rho = 0$. That is, two provinces are converging iff

$$H_0 : S_\rho = 0$$

This produces a test statistic that satisfies the following properties: (i) it is well defined for both continuous and discrete variables, (ii) it is normalized to zero if X and Y are equal, and lies between 0 and 1, (iii) it is a metric, that is, it is a true measure of "distance" and not just of divergence, and (iv) the measure is invariant under continuous and strictly increasing transformations $h(.)$ on the undelying variables. This measure has further ideal properties as an index of general dependence.

2.2 Cluster Analysis

When there fails to exist nationwide convergence, we examine whether or not economies are converging to "clubs" with similar distributions of growth rates. Based on the entropy measure S_ρ above, we implement Hierarchical Agglomerative Clustering techniques. Clustering methods have been widely applied in economics (see Hirschberg *et al.* 2001; Borland *et al.* 2001; Hirschberg and Dayton 1996, just to name a few). Our methodology is similar to Hirschberg *et al.* (2001), and conceptually, closely related to Hobijn and Franses (2000) and Corrado *et al.* (2005) who use different criteria to measure distances. The former employs clustering analysis based on the same entropy measure S_ρ to identify distinct dimensions in the 15 indicators of well-being that are commonly used, and the latter two studies implement clustering analysis on time series to investigate the convergence of per capita productivity across countries and across Europe, respectively.

Rather than fixing the number of clusters (for example, Partition clustering techniques), Hierarchical Agglomerative clustering techniques allow one to vary the number of clusters. In addition, one can study the resulting clustering characteristics and graphical representations, allowing the researcher to decide on the most suitable value of the number of clusters (Kaufman and Rousseeuw 1990, p199). The algorithm is as follows.

1. First stage, each variable is one cluster itself.
2. Second stage, we calculate the distance measure between clusters as follows.[3]

$$d_{k(ij)} = \alpha_i d_{ki} + \alpha_j d_{kj} + \beta d_{ij} + \gamma |d_{ki} - d_{kj}|$$

   where d_{ij} is the distance between cluster i and cluster j; $d_{k(ij)}$ is the distance between cluster k and new cluster formed by joining cluster i and j; and α_i, α_j, β, and γ are parameters that are set based on the particular hierarchical cluster analysis method. For example, for complete linkage, $\alpha_i = \frac{1}{2}$, $\alpha_j = \frac{1}{2}$, $\beta = 0$, and $\gamma = \frac{1}{2}$.

3. Based on the distance from the second stage, two *closest* clusters are merged and form a new cluster.
4. Repeat stage 2 and 3 until all the variables are in the same cluster.

In our analysis, we use the "complete linkage" clustering algorithm that finds the closest two groups based on the "farthest" observations between the two groups, as judged by a chosen criterion of distance.

[3] Refer to Stata Maual, "Cluster Analysis" for details.

The algorithm requires a *metric* measure of *distance*, since any measures that violate the triangle rule will lead to inconsistent decisions (Hirschberg *et al.* 2001). As we mentioned earlier, one of advantages of Hierarchical Agglomerative Clustering techniques is it allows us to find the most suitable number of clusters. However, choosing the optimal number of clusters is a vital aspect of our analysis; This is the so-called "stopping rule problem". Mojena (1977) suggests using the examination of the distances needed to form the next cluster. Following Hirschberg *et al.* (2001), we plot the change in distance from the last member added to the cluster against the number of clusters. By doing so, we can visualize how the distance changes as clustering analysis continues. Particularly, this allows us to detect the cases where a large change in distance occurs.

3 Data

The data used in our analysis comes from two sources: one is Hsuech and Li (1999) for the period 1952 – 1995, and the other is pooled from *China Statistical Yearbook* for the period 1996 – 2003. While the data quality in China is always considered questionable by researchers, especially prior to economic reforms, the data compiled by Hsuech and Li (1999) is widely considered to be "the most complete set of Chinese national income from 1952 to 1995" (Pedroni and Yao 2002) and has been used in many studies, for example, Weeks and Yao (2003) and Pedroni and Yao (2005). See Pedroni and Yao (2002) for detailed discussion on the data quality and suitablity in the context of studying growth as well as information on statistical reporting system in China. China currently has twenty-three provinces, five autonomous regions and four Centrally Administered Municipalities.[4] The data is missing for Tibet and Hainan prior to 1987 and 1988, respectively, and following the literature, we exclude these two provinces in our analysis.[5] Also, Chongqing city was separated from Sichuan province and became a new Municipality in 1997. In our analysis, the data on Chongqing is added back to Sichuan province. Hence, the data finally consists of 28 provinces which are listed in Table 1.

4 Results

In Figure 1 and 2, we plot the time series of growth rates of each province for both the pre- and post-reform periods. Examining the figures of the time series for the pre-reform period, we find no obvious trend in the time series, and that the time series of growth rates of some provinces are around zero while those of

[4] Since province, autonomous region and municipality city are administratively equal, we will stick to the terminology "province" throughout the paper.

[5] Hainan is a relatively new province and became the 31th province in China in 1988.

other provinces are around some positive numbers. Hence, we elect to conduct our unit root tests for the case where there is no trend but with a drift. The Phillips-Perron unit root test results are presented in Table 2. The null hypothesis that there exists a unit root is rejected significantly for all the time series. Moreover, the results do not change when we conduct our tests for the case where there is no trend and no drift. Examining the figures for the post-reform period, we find that there is no obvious trend but a drift for all the time series. Hence, we elect to conduct our unit root tests for the case where there is no trend but with a drift. We again reject the null hypothesis that there is a unit root.

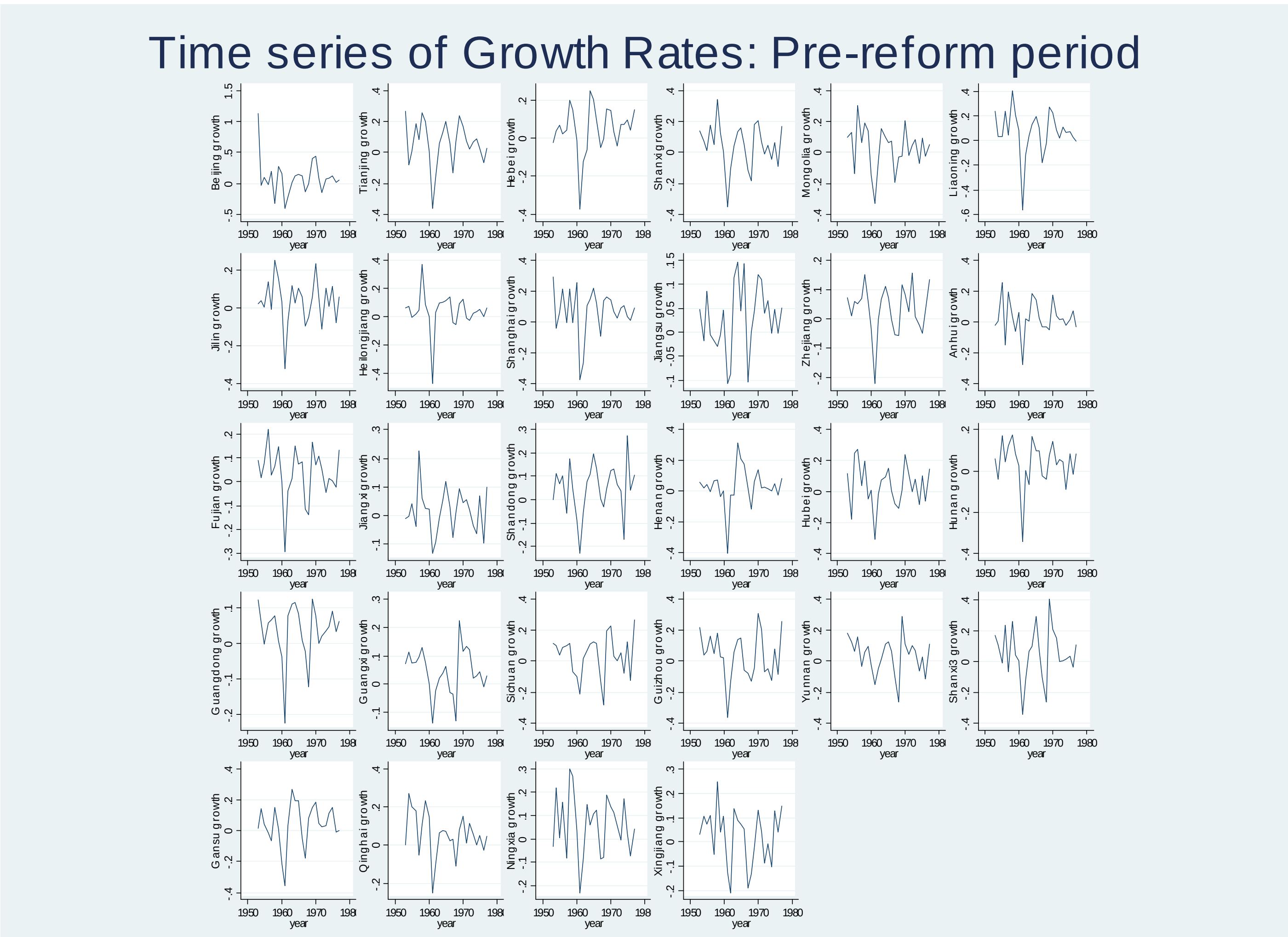

Figure 1

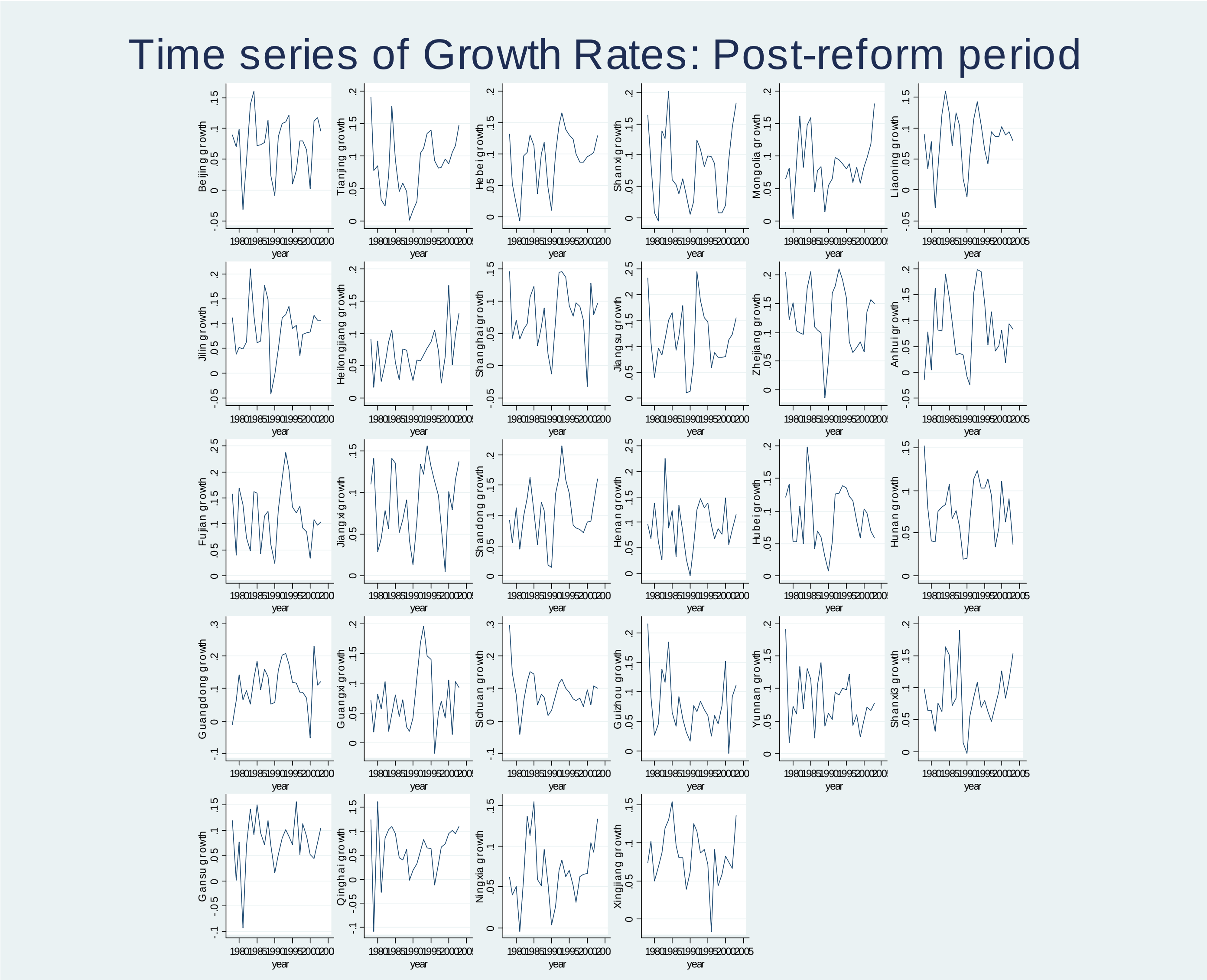
Time series of Growth Rates: Post-reform period
Beijing growth
Tianjing growth
Hebei growth
Shanxi growth
Mongolia growth
Liaoning growth
Jilin growth
Heilongjiang growth
Shanghai growth
Jiangsu growth
Zhejiang growth
Anhui growth
Fujian growth
Jiangxi growth
Shandong growth
Henan growth
Hubei growth
Hunan growth
Guangdong growth
Guangxi growth
Sichuan growth
Guizhou growth
Yunnan growth
Shanxi3 growth
Gansu growth
Qinghai growth
Ningxia growth
Xingjiang growth
year

Figure 2

Table 2: Phillips-Perron Unit Root Tests

Province	Pre-reform		Post-reform	
	Test Statistic	P Value	Test Statistic	P Value
Beijing	-7.27	0.00	-4.16	0.00
Tianjing	-3.63	0.01	-3.63	0.01
Hebei	-3.15	0.02	-3.08	0.03
Shanxi	-3.65	0.00	-2.94	0.04
Mongolia	-4.45	0.00	-3.22	0.02
Liaoning	-3.79	0.00	-3.78	0.00
Jilin	-4.30	0.00	-3.86	0.00
Heilongjiang	-4.14	0.00	-4.76	0.00
Shanghai	-4.96	0.00	-4.08	0.00
Jiangsu	-4.19	0.00	-4.17	0.00
Zhejiang	-3.37	0.01	-2.90	0.05
Anhui	-6.03	0.00	-3.46	0.01
Fujian	-3.85	0.00	-3.62	0.01
Jiangxi	-4.38	0.00	-3.29	0.02
Shandong	-4.27	0.00	-2.96	0.04
Henan	-3.67	0.00	-5.06	0.00
Hubei	-4.57	0.00	-3.38	0.01
Hunan	-4.45	0.00	-3.19	0.02
Guangdong	-4.09	0.00	-4.16	0.00
Guangxi	-3.48	0.01	-3.55	0.01
Sichuan	-4.07	0.00	-3.38	0.01
Guizhou	-3.68	0.00	-4.58	0.00
Yunnan	-4.62	0.00	-5.39	0.00
Shanxi3	-4.41	0.00	-3.74	0.00
Gansu	-3.16	0.02	-5.31	0.00
Qinghai	-3.85	0.00	-6.59	0.00
Ningxia	-4.60	0.00	-2.82	0.05
Xinjiang	-4.20	0.00	-4.04	0.00

Note: Unit root test both for pre-reform period and post-reform are implemented with no trend and no drift option

Table 3 presents the distances across individual provinces for the *pre-reform* period. The calculated $S\rho$ in a grey box indicates significance at the 95 percent level. From Table 3, we can clearly see that many of provinces have different *time* distributions of growth rates, because many of the pair-wise distances $S\rho$ are significant. In particular, 140 out of 351 pair-wise distances are significant. These results make it evident that there exists no nation-wide convergence during the pre-reform period in China. This is also consistent with the findings of Jian *et al.* (1996) who detect little evidence of absolute convergence during the pre-reform period. As we mentioned before, this Table provides detailed information about how one province is different from the remaining provinces in the country. Taking Beijing as an example, in the first row of Table 2, we first note that the distance $S\rho$ between Beijing and two other Municipalities – Shanghai and Tianjin – is significant at the 95 percent level, which means that the (time) distributions of the growth rates of Beijing and two other provinces were diverging during the pre-reform period. In particular, the distance between Beijing and Tianjing and Shanghai are 0.12 and 0.15, respectively. Moving along, we then note that the distances between Beijing and three northeastern provinces – Heilongjiang, Jilin and and

Liaoning, which are heavily-industrialized "rich" economies during the pre-reform period – are significant; these results again imply that Beijing and each of these three provinces were diverging during the pre-reform period. On the other hand, the distances between Beijing and three southwestern interior provinces – Guangxi, Yunnan and Guizhou – are insignificant, implying that Beijing was converging to each of the three provinces.

Table 3: Distances $D(i,j)$ **computed between each series (Pre-reform)**

	Beijing	Tianjing	Hebei	Shanxi	Mongolia	Liaoning	Jilin	Heilongjiang	Shanghai	Jiangsu	Zhejiang
Beijing		0.12	0.17	0.08	0.21	0.20	0.11	0.10	0.15	0.05	0.03
Tianjing			0.10	0.26	0.06	0.20	0.10	0.08	0.16	0.11	0.06
Hebei				0.17	0.02	0.10	0.06	0.11	0.07	0.02	0.07
Shanxi					0.13	0.21	0.12	0.12	0.09	0.03	0.11
Mongolia						0.08	0.13	0.11	0.03	0.02	0.03
Liaoning							0.10	0.11	0.12	0.04	0.15
Jilin								0.09	0.05	0.03	0.04
Heilongjiang									0.06	0.04	0.07
Shanghai										0.07	0.03
Jiangsu											0.02
Zhejiang											
Anhui											
Fujian											
Jiangxi											
Shandong											
Henan											
Hubei											
Hunan											
Guangdong											
Guangxi											
Sichuan											
Guizhou											
Yunnan											
Shanxi3											
Gansu											
Qinghai											
Ningxia											
Xinjiang											

Table 3 (cont.): Distances *D(i,j)* computed between each series (Pre-reform)

	Anhui	Fujian	Jiangxi	Shandong	Henan	Hubei	Hunan	Guangdong	Guangxi	Sichuan	Guizhou
Beijing	0.07	0.03	0.08	0.05	0.06	0.05	0.05	0.03	0.06	0.18	0.03
Tianjing	0.09	0.07	0.05	0.05	0.04	0.05	0.08	0.05	0.08	0.08	0.05
Hebei	0.05	0.06	0.06	0.04	0.09	0.03	0.08	0.05	0.03	0.06	0.04
Shanxi	0.21	0.16	0.11	0.06	0.08	0.26	0.08	0.05	0.10	0.26	0.16
Mongolia	0.06	0.04	0.03	0.04	0.04	0.15	0.12	0.04	0.05	0.16	0.08
Liaoning	0.10	0.11	0.04	0.06	0.09	0.05	0.07	0.07	0.09	0.09	0.05
Jilin	0.04	0.09	0.08	0.07	0.05	0.09	0.07	0.04	0.13	0.09	0.06
Heilongjiang	0.09	0.20	0.03	0.06	0.13	0.04	0.09	0.11	0.06	0.11	0.05
Shanghai	0.05	0.04	0.04	0.05	0.05	0.03	0.04	0.03	0.03	0.05	0.05
Jiangsu	0.02	0.03	0.04	0.02	0.05	0.41	0.38	0.03	0.02	0.04	0.02
Zhejiang	0.08	0.07	0.03	0.04	0.08	0.03	0.06	0.06	0.16	0.08	0.05
Anhui		0.08	0.04	0.03	0.10	0.06	0.08	0.05	0.04	0.12	0.04
Fujian			0.05	0.05	0.08	0.03	0.07	0.06	0.10	0.09	0.06
Jiangxi				0.04	0.06	0.19	0.03	0.02	0.03	0.08	0.04
Shandong					0.05	0.03	0.04	0.04	0.03	0.05	0.07
Henan						0.05	0.11	0.07	0.05	0.27	0.04
Hubei							0.07	0.03	0.08	0.11	0.14
Hunan								0.04	0.04	0.07	0.05
Guangdong									0.05	0.11	0.03
Guangxi										0.08	0.06
Sichuan											0.05
Guizhou											
Yunnan											
Shanxi3											
Gansu											
Qinghai											
Ningxia											
Xinjiang											

Table 3 (cont.): Distances *D(i,j)* computed between each series (Pre-reform)

	Yunnan	Shanxi3	Gansu	Qinghai	Ningxia	Xinjiang
Beijing	0.04	0.09	0.06	0.06	0.09	0.10
Tianjing	0.09	0.10	0.07	0.08	0.13	0.06
Hebei	0.03	0.06	0.07	0.04	0.03	0.03
Shanxi	0.19	0.17	0.05	0.05	0.06	0.08
Mongolia	0.06	0.08	0.06	0.12	0.12	0.11
Liaoning	0.09	0.15	0.07	0.04	0.06	0.08
Jilin	0.04	0.14	0.05	0.11	0.08	0.07
Heilongjiang	0.04	0.12	0.11	0.04	0.06	0.06
Shanghai	0.04	0.09	0.05	0.06	0.05	0.04
Jiangsu	0.03	0.04	0.04	0.03	0.27	0.04
Zhejiang	0.05	0.04	0.07	0.05	0.03	0.04
Anhui	0.07	0.04	0.06	0.05	0.02	0.02
Fujian	0.09	0.12	0.05	0.04	0.05	0.05
Jiangxi	0.09	0.04	0.03	0.03	0.04	0.03
Shandong	0.09	0.17	0.06	0.04	0.09	0.12
Henan	0.04	0.05	0.12	0.04	0.01	0.03
Hubei	0.05	0.08	0.04	0.09	0.04	0.04
Hunan	0.04	0.03	0.07	0.04	0.04	0.03
Guangdong	0.06	0.06	0.10	0.04	0.02	0.07
Guangxi	0.08	0.09	0.04	0.05	0.04	0.04
Sichuan	0.10	0.08	0.23	0.03	0.04	0.06
Guizhou	0.05	0.11	0.04	0.12	0.02	0.08
Yunnan		0.10	0.04	0.05	0.04	0.05
Shanxi3			0.04	0.05	0.09	0.08
Gansu				0.03	0.03	0.03
Qinghai					0.08	0.04
Ningxia						0.04
Xinjiang						

Table 4 presents the distances across individual provinces for the *post-reform* period. We can clearly see that many of provinces have different *time* distributions of growth rates than others because many of the pair-wise distances $S\rho$ are significant. These results again imply that there exists no nation-wide convergence during the post-reform period in China. Before proceeding one interesting result is worth mentioning. There are fewer singificant distances across individual provinces during the post-reform period than during the pre-reform period. In particular, only eighty-four, as opposed to one hundred and forty during the pre-reform period, out of 351 pair-wise distances are significant. This reduction in the number of pairwise significant differences suggests that the extent of divergence is less severe during the post-reform period than during the pre-reform period. However, without a formal clustering analysis, the simple count exercise does not necessarily imply that this is indeed the case.

Table 4: Distances *D(i,j)* **computed between each series (Post-reform)**

	Beijing	Tianjing	Hebei	Shanxi	Mongolia	Liaoning	Jilin	Heilongjiang	Shanghai	Jiangsu	Zhejiang
Beijing		0.16	0.04	0.07	0.12	0.08	0.15	0.04	0.04	0.02	0.02
Tianjing			0.05	0.04	0.05	0.04	0.14	0.02	0.04	0.11	0.11
Hebei				0.08	0.11	0.08	0.09	0.19	0.10	0.37	0.10
Shanxi					0.06	0.01	0.03	0.02	0.02	0.04	0.01
Mongolia						0.03	0.04	0.11	0.03	0.05	0.06
Liaoning							0.05	0.03	0.05	0.03	0.03
Jilin								0.01	0.05	0.12	0.07
Heilongjiang									0.07	0.02	0.02
Shanghai										0.07	0.17
Jiangsu											0.14
Zhejiang											
Anhui											
Fujian											
Jiangxi											
Shandong											
Henan											
Hubei											
Hunan											
Guangdong											
Guangxi											
Sichuan											
Guizhou											
Yunnan											
Shanxi3											
Gansu											
Qinghai											
Ningxia											
Xinjiang											

Table 4 (cont.): Distances $D(i,j)$ computed between each series (Post-reform)

	Anhui	Fujian	Jiangxi	Shandong	Henan	Hubei	Hunan	Guangdong	Guangxi	Sichuan	Guizhou
Beijing	0.01	0.01	0.01	0.03	0.02	0.02	0.01	0.03	0.04	0.06	0.02
Tianjing	0.02	0.01	0.05	0.11	0.05	0.05	0.04	0.02	0.01	0.04	0.01
Hebei	0.05	0.13	0.24	0.26	0.06	0.10	0.15	0.07	0.05	0.15	0.06
Shanxi	0.01	0.00	0.06	0.02	0.01	0.08	0.03	0.01	0.02	0.02	0.02
Mongolia	0.05	0.12	0.04	0.05	0.03	0.07	0.03	0.03	0.02	0.06	0.04
Liaoning	0.02	0.01	0.01	0.05	0.04	0.05	0.03	0.03	0.01	0.07	0.02
Jilin	0.01	0.02	0.05	0.05	0.05	0.04	0.02	0.06	0.01	0.03	0.01
Heilongjiang	0.01	0.01	0.01	0.04	0.16	0.02	0.01	0.07	0.01	0.02	0.08
Shanghai	0.03	0.09	0.03	0.07	0.07	0.09	0.03	0.13	0.02	0.04	0.01
Jiangsu	0.04	0.04	0.08	0.34	0.06	0.04	0.05	0.16	0.09	0.06	0.02
Zhejiang	0.05	0.06	0.06	0.21	0.04	0.05	0.04	0.10	0.04	0.05	0.01
Anhui		0.08	0.03	0.03	0.01	0.04	0.02	0.02	0.02	0.03	0.08
Fujian			0.01	0.04	0.05	0.02	0.01	0.06	0.03	0.05	0.01
Jiangxi				0.05	0.03	0.12	0.08	0.10	0.01	0.06	0.01
Shandong					0.06	0.08	0.02	0.06	0.04	0.09	0.01
Henan						0.03	0.06	0.14	0.04	0.07	0.01
Hubei							0.10	0.03	0.03	0.05	0.06
Hunan								0.01	0.02	0.04	0.02
Guangdong									0.06	0.07	0.02
Guangxi										0.03	0.01
Sichuan											0.03
Guizhou											
Yunnan											
Shanxi3											
Gansu											
Qinghai											
Ningxia											
Xinjiang											

Table 4 (cont.): Distances $D(i,j)$ computed between each series (Post-reform)

	Yunnan	Shanxi3	Gansu	Qinghai	Ningxia	Xinjiang
Beijing	0.03	0.03	0.03	0.04	0.11	0.02
Tianjing	0.01	0.05	0.01	0.02	0.04	0.01
Hebei	0.09	0.13	0.20	0.27	0.06	0.12
Shanxi	0.05	0.02	0.01	0.02	0.04	0.06
Mongolia	0.05	0.12	0.04	0.10	0.06	0.06
Liaoning	0.02	0.04	0.05	0.05	0.06	0.03
Jilin	0.01	0.07	0.03	0.05	0.10	0.01
Heilongjiang	0.01	0.03	0.03	0.04	0.02	0.01
Shanghai	0.02	0.05	0.01	0.01	0.02	0.01
Jiangsu	0.02	0.07	0.01	0.02	0.03	0.04
Zhejiang	0.04	0.03	0.02	0.02	0.02	0.03
Anhui	0.00	0.01	0.01	0.01	0.04	0.01
Fujian	0.02	0.01	0.01	0.01	0.01	0.00
Jiangxi	0.02	0.07	0.01	0.02	0.02	0.04
Shandong	0.03	0.03	0.03	0.03	0.03	0.02
Henan	0.11	0.03	0.12	0.02	0.13	0.01
Hubei	0.06	0.03	0.02	0.04	0.06	0.04
Hunan	0.03	0.03	0.01	0.01	0.01	0.02
Guangdong	0.03	0.02	0.01	0.01	0.02	0.01
Guangxi	0.05	0.02	0.02	0.01	0.03	0.01
Sichuan	0.02	0.07	0.04	0.05	0.07	0.03
Guizhou	0.01	0.02	0.01	0.08	0.10	0.02
Yunnan		0.02	0.02	0.01	0.02	0.01
Shanxi3			0.05	0.07	0.16	0.04
Gansu				0.02	0.10	0.02
Qinghai					0.17	0.04
Ningxia						0.06
Xinjiang						

Looking at the results in Table 2 and 3 together, we can also examine how one province is different from another before and after economic reforms. Such comparisons are presented in Table 5. The values are the changes in distance between two provinces before and after economic reforms, and negative values which are highlighted in grey mean that the distance between two provinces decreases after economic reform. We can see that most of the changes in the distance between individual provinces for the post- and pre-reform periods are negative. This result implies that for most of provinces, they may be still diverging from each other but the extent of divergence has been decreasing during the post-reform period. Given the extended whole distribution basis of our statements above, these results are rather definitive on the process of convergence and its extent.

Table 5: Change in Distances $D(i,j)$ **between pre- and post-reform**

	Beijing	Tianjing	Hebei	Shanxi	Mongolia	Liaoning	Jilin	Heilongjiang	Shanghai	Jiangsu	Zhejiang
Beijing		0.04	-0.12	0.00	-0.09	-0.13	0.03	-0.07	-0.12	-0.02	-0.01
Tianjing			-0.05	-0.22	-0.01	-0.15	0.05	-0.06	-0.13	0.00	0.05
Hebei				-0.09	0.09	-0.02	0.02	0.08	0.03	0.35	0.02
Shanxi					-0.07	-0.20	-0.09	-0.10	-0.08	0.00	-0.10
Mongolia						-0.05	-0.09	0.00	0.00	0.02	0.03
Liaoning							-0.06	-0.08	-0.07	-0.01	-0.12
Jilin								-0.08	0.00	0.08	0.03
Heilongjiang									0.01	-0.02	-0.05
Shanghai										0.00	0.15
Jiangsu											0.11
Zhejiang											
Anhui											
Fujian											
Jiangxi											
Shandong											
Henan											
Hubei											
Hunan											
Guangdong											
Guangxi											
Sichuan											
Guizhou											
Yunnan											
Shanxi3											
Gansu											
Qinghai											
Ningxia											
Xinjiang											

Table 5 (cont.): Change in Distances *D(i,j)* between pre- and post-reform

	Anhui	Fujian	Jiangxi	Shandong	Henan	Hubei	Hunan	Guangdong	Guangxi	Sichuan	Guizhou
Beijing	-0.07	-0.02	-0.07	-0.02	-0.04	-0.04	-0.04	0.00	-0.02	-0.12	-0.01
Tianjing	-0.07	-0.06	0.00	0.06	0.01	0.00	-0.04	-0.04	-0.06	-0.04	-0.04
Hebei	0.00	0.08	0.18	0.22	-0.02	0.07	0.06	0.02	0.02	0.09	0.02
Shanxi	-0.20	-0.16	-0.05	-0.04	-0.07	-0.18	-0.05	-0.04	-0.08	-0.24	-0.15
Mongolia	-0.01	0.08	0.01	0.01	-0.01	-0.08	-0.09	-0.01	-0.02	-0.09	-0.04
Liaoning	-0.08	-0.10	-0.02	-0.01	-0.05	0.00	-0.04	-0.04	-0.08	-0.01	-0.03
Jilin	-0.03	-0.07	-0.03	-0.01	0.00	-0.05	-0.05	0.02	-0.12	-0.05	-0.05
Heilongjiang	-0.09	-0.19	-0.02	-0.02	0.03	-0.02	-0.08	-0.04	-0.05	-0.08	0.03
Shanghai	-0.02	0.05	-0.01	0.03	0.02	0.05	-0.01	0.10	-0.01	0.00	-0.03
Jiangsu	0.02	0.01	0.04	0.32	0.01	-0.36	-0.33	0.13	0.06	0.01	0.00
Zhejiang	-0.02	-0.01	0.03	0.17	-0.05	0.02	-0.02	0.04	-0.12	-0.03	-0.04
Anhui		0.00	-0.01	-0.01	-0.09	-0.02	-0.06	-0.03	-0.02	-0.10	0.04
Fujian			-0.04	-0.01	-0.03	-0.01	-0.05	0.00	-0.07	-0.04	-0.06
Jiangxi				0.01	-0.03	-0.07	0.05	0.09	-0.02	-0.02	-0.03
Shandong					0.01	0.05	-0.02	0.02	0.01	0.04	-0.06
Henan						-0.02	-0.05	0.07	-0.01	-0.20	-0.03
Hubei							0.02	0.00	-0.06	-0.05	-0.08
Hunan								-0.03	-0.02	-0.03	-0.04
Guangdong									0.00	-0.04	-0.02
Guangxi										-0.05	-0.05
Sichuan											-0.02
Guizhou											
Yunnan											
Shanxi3											
Gansu											
Qinghai											
Ningxia											
Xinjiang											

Table 5 (cont.): Change in Distances *D(i,j)* between pre- and post-reform

	Yunnan	Shanxi3	Gansu	Qinghai	Ningxia	Xinjiang
Beijing	0.00	-0.05	-0.03	-0.02	0.03	-0.08
Tianjing	-0.08	-0.05	-0.05	-0.06	-0.09	-0.05
Hebei	0.06	0.08	0.13	0.23	0.02	0.08
Shanxi	-0.14	-0.15	-0.04	-0.03	-0.02	-0.02
Mongolia	-0.02	0.04	-0.02	-0.03	-0.06	-0.05
Liaoning	-0.06	-0.11	-0.02	0.00	0.00	-0.05
Jilin	-0.03	-0.07	-0.02	-0.06	0.02	-0.06
Heilongjiang	-0.03	-0.09	-0.08	-0.01	-0.04	-0.05
Shanghai	-0.02	-0.04	-0.04	-0.05	-0.02	-0.03
Jiangsu	-0.01	0.03	-0.03	0.00	-0.23	0.00
Zhejiang	-0.01	-0.01	-0.04	-0.03	-0.01	-0.01
Anhui	-0.06	-0.03	-0.04	-0.04	0.01	-0.01
Fujian	-0.07	-0.11	-0.03	-0.03	-0.04	-0.05
Jiangxi	-0.07	0.03	-0.02	-0.02	-0.02	0.01
Shandong	-0.06	-0.14	-0.03	-0.01	-0.06	-0.09
Henan	0.07	-0.02	0.00	-0.03	0.12	-0.03
Hubei	0.02	-0.05	-0.01	-0.05	0.02	0.00
Hunan	-0.01	-0.01	-0.06	-0.03	-0.03	-0.01
Guangdong	-0.03	-0.04	-0.09	-0.03	-0.01	-0.07
Guangxi	-0.03	-0.07	-0.03	-0.04	-0.01	-0.03
Sichuan	-0.09	-0.01	-0.19	0.02	0.03	-0.03
Guizhou	-0.05	-0.08	-0.03	-0.04	0.08	-0.06
Yunnan		-0.08	-0.03	-0.04	-0.03	-0.04
Shanxi3			0.00	0.02	0.07	-0.04
Gansu				-0.01	0.07	-0.01
Qinghai					0.08	0.00
Ningxia						0.02
Xinjiang						

As we mentioned above, although we reject that there exists a nation-wide convergence, we find that there are still some distances between individual provinces that are not significant. This finding makes us suspect that there might exist a club convergence. Clustering analysis allows us to find out whether or not this is indeed the case, and if so, how many groups or clubs do we have, and what are the members within each group? The results obtained from clustering analysis for the pre-reform period are summarized in Figure 3. This figure demonstrates how our clustering method proceeds, combining the clusters beginning with the case where each province is its own cluster to the case where all the provinces are in the same cluster. Figure 4 plots the changes in the distances to last member added to the cluster. From Figure 4, we can see there is a marked spike at seven clusters (from the right); Therefore, a much greater distance must be tolerated when the provinces are reduced into seven groups. Hence, it appears reasonable that we have seven convergence clubs. The membership of each club is summarized in Table 6. These results are very interesting. First, although we donot find a nation-wide convergence, we do find club convergence. Also, these convergence clubs are very small, with each of them having no more than five members, except for cluster 3. These results are consistent with Hobijn and Franses (2000) and Corrado *et al* (2005); the former investigates convergence across 115 countries finding 63 asymptotically perfect convergence clubs, and the latter studies the regional convergence in Europe finding more than twenty convergence clubs in all the sectors and most of clubs having only two or three members. Second, these groups cannot be characterized by such unique features as region or the extent of policy preference level. To visualize this fact, we display our clustering groups in Figure 7 and 8, according to their geographical locations and the extent of policy preference level, respectively. From these two figures, one can clearly see that the clustering groups are not at all coincided with the groups based on geographical locations or the extent of policy preference level.

Table 6: Cluster Analysis Results: Prereform Period 1952-1977

Cluster 1:							
	Beijing	Jilin					
Cluster 2:							
	Zhejiang	Gansu	Hebei	Jiangsu	Jiangxi		
Cluster 3:							
	Fujian	Hubei	Hunan	Tianjing	Shanghai	Guangdong	Yunnan
Cluster 4:							
	Shandong	Shanxi	Liaoning				
Cluster 5:							
	Shanxi3	Mongolia	Ningxia	Sichuan			
Cluster 6:							
	Qinghai	Anhui	Guangxi	Heilongjiang			
Cluster 7							
	Henan	Guizhou	Xinjiang				

Table 7: Cluster Analysis Results: Postreform Period 1978-2003

Cluster 1:								
	Beijing	Hunan	Liaoning					
Cluster 2:								
	Jilin	Hebei	Jiangsu	Guangdong	Yunnan	Shandong	Shanxi3	Mongolia
	Ningxia	Heilongjiang	Guizhou	Xinjiang				
Cluster 3:								
	Zhejiang							
Cluster 4:								
	Gansu	Tianjing	Shanxi	Qinghai	Guangxi			
Cluster 5:								
	Jiangxi	Fujian	Hubei	Shanghai	Sichuan	Anhui	Henan	

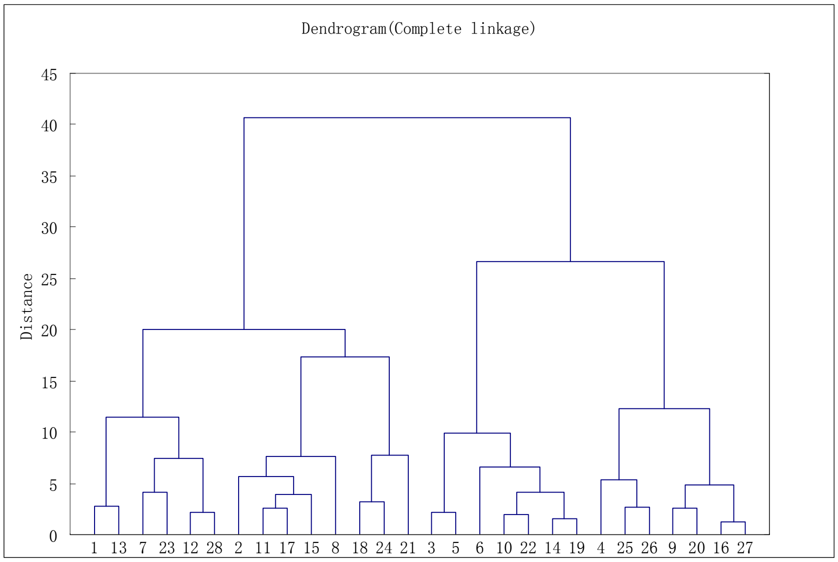

Figure 3

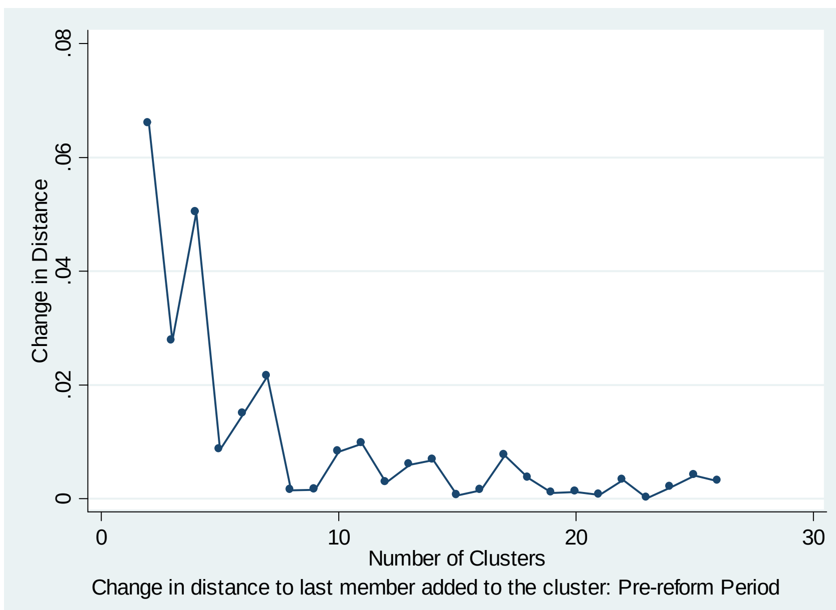

Figure 4

The results obtained from clustering analysis for the post-reform period are summarized in Figure 5 and 6. Examining the changes in the distances to last member added to the cluster in Figure , we can see the first marked spike is at five clusters; this result means that a much greater distance need to be tolerated when the provinces are reduced into five groups. Hence, it would be plausible that we have five convergence clubs. The membership of each club is summarized in Table 7. We again find that there exist a club convergence, and there are three small convergence clubs with less than five members and two large convergence clubs. Moreover, these groups cannot be characterized by such unique features as region or the extent of policy preference level (see Figure 9 and 10). These results are consistent with Pedroni and

Yao (2005); they find that there exists no convergence within the group of interior provinces. However, they were unable to go beyond this finding and answer the question: if they are not converging within this group, which group(s), if any, they are converging to? For example, Pedroni and Yao (2005) detect a *marginal* evidence that the group of northwestern provinces exhibit club convergence. Our results show that this *marginal* evidence comes from the convergence within the majority of the group. In particular, four of them – Shannxi, Mongolia, Ningxia and Xinjiang – are converging to other provinces in the cluster 2, while two remaining provinces – Gansu and Qinghai – are converging to other provinces in the cluster 4. Moreover, one interesting result is noteworthy. There is a cluster with only Zhejiang province. Such a result also reflects the flexibility of our clustering method which allows arbitrarily small clubs. Finally, in comparing the number and size of convergence clubs for both the pre- and post-reform periods, it could be argued that the extent of convergence is more prevalent during post-reform period than during pre-reform period.

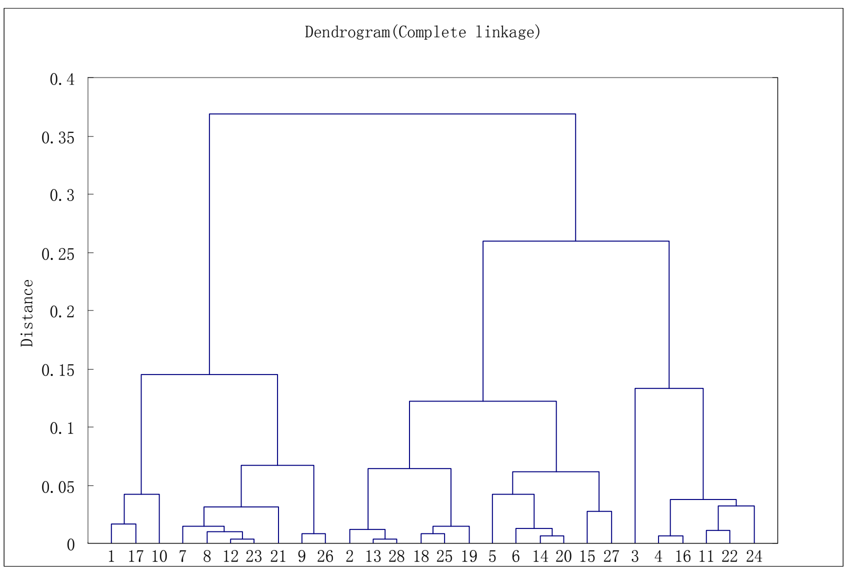

Figure 5

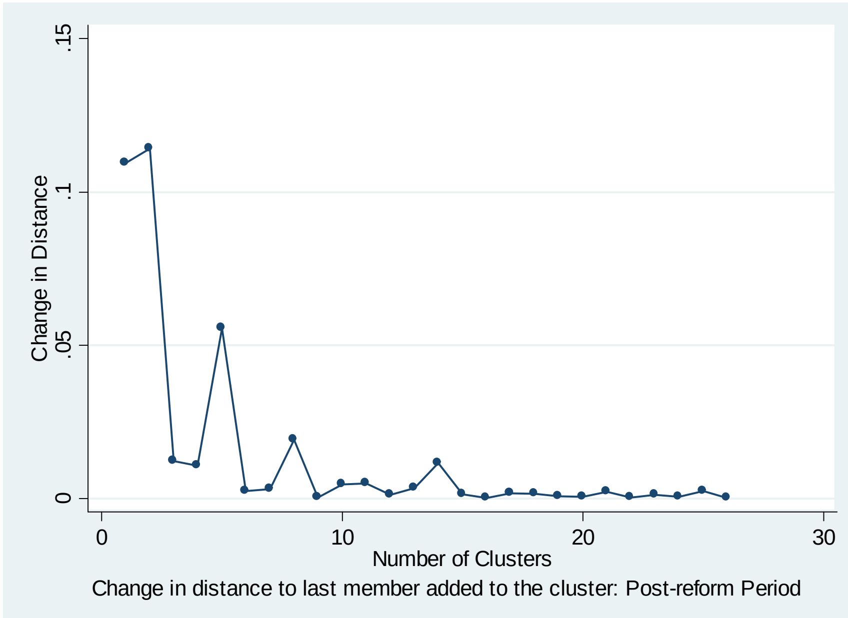

Figure 6

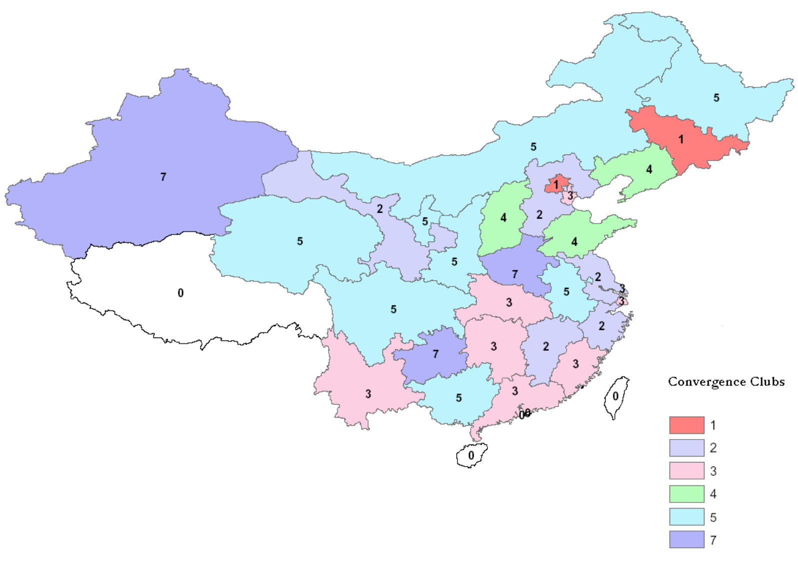

Figure 7: Convergence Clubs: Prereform Period 1952-1977

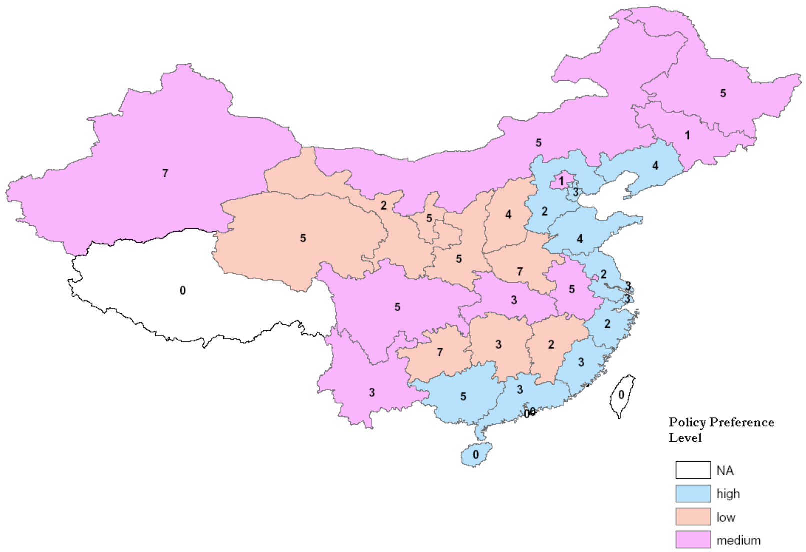

Figure 8: Convergence Clubs and Their Corresponding Policy Preference Level: Prereform Period 1952-1977

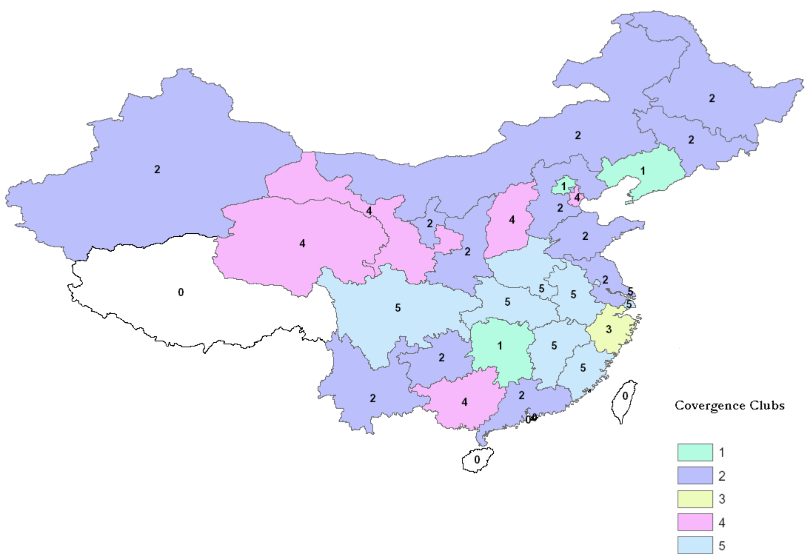

Figure 9: Convergence Clubs Postreform Period 1978-2003

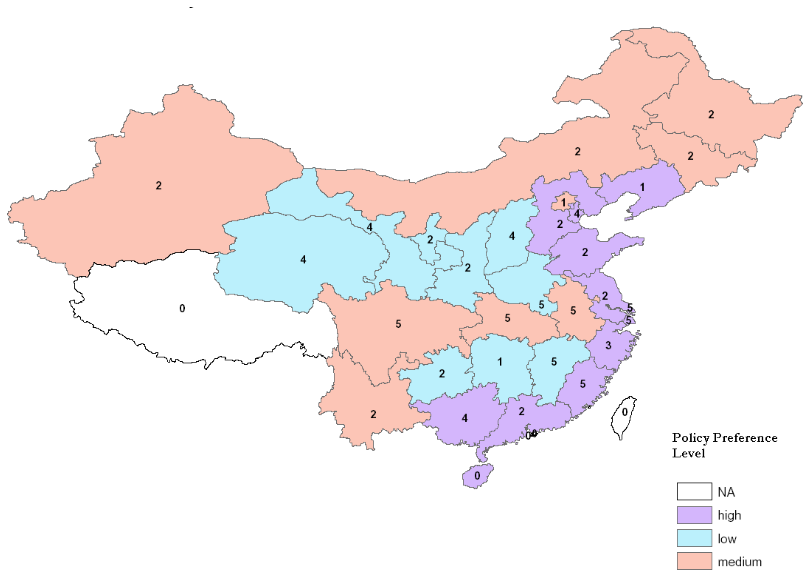

Figure 10: Convergence Clubs and Their Corresponding Policy Preference Level: Postreform Period 1978-2003

5 Conclusions

In this paper, we examine a new concept of convergence based on a metric entropy measure recently proposed by Granger *et al.* (2004). This entropy measure compares whole distributions of growth rates across individual provinces. Based on this entropy measure, we also implement cluster analysis to identify the convergence clubs. Our four main conclusions are: (1) while we certainly reject the null hypothesis that there exists a nation-wide convergence, we do find that there exist convergence clubs for both the pre- and post-reform periods, (2) we find a number of very small convergence clubs. In particular, there are seven and five convergence clubs for the pre- and post-reform periods, respectively. (3) in comparing the number and size of convergence clubs for both the pre- and post-reform periods, it could be argued that the extent of convergence is more prevalent during the post-reform period than during the pre-reform period, (4) convergence groups cannot be characterized by such unique features as region or the extent of policy preference level that are commonly used in the literature.

There are two limitations of our analysis left for future study. First, we forcefully split the sample into two subperiods at the year of 1978, which we consider as the structural break of economic development in China. As Demurger *et al.* (2002) note, economic reforms in China have been, however, proceeding gradually, as opposed to a "big bang" reform in the former Soviet Union and Eastern Europe. Since the latent structural break point may not be at 1978, in future research it can be endogenously determined by the data. Second, the convergence groups found in our analysis can not be simply characterized by such unique features as region or the extent of policy preference level. Then the question is: what are those features charactering the convergence groups that we find in the paper? These questions are still open.

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