Original Paper

Examining Convergence Clubs in Chinese Provinces (1952-2017): New Findings from the Simplified Clustering Convergence Test

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Abstract

This paper empirically investigates the convergence clustering in 31 Chinese provinces regarding the popular and important economic indicator of GDP per capita over the period 1952-2017. Using the club convergence and clustering procedure of Phillips and Sul (2007) with necessary simplifications, a few provincial clusters are identified. It is clearly verified as expected that the Chinese provincial GDP per capita series contain significant nonlinear components. It is found that there are two or three convergence clubs depending on different starting years or initial conditions, and the clustering results are somewhat stable with respect to different starting years. The results can help local and central governments to select appropriate growth promotion strategies for different groups of provinces in general and, due to the evidence that GDP per capita in China heavily inclines to a few major provinces (such as Beijing, Shanghai, Tianjin, Jiangsu and Zhejiang), can also help provide useful information to relevant authorities to fight against the increasing income inequality across provinces in particular.

Keywords

Chinese economy, provincial convergence clubs, convergence clustering, econometric method, GDP per capita, nonlinearity, ordinary least squares

1. Introduction

The neoclassical Solow growth model directly implies the natural assumption of diminishing returns to capital and labor (Mankiw et al., 1992; Sala-i-Martin, 1996; Solow, 1956). Since capital per efficient

unit of labor will converge to a steady state level common to all regions (or countries), regions with the same controlling parameters such as the commonly considered savings rates and population growth rates must eventually arrive at similar levels of per capita income. This will happen in the long-run (e.g., in hundreds or thousands of years), irrespective of each region's initial state as measured by its starting value of per capita income.

The above claim of growth convergence relies on two strong assumptions, i.e., diminishing returns and equal controlling parameters across regions (or countries). It is therefore called overall or unconditional convergence, whose realization may take a very long time. This is well beyond most practical observations, and it may only be possible to empirically show the trend or tendency for unconditional convergence across regions or countries using real world data of, at most, the recent one or two hundred years. Largely due to the limit of real observations, it seems more likely to observe the so called conditional convergence, which can allow for different parameters across regions or countries in a seemingly more practical sense. That is, convergence clubs or groups of, e.g., countries within the European Union (EU), provinces or states within a big economy like China and the US, are more likely to be identified with each club composed of some regions (countries or provinces) exhibiting the tendency of unconditional convergence to a different steady-state level.

Overall or unconditional convergence has been questioned and conditional convergence preferred especially since late 1980s when the new growth theories got started with Romer (1986) and Lucas (1988) which pointed out the clear absence of overall convergence between the poor and rich nations from practical observations. This has spurred a wide range of relevant studies, including various convergence definitions and testing methods. Among a number of convergence definitions are the more popular β-convergence (that poorer countries tend to grow faster than richer countries) and σ-convergence (that income gap between poor and rich countries tends to decline over time) (Baumol, 1986; Barro & Sala-i-Martin, 1992; Mankiw et al., 1992), or the similar catch-up convergence and output convergence (Bernard & Durlauf, 1995, 1996). And most convergence testing methods can be classified into cross-section augmented Solow regressions (Barro & Sala-i-Martin, 1992; Mankiw et al., 1992) and unit-root and cointegration based time series approaches (Bernard & Durlauf, 1995, 1996; Greasley & Oxley, 1997). See Borsi and Metiu (2015), Diaz del Hoyo et al. (2017), and Islam (2003) for overviews of convergence concepts and empirical research methodologies.

Traditionally economists like to examine the idea of growth convergence, which is also of clear policy value for different regions or countries, richer or poorer, to adopt different growth strategies. A general idea is that resources tend to leave richer countries, where economies are already mature with slowed-down growth rates, higher price levels or economic costs, and lower growth potentials, to poorer countries with more and higher growth potentials, which will be highly likely to promote growth convergence between richer and poorer regions or countries.

Many studies have been conducted to show whether or not there is growth convergence across regions or countries using real data and various statistical methods, especially for developed economies such as

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the US and EU countries where higher quality data are more available over a longer time period (Canova, 2004; Cavenaile & Dubois, 2011; Corrado et al., 2005; Mora, 2005; Quah, 1996; Ramajo et al., 2008; Sala-i-Martin, 1996). In this regard, it is worth to mention the special contribution made by the ongoing Maddison Project (Maddison, 1982, 1991, 2007; see also http://www.ggdc.net/maddison/) that compiles data on a larger group of countries over a much longer time period back to the mid-19th century and even earlier.

This paper investigates the issue from another perspective, focusing on growth convergence among the many Chinese provinces from 1952 to the recent year of 2017. Having increasingly more international influence, China is very big in terms of land area, population, and economic scale, with 31 inland provinces (including 22 provinces, five autonomous regions of ethnic minorities, and four municipalities, all called "provinces" for convenience). (Hong Kong, Macao, and Taiwan are the other three special regions of China, which are quite different from the 31 inland provinces historically, economically, and politically, and hence will not be included as in many similar studies.) Each Chinese province is still quite big in land area and population compared to, for example, many EU countries. Thus it is meaningful to study the growth convergence among these Chinese provinces regarding the important economic indicator of gross domestic product (GDP) per capita, which is useful for different provinces to consider different development strategies for future growth. This kind of study is also of certain methodological advantage with no sample selection bias since all inland Chinese provinces are included.

The paper unfolds as follows. After this introduction section, the next section will provide a brief literature review on studies related to growth convergence in general and in relation to Chinese economy in particular, as well as on research methodologies. Section 3 explains the issues related to research methods, especially in relation to the important approach of Phillips and Sul (2007). Data issues, empirical study results and discussions of their potential implications are presented in section 4. Section 5 concludes the paper with some considerations for further studies in the research area.

2. Literature Review

This paper empirically investigates the convergence clustering in China's 31 inland provinces regarding the popular GDP per capita indicator over the period from 1952 to 2017. Using the club convergence and clustering procedure of Phillips and Sul (2007), potential provincial clusters are to be identified to help central and local planners better promote economic growth in different provinces. The main advantage of the innovative method of Phillips and Sul (2007) is that it can take into account the likely heterogeneity across the Chinese provinces within a nonlinear time-varying framework.

Indeed, it is important to investigate the convergence clustering of the Chinese provinces regarding key economic indicators. One of the stylized facts in the literature is that the income inequality in the Chinese provinces has been increased (divergence across provinces) since 1979, due to the significant institutional reforms (Cheong & Wu, 2013, 2014; Ho & Li, 2010; Knight, 2014; Lau, 2010; Lyhagen &

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Rickne, 2014). For instance, Ho and Li (2010) investigate the stochastic properties of output per capita across the Chinese provinces for the period from 1984 to 2003, and they observe the significant evidence of output divergence across the provinces. Similar evidence is also obtained by Lyhagen and Rickne (2014) for half of Chinese cities by using nonlinear trend functions in the vector error correction model (VECM) over the longer period between 1952 and 2007.

However, there are also many papers in the literature which obtain the evidence of convergence of per capita income (output) across the Chinese provinces (e.g., Herrerias & Monfort, 2015; Herrerias & Ordóñez, 2012; Herrerias et al., 2011; Sakamoto & Islam, 2008). For instance, Herrerias et al. (2011) find the evidence of convergence for the GDP per capita across 28 Chinese provinces for the period from 1952 to 2005. Using the panel unit root method of Phillips and Sul (2007), Herrerias and Ordóñez (2012) investigate the stochastic properties of club convergence of Chinese provinces in terms of per capita income, labor productivity, and capital intensity for the period from 1952 to 2008, and find a statistically significant club convergence in the Chinese provinces over the period under concern. Herrerias and Monfort (2015) also investigate the stochastic properties of convergence across 28 Chinese provinces for the period from 1952 to 2008 using the test technique of Phillips and Sul (2007), and observe a significant degree of convergence in capital intensity, labor productivity and total factor productivity in the Chinese provinces.

As a short summary, in the literature there are two types of empirical results regarding the stochastic properties of the per capita income across Chinese provinces. On one hand, there are those which support a *significant divergence* across the Chinese provinces. On the other hand, there are also those which reveal a non-linear *club convergence* across the Chinese provinces. The findings in the current paper will align with the *divergence* one.

The current paper identifies several provincial clusters for GDP per capita in the 31 Chinese provinces for the relatively longer period from 1952 to 2017, contributing to the existing literature (e.g., Herrerias & Ordóñez, 2012, Herrerias & Monfort, 2015) by further implementing the club convergence approach in exploring the long-run behavior of GDP per capita, especially in relation to different starting years. This new evidence can help local and central decision makers select appropriate growth promotion strategies for different groups of provinces in general. And the results of the paper can also help provide useful information to China's relevant authorities to deal with the increasing provincial income inequality in particular.

3. Econometric Methodology

Phillips and Sul (2007) propose a new methodological approach to testing for convergence and identification of convergence clubs. Their method uses a nonlinear time-varying factor model capturing the nonlinear transition mechanisms. One advantage of the methodology is that it does not require the assumptions of stationary series or existence of common factors in the data generating process. Another unique feature of the approach of Phillips and Sul (2007) is that it allows for individual heterogeneity

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of source markets within a panel. The method has been effectively used in identifying convergence clubs among, e.g., many EU economies (Bartkowska & Riedl, 2012; Fritsche & Kuzin, 2011; Simionescu, 2015). In the context of China, this test allows for transitional dynamics of the Chinese provinces to be different in convergence testing within a panel no matter some particular source markets are initially in a state of transition or near steady state equilibrium. Since the growth rates for the individual provinces take a wide range of values over the period from 1952 to 2017, and possibly have different convergence paths, this methodological approach is very appropriate to test for convergence of the Chinese provinces. And the major research goal of this paper is just to identify the convergence clubs in the Chinese provinces using this empirical approach as described below.

3.1 Relative Transition Paths

Let X_{it} denote the variable of interest for province i at time t (i.e., time enters the model in a non-linear fashion), where $i = 1, 2, …, N$ and $t = 1, 2, …, T$. Following Phillips and Sul (2007), the variable can be decomposed into two components: the common component of cross-sectional dependence in a panel, g_{it}, and transitory component, a_{it}, as follows:

$$X_{it} = g_{it} + a_{it}, \text{ for all } i \text{ and } t \tag{1}$$

Phillips and Sul (2007) reformulate eq. (1) as common and idiosyncratic components are separated, and the model takes a nonlinear form as follows:

$$X_{it} = [(g_{it} + a_{it})/\mu_t]\mu_t = \delta_{it}\,\mu_t, \text{ for all } i \text{ and } t \tag{2}$$

where μ_t is a common component and $\delta_{it} = (g_{it} + a_{it})/\mu_t$ is a time varying idiosyncratic element. That is, δ_{it} measures the economic distance between the common trend component μ_t and a source market's individual value of X_{it} at time t in eq. (2). In the scenario of the Chinese GDP per capita for example, μ_t stands for a common GDP per capita trend in the entire 31 provinces, while δ_{it} depicts a relative share of a specific province's GDP per capita in common provincial trend in the entire economy at time t. The main procedure in the convergence test of Phillips and Sul (2007) is to calculate the time-varying loadings δ_{it} such that they can be used to determine the club convergence, if the loadings converge. Next, Phillips and Sul (2007) define the transition coefficient as h_{it} and to extract the time varying factor loading δ_{it} as follows:

$$h_{it} = X_{it}\,/[\textstyle\sum_{j=1\sim N} X_{jt}/N] = \delta_{it}\,\mu_t/[\textstyle\sum_{j=1\sim N} \delta_{jt}\,\mu_t/N] = \delta_{it}/[\textstyle\sum_{j=1\sim N} \delta_{jt}/N] \tag{3}$$

where h_{it} is the transition parameter that measures δ_{it} in relation to the panel average at time t, and therefore it describes the transition path for source market i relative to the panel average. It is suggested that the original data could be smoothed using, e.g., the Hodrick and Prescott (1997) filter, to remove the cyclical trend from the original data (Phillips & Sul, 2007). But to avoid this additional dimension of complexity or uncertainty (which may also not be so necessary for annual macroeconomic series, especially for relative ratios like h_{it}), this step will be omitted in the already quite complex procedure.

The most important part of the club convergence test is to construct the cross sectional variance ratio H_1/H_t where:

$$H_t = \textstyle\sum_{i=1\sim N} (h_{it} - 1)^2/N \tag{4}$$

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Phillips and Sul (2007) prove that the transition distance H_t has a limiting form as such:

$$H_t \sim A/[L^2(t)t^{2\alpha}] \text{ as } t \to \infty \qquad (5)$$

where A is a positive constant, $L(t)$ is a slowly varying function of t with $L(t) \to \infty$ as $t \to \infty$, and α denotes the convergence speed. To test for the null hypothesis of convergence, Phillips and Sul (2007) perform the log t regression such that the null hypothesis of convergence is:

H$_0$: $\delta_i = \delta$ and $\alpha \geq 0$, against the alternative H$_1$: $\delta_i \neq \delta$ for all i or $\alpha < 0$,

where $\delta_{it} \to_p \delta_i$ as $t \to \infty$ (i.e., plim$_{t \to \infty} \delta_{it} = \delta_i$) and δ_{it} is defined in eqs. (2) and (3).

3.2 The log t Regression

Next, the following regression model where $\beta = 2\alpha$:

$$\log(H_1/H_t) - 2 \log L(t) = \alpha + \beta \log t + \varepsilon_t \qquad (6)$$

is estimated using the ordinary least squares (OLS) and sample data as:

$$\log(H_1/H_t) - 2 \log L(t) = a + b \log t + e_t \qquad (7)$$

where $L(t) = \log(t+1)$ is used as suggested by Phillips and Sul (2007) and the fitted coefficient of log t is $b = 2a$, where a is the estimate of α in the null hypothesis. To take into account the impact of initial conditions on the test, the empirical regression is run after a fraction of the sample is removed. The data for this regression starts at some time point $t = [rT]$ with $r > 0$. It is recommend by Phillips and Sul (2007) that $r = 1/3$. For inference purpose, a one-sided t test of the null hypothesis $\alpha \geq 0$ is performed based on the estimate of b and the standard error of the estimate which are calculated using a heteroskedasticity and autocorrelation consistent (HAC) estimator for the long-run variance of the residuals (so the test statistic t_b is normally distributed). The decision rule is that the null hypothesis of convergence is rejected at the 5% significance level if $t_b < -1.645$.

3.3 Club Convergence Algorithm

Phillips and Sul (2007) also argue that a strict rejection of the null of global convergence may not necessarily rule out the existence of sub-group convergence within the panel, and a club convergence algorithm is thus developed to detect possible convergence clusters. Following this procedure, the current paper will bring new information into the convergence process within the 31 provinces in China by revealing whether or not convergence clusters are present in the sample period from as early as 1952 to as recent as 2017. This examination of club convergence is important because the causality relationship within the clusters could be further investigated based on members' economic or structural characteristics within each club. The clustering algorithm is based on repeated log t regressions, and it contains the following four main steps.

Step 1 (Ordering): Order the members (i.e., the X_{it} series) in the panel according to their last observations (i.e., the X_{iT} values).

Step 2 (Core Group Formation): For some $k = 2, 3, …, N$, select k panel members that have the first k highest individual X_{iT} values in the panel to form the subgroup G_k; run the log t regression using data of members in G_k and calculate the convergence test statistic $t_b(k) = t(G_k)$ for this subgroup. Choose the *core group* size k^* by maximizing $t_b(k)$ over $k = 2, 3, …, N$ according to the criterion:

$$k^* = \text{Max}_k\{t_b(k)\} \text{ subject to Min}\{t_b(k)\} > -1.65. \tag{8}$$

Step 3 (Club Membership): Select provinces for membership in the core group G_{k*} (Step 2) by adding ONE remaining province (not in G_{k*}) separately to the core group, and then the log t regression is run and the log t test is done. The new province (member) will be included, if the associated t-statistic is greater than zero (a conservative rule). Convergence criterion will be checked for the club as usual.

Step 4 (Recursion and Stopping): The log t test is run on the group of provinces not selected in Step 3. If this set of provinces converges, then the second club is formed. Otherwise, repeat Steps 1-3 to reveal some sub-convergent clusters. If no subgroups are found (Step 2), then these provinces display a divergent behavior.

It should be noticed that in the first round of calculations of the above algorithm, Step 2 needs to run the not-simple log t regression many (up to N-1) times for finding the first core group G_{k*}, then Step 3 also needs to run the log t regression many (up to N-k^*) times for determining the first convergence club. If the provinces not in the just-determined club 1 do not converge (based on a log t regression for them), then Steps 1-3 are repeated on them to determine the second convergence club, and so on. Clearly, many log t regressions need to run on different groups of provinces and for each of such regressions many new h_{it} and H_t values as defined in eqs. (3) and (4) need to be calculated on the corresponding new group of provinces, which is really too complex and cumbersome, especially for large N as in this paper. Necessary simplifications are thus worth of considerations in practically applying the above algorithm, especially in the seemingly not so crucial Step 3, for clustering many regions into a number of convergence clubs, which will be carefully proposed when needed in the following real application of the convergence clustering algorithm.

4. Empirical Results, Discussions, and Policy Implications

4.1 Data

This paper investigates China's potential provincial convergence clusters for the popular and important economic indicator of GDP per capita. The study covers the 31 inland Chinese provinces over the 66 years' period from 1952 to the recent year of 2017. The related data are obtained from the database of the China Yearly Provincial Macro-economy Statistics of China Data Online (https://www.china-data-online.com/), and the frequency of the data is yearly. A summary of the descriptive statistics of the GDP per capita data is shown in Table 1, where the average and standard deviation of GDP per capita in the covered 66 years are especially reported for each province. The 31 provinces are ranked based on their actual GDP per capita in the last sample year of 2017, and the ranking is quite similar to that based on the last five years' average as shown in Table 1, showing certain stability in the provinces' average income positions. The relative share of each province's per capita GDP in the last report year of 2017 over the 31 provinces' total is also listed in the last column of Table 1, based on which it can be seen that the Chinese GDP per capita heavily inclines to five major provinces: Beijing, Shanghai, Tianjin, Jiangsu, and Zhejiang with a sub-total share of 30.41%. By

comparing the average annual growth rates of the 31 provinces' GDP per capita in the last five, ten and twenty years (not reported here for the sake of saving space), it is interesting to notice that provinces with higher final-year GDP per capita generally grow more slowly, showing certain trend in growth convergence. This stylized fact is similar to that found in, e.g., Lau (2010).

Table 1. GDP per Capita in the 31 Chinese Provinces (1952-2017, RMB Yuan)

Code	Province	Average (1952-2017)	StDev (1952-2017)	Average (2013-2017)	2017	Share (2017)
1	Beijing	21204.49	33914.17	109666.40	128994.11	6.84%
2	Shanghai	22756.32	33533.96	107070.94	126634.15	6.71%
3	Tianjin	19512.81	33432.55	109458.69	118943.57	6.30%
4	Jiangsu	14566.08	26655.70	89852.00	107150.00	5.68%
5	Zhejiang	14072.44	24179.20	79284.69	92057.01	4.88%
6	Fujian	11411.44	20487.84	69393.30	82677.00	4.38%
7	Guangdong	12512.22	21002.17	68950.60	80932.00	4.29%
8	Shandong	11036.64	19547.84	64694.50	72807.14	3.86%
9	Inner Mongolia	11323.70	21459.04	69162.10	63764.00	3.38%
10	Chongqing	8060.06	15417.03	53067.60	63442.00	3.36%
11	Hubei	7991.07	14937.31	51297.64	60199.00	3.19%
12	Shaanxi	7499.82	14411.02	49190.66	57266.31	3.04%
13	Jilin	8654.55	15384.04	51476.00	54838.00	2.91%
14	Liaoning	11160.87	18528.92	59373.88	53526.65	2.84%
15	Ningxia	7239.57	13257.90	44642.20	50765.00	2.69%
16	Hunan	6913.94	12695.70	43181.48	49558.00	2.63%
17	Hainan	11490.20	14017.06	41636.34	48430.00	2.57%
18	Henan	6638.91	11947.56	39930.96	46674.00	2.47%
19	Hebei	7681.89	12870.75	41519.40	45387.00	2.41%
20	Xinjiang	7263.38	12164.10	40748.31	44941.00	2.38%
21	Sichuan	6048.64	11114.54	37834.86	44651.32	2.37%
22	Qinghai	6764.38	12103.03	41075.20	44047.00	2.33%
23	Jiangxi	6042.93	10998.06	37430.47	43424.37	2.30%
24	Anhui	5913.58	10845.69	37076.88	43401.36	2.30%
25	Shanxi	6777.49	11450.93	36512.91	42060.00	2.23%
26	Heilongjiang	7702.18	12202.21	39746.57	41916.00	2.22%
27	Tibet	5314.44	9386.98	32405.60	39267.00	2.08%
28	Guangxi	5706.18	10328.11	35029.96	38102.00	2.02%

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29	Guizhou	4249.91	8540.28	30127.46	37956.06	2.01%
30	Yunnan	4902.63	8535.20	29341.13	34221.00	1.81%
31	Gansu	4597.73	7910.57	26655.31	28496.50	1.51%
	Average	**9451.952**	**16234.176**	**53768.841**	**60855.760**	**100.00%**

4.2 Overall Convergence or Not

The practical algorithm for the econometric approach of Phillips and Sul (2007) as outlined in section 3.3 is applied to identify possible provincial clusters for Chinese GDP per capita into distinct convergence clubs. To avoid or reflect the potential base year effect in the results, for the 66 years' available data from 1952 to 2017, calculations and estimations are conducted just using data starting from year [66r], where r, a proportion between 0 and 1, takes the following values:

1) $r = 0$, i.e., all data will be used with 1952 as the starting year.

2) $r = 1/6$, i.e., calculations will use data starting from year 11 or 1962.

3) $r = 1/3$, i.e., calculations will use data starting from year 12 or 1973.

Since China's economic reform started in 1978 has very important effect in Chinese economy, one more test using data started from 1978 is also considered.

Firstly, equations for the overall log t regression with the four different starting years are estimated as follows using the professional EViews package:

1952-2017: $\log(H_1/H_t) - 2 \log\log(t+1)$ =   -0.731 $- 0.579 \log t$

                                                         (-3.337)   (-8.869)

                                                         [-1.424]   [-3.760]

1962-2017: $\log(H_1/H_t) - 2 \log\log(t+1)$ =   -0.625 $- 0.509 \log t$

                                                         (-2.778)   (-7.246)

                                                         [-1.087]   [-2.902]

1973-2017: $\log(H_1/H_t) - 2 \log\log(t+1)$ =   -0.400 $- 0.367 \log t$

                                                         (-2.271)   (-6.257)

                                                         [-0.935]   [-2.542]

1978-2017: $\log(H_1/H_t) - 2 \log\log(t+1)$ =   0.044 $- 0.435 \log t$

                                                         (0.280)   (-7.956)

                                                         [0.167]   [-4.084]

Here, under each regression equation, the numbers in parentheses are the traditional *t*-statistics while the numbers in square brackets are the HAC *t*-statistics. Although the HAC *t*-statistics for the estimated log *t* coefficients are much less negative than the traditional *t*-statistics as expected, they are still much smaller than the critical value of -1.65, implying that the null hypothesis of convergence in the 31 Chinese provinces' GDP per capita is clearly rejected at the 5% significance level. Therefore, it is meaningful to consider to appropriately group the Chinese provinces into some convergence clusters in order to have different effective economic policies.

4.3 The First Convergence Club

Secondly, the previously outlined algorithm is used to find convergence clusters for the 31 Chinese provinces. Intuitively, when there is evidence of multiple club convergence in the long-run, this should be apparent in the final (time series) observations such that regions with closer final observations are more likely to be in the same convergence group. Therefore, initially the 31 Chinese provinces are ranked and clustered according to their last observations (i.e., their 2017 per capita GDP values). In detail, 30 subgroups, each with k provinces, denoted $G_k = \{1, \ldots, k\}$, are constructed for provinces with the k highest final observations in 2017, for $k = 2, \ldots, 31$. For example, the first subgroup is $G_2 = \{1, 2\}$ and includes Beijing and Shanghai, the first two provinces with the first two highest per capita GDP in 2017. Then the province with the next highest 2017 per capita GDP is added to the latest subgroup to form the next subgroup. Within each of these 30 subgroups, the log t regression is estimated and the corresponding HAC t-statistic is reported for doing club convergence test for the subgroup, with the afore-mentioned four different starting years so as to check the base year effect on the convergence test. The full results are reported in Table 2 where, for example, the row corresponding to code 10 indicates that Chongqing is the province with the 10th highest per capita GDP in 2017, and each t-statistic in that row is for the log t coefficient of the estimated regression equation for subgroup G_{10} (of the 10 provinces with the 10 highest GDP per capita in 2017) with data started from a specific year.

Table 2. t-statistics (Based on HAC Standard Errors) of log t Regressions for Different Groups of Chinese Provinces in Different Time Periods (Club 1)

Code	Province	GDP per capita 2017	t-statistics (based on HAC standard errors)			
			1952-2017	1962-2017	1973-2017	1978-2017
1	Beijing	128994.11				
2	Shanghai	126634.15	1.317	1.878	2.050	2.325
3	Tianjin	118943.57	0.408	1.030	1.192	1.358
4	Jiangsu	107150.00	-0.127	0.358	0.590	0.599
5	Zhejiang	92057.01	-0.067	0.377	0.705	0.629
6	Fujian	82677.00	-0.312	0.162	0.527	0.360
7	Guangdong	80932.00	-0.299	0.135	0.573	0.363
8	Shandong	72807.14	-0.308	0.111	0.531	0.263
9	Inner Mongolia	63764.00	-0.575	-0.060	0.468	0.257
10	Chongqing	63442.00	-0.881	-0.330	0.202	-0.128
11	Hubei	60199.00	-1.119	-0.573	-0.053	-0.485
12	Shaanxi	57266.31	-1.336	-0.755	-0.254	-0.715
13	Jilin	54838.00	-1.526	-0.912	-0.385	-0.892
14	Liaoning	53526.65	**-1.666**	-1.015	-0.515	-1.065

15	Ningxia	50765.00	-1.881	-1.224	-0.731	-1.310
16	Hunan	49558.00	-2.007	-1.360	-0.870	-1.494
17	Hainan	48430.00	-2.147	-1.484	-1.016	**-1.739**
18	Henan	46674.00	-2.172	-1.525	-1.082	-1.857
19	Hebei	45387.00	-2.197	-1.559	-1.140	-1.971
20	Xinjiang	44941.00	-2.405	**-1.673**	-1.220	-2.169
21	Sichuan	44651.32	-2.432	-1.726	-1.306	-2.306
22	Qinghai	44047.00	-2.633	-1.895	-1.460	-2.483
23	Jiangxi	43424.37	-2.766	-2.016	-1.555	-2.605
24	Anhui	43401.36	-2.854	-2.095	-1.639	-2.733
25	Shanxi	42060.00	-2.997	-2.198	**-1.743**	-2.915
26	Heilongjiang	41916.00	-3.193	-2.356	-1.907	-3.174
27	Tibet	39267.00	-3.391	-2.561	-2.127	-3.496
28	Guangxi	38102.00	-3.386	-2.573	-2.158	-3.528
29	Guizhou	37956.06	-3.511	-2.663	-2.255	-3.655
30	Yunnan	34221.00	-3.600	-2.738	-2.342	-3.830
31	Gansu	28496.50	-3.760	-2.902	-2.542	-4.084

4.3.1 Some Basic Results

It can be seen from Table 2 that, for a given subgroup G_k of provinces with the k highest per capita GDP in 2017 ($k = 2, …, 31$), generally the HAC t-statistic for the log t regression with data starting from 1952 is clearly smaller than that with data starting from 1962, which in turn is clearly smaller that with data starting from 1973. This means that, if starting from later years (or discarding earlier years) before 1978, the group of provinces tends to be more convergent if convergent or less divergent if not convergent in terms of average income, an evidence that tends to be in favour of long-run economic convergence among the group of provinces.

The results as summarized in Table 2 also show that the HAC t-statistics for the log t regressions with data starting from 1978 are:

1) larger than those with data starting from 1952, 1962 and 1973 (and all are bigger than the critical value of -1.645) for the first three subgroups G_2, G_3 and G_4, implying stronger convergence trend for the four highest income provinces (Beijing, Shanghai, Tianjin and Jiangsu) after 1978 than before.

2) larger than those with data starting from 1952 and 1962 but smaller than those with data starting from 1973 (and all are bigger than the critical value of -1.645) for the next nine subgroups G_4 to G_{13}, implying stronger convergence trend for these subgroups of higher income provinces after 1973 and 1978 than before.

3) smaller than those with data starting from 1962 and 1973 but bigger than those with data starting from 1952 for the next 13 subgroups G_{14} to G_{26}, implying that the convergence trend starting from 1978

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when lower income provinces (codes 14-26) are included into the previous groups is weaker than that if starting from 1962 and 1973 but stronger than that if starting from 1952.

4) smaller than those with data starting from 1952, 1962 and 1973 (and all are smaller than the critical value of -1.645) for the last five subgroups G_{27} to G_{31}, implying stronger divergence trend when the five lowest income provinces (Tibet, Guangxi, Guizhou, Yunnan and Gansu) are also included after 1978 than before. These different results show that China's economic reform started in late 1978 has big but different effects in economic convergence among its provinces.

Another simple and also reasonable observation from Table 2 is that, with more and more relatively lower income provinces are included, the bigger group of provinces tends to be less convergent or more divergent, as evidenced by the generally smaller (or more negative) HAC t-statistics for the log t regressions with data starting from any of the four chosen years of 1952, 1962, 1973 and 1978.

4.3.2 Clustering Results

If no data are dropped and the initial year of 1952 is just used as the *real* base year for modelling and calculations, then it is clear from Table 2 that G_{13} of the 13 provinces with the highest 2017 per capita GDP still has an HAC t-statistic of -1.526, smaller than -1.645, and thus can be viewed as a meaningful (first) convergence club. Here as well as in the following section 4.4, the complex and cumbersome procedures in the club convergence algorithm of Phillips and Sul (2007), especially the seemingly not so crucial Step 3, will *not be fully followed*, but just the log t regression test will be applied mainly to bigger and clearer clusters, for determining convergence clubs. The remaining 18 provinces (with codes 14-31) with lower 2017 per capita GDP will similarly be clustered later.

If all calculations are done using data just from 1962, 1973 or 1978, then it can be concluded from the results shown in Table 2 that G_{19}, G_{24} and G_{16} are the corresponding meaningful (first) convergence clubs respectively. In each case, the remaining provinces with lower 2017 per capita GDP will similarly be further clustered.

Clearly, with different starting years, the first convergence clubs as determined above are different, which is worth of further examinations. Just taking one example here for future considerations: what happened to the three provinces of Liaoning, Ningxia and Hunan (codes 14-16 in term of 2017 per capita GDP among the 31 provinces) from 1952 to 1978 such that without including these three provinces, the 13 provinces with the highest 2017 per capita GDP form a convergence club (G_{13}) if evaluated from 1952, and when adding these three provinces sequentially to G_{13}, they will not form convergence clubs if evaluated from 1952, but still form convergence clubs if evaluated from 1978? In other words, what were the reasons making these three provinces more different from the 13 higher income provinces from 1952 to 1978 but more similar after 1978?

4.4 Other Convergence Clubs

Thirdly, after determining the first convergence club in each of the four cases with different starting years as above, the same procedure is used among the remaining provinces to determine the next convergence clubs. The key results are given in Table 3, where the third row shows the first

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convergence clubs in the four cases (G_{13}, G_{19}, G_{24} and G_{16} respectively), the next row just shows that in each case, if the province with the next highest 2017 per capita GDP is included into the group, the group is no longer a convergence one because of the resulting HAC t-statistic < -1.645.

Table 3. t-statistics (Based on HAC Standard Errors) of log t Regressions for Different Groups of Chinese Provinces in Different Time Periods (All Clubs)

1952-2017		1962-2017		1973-2017		1978-2017	
Group members (codes*)	t-statistic	Group members (codes*)	t-statistic	Group members (codes*)	t-statistic	Group members (codes*)	t-statistic
1-13	-1.526	1-19	-1.559	1-24	-1.639	1-16	-1.494
1-14	-1.666	1-20	-1.673	1-25	-1.743	1-17	-1.739
14-31	-2.216	20-31	-1.479	25-31	-1.791	17-31	-3.067
14-30	-1.771	20-30	-0.951	25-30	-0.972	17-30	-2.048
14-29	-1.598					17-29	-1.565
14-28	-1.213					17-28	-1.000
30-31	1.155						
29-31	-1.375						
28-31	-3.852						

*: See Tables 1-2 for which province is tagged with which code number.

If just the initial starting year of 1952 is used as the real base year without dropping any data, then G_{13} of the 13 provinces with the highest 2017 per capita GDP forms the first convergence club. Then the same procedure is applied as above for the remaining 18 provinces (with codes 14-31) with lower 2017 per capita GDP to determine the next convergence club(s). A group with only the 14th province (of Liaoning) is first formed initially and the province with the next higher 2017 per capita GDP is added sequentially one-by-one into it, then the log t regression is run for the group until the corresponding HAC t-statistic is still bigger than the critical value of -1.645. As expected and also as shown in rows 5-8 of the first panel (for 1952-2017) of Table 3, when more provinces are included into the group, the resulting HAC t-statistic generally decreases, and finally provinces 14-29 (with codes 14-29) form the second convergence club with a corresponding HAC t-statistic of -1.598, still bigger than -1.645. The remaining two provinces of Yunnan and Gansu (codes 30 and 31) with the lowest 2017 per capita GDP form the third convergence club with an HAC t-statistic of 1.155, much bigger than -1.645. Based on the calculations as shown in the first panel (for 1952-2017) of Table 3, it is also statistically acceptable that provinces 14-28 form the second convergence (HAC t-statistic = -1.213) and the last three provinces with the lowest 2017 per capita GDP form the third convergence club (HAC t-statistic = -1.375).

If the year of 1962 is used as the starting year for calculations, then as analysed above, the first convergence club can be as large as G_{19} composed of provinces with the 19 highest 2017 per capita GDP with an HAC t-statistic of -1.559, still bigger than -1.645. As shown in the second panel (for 1962-2017) of Table 3, the remaining 12 provinces (codes 20-31) with lower 2017 per capita GDP can be the second convergence club (HAC t-statistic = -1.479 > -1.645).

If the year of 1973 is considered as the starting year for calculations, then the first convergence club can be very large, i.e., as large as G_{24} composed of 24 provinces with relatively higher 2017 per capita GDP (HAC t-statistic = -1.639, still bigger than -1.645). As shown in the third panel (for 1973-2017) of Table 3, among the remaining 7 provinces (codes 25-31) with lower 2017 per capita GDP, the first six provinces (codes 25-30) can be further clustered into a convergence club (HAC t-statistic = -0.972 > -1.645). The last province of Gansu with the lowest 2017 per capita GDP, if needed, could be viewed as another club.

If the year of 1978 when China started its economic reform is adopted as the starting year for calculations, then the first convergence club can be as large as G_{16} with the first 16 highest 2017 per capita GDP provinces (HAC t-statistic = -1.494 > -1.645). As shown in the last panel (for 1978-2017) of Table 3, among the remaining 15 provinces (codes 17-31) with lower 2017 per capita GDP, the first 13 provinces (codes 17-29) can be further clustered into a second convergence club (HAC t-statistic = -1.565, still larger than -1.645). The last two provinces of Yunnan and Gansu (codes 30 and 31) with the lowest 2017 per capita GDP form the third convergence club (HAC t-statistic = 1.658 > -1.645).

4.5 Discussions and Policy Implications

Firstly, it is found that China's per capita GDP time series contains significant nonlinear components as implied by the successful applications of Phillips and Sul's (2007) approach, and heavily inclines to five major provinces, Beijing, Shanghai, Tianjin, Jiangsu, and Zhejiang with a sub-total share of as high as 30.41% (see Table 1).

Secondly, it is observed that there are two or three significant convergence clusters for GDP per capita in China's 31 inland provinces. However, the clustering results vary depending on starting years or initial conditions. In general, there can be two to three convergence clubs. In detail, if the convergence clustering analysis is conducted from the earliest year of 1952, then provinces 1-13 (G_{13}) with the first 13 highest 2017 GDP per capita form the first convergence club, the next 16 provinces (codes 14-29) with lower 2017 GDP per capita form the second convergence club, and the last two provinces (codes 30-31) with the lowest 2017 GDP per capita form the third convergence club. If the convergence clustering analysis is performed from the later year of 1962, then provinces 14-19 can be added to the previous G_{13} to form a bigger convergence club of 19 provinces (G_{19}) with the first 19 highest 2017 GDP per capita. The remaining 12 provinces (codes 20-31) with the 12 lowest 2017 GDP per capita form another convergence club. It can be concluded from these observations that provinces 14-19 (Liaoning, Ningxia, Hunan, Hainan, Henan and Hebei) tended to be more similar with provinces 1-13 and more dissimilar with provinces 20-29 after 1962 than from 1952-1961. Therefore it is of theoretical

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and practical interests to examine what big changes (e.g., increased or decreased industrial investments) had occurred to provinces 14-19 after 1962 compared with before and relative to other provinces.

Thirdly, if the convergence clustering analysis starts from an even later year of 1973, then provinces 20-24 can further be added to the previous G_{19} to form a very big convergence club of 24 provinces (G_{24}) with the first 24 highest GDP per capita in 2017. The next six provinces (codes 25-30) with lower 2017 GDP per capita form another convergence club, and the last province (Gansu, code 31) with the lowest 2017 GDP per capita cannot be clustered into the previous group. It can thus be concluded that these five provinces 20-24 (Xinjiang, Sichuan, Qinghai, Jiangxi and Anhui) tended to be more similar with provinces 1-19 and more dissimilar with provinces 25-30 after 1973 than from 1962-1972. Therefore again it is worth to examine what structural changes (e.g., increased or decreased agricultural investments) had occurred to provinces 20-24 after 1973 compared with the previous years from 1962-1972 and relative to other higher GDP per capita provinces as well as other lower GDP per capita provinces.

Fourthly and more interestingly, if the whole analysis is from the later historical year of 1978 when China started its unprecedented economic reform, then the convergence clustering results are quite similar to those obtained from using the earliest year of 1952 as the natural starting point. The small difference is just that, if started from 1978 rather than 1952, provinces 14-16 (Liaoning, Ningxia and Hunan) would be moved from the second convergence club into the first one. This implies that the three middle-income provinces 14-16 were more similar with the higher income provinces 1-13 and more dissimilar with the lower-income provinces 17-29 after 1978 than before, suggesting that it is meaningful to explore what fundamental changes (e.g., more or less economic reform) had occurred to these three provinces after 1978 compared with the previous years from 1962-1972 and relative to other higher GDP per capita provinces as well as other lower GDP per capita provinces. This finding provides an important new evidence for the club or conditional convergence of Chinese average income at provincial level, which, as it should be, does not depend much on starting years.

From the practical perspective, the above results provide useful information to China's central government and local authorities to deal with the increasing provincial income inequality, especially among the identified convergence clubs. The key point is that provinces clustered into different convergence clubs in terms of average income are expected to exhibit clear differences in some macroeconomic indicators or policies (such as inflation rate, consumption-income ratio, the ratio of fixed asset investment over GDP, and government expenditures in education as a ratio of total government expenditures), which, through comparative studies, can help higher income provinces maintain and enhance their competitive advantages and especially help lower income provinces catch up with the wealthier ones more quickly.

It is also worth mentioning that the clustering results of this study are largely stable irrespective of the different starting years used. This could also have a negative implication that it has been difficult for poorer provinces to leave the poorer club. Therefore, poorer Chinese provinces should work harder in

more strategically important areas such as investing more in education and providing favorable conditions to attract more and higher quality investments from other Chinese provinces and other countries, in order to establish some important competitive advantages so as to catch up with the wealthier ones in the long-run.

5. Conclusions and Future Research Directions

The current paper empirically investigates the convergence clustering in 31 Chinese provinces regarding the important and popular economic indicator of GDP per capita over the period from 1952 to the recent year of 2017. Using the club convergence and clustering procedure of Phillips and Sul (2007) with necessary simplifications, a few provincial clusters are identified. It should be noticed that, over the period under study, China has undergone a number of significant transformations, including transferring from the command or planned economy before 1978 to the socialist market economy after 1978, reforming its public ownership and especially the dominant state-owned enterprises (SOEs) to have more and more private ownership and non-SOEs since mid-1990s, as well as joining WTO (World Trade Organization) in 2001 and having more and more economic integrations with other countries and regions (especially with the developed economies) since then. Hence the econometric methodology adopted in this paper is deemed a suitable technique which can capture the time-varying effects and heterogeneity among the Chinese provinces with quite different natural, historical and socioeconomic conditions. As such, absolute or overall convergence may not be expected for the Chinese provinces, at least at this stage, but as in some similar investigations in the Chinese context and in some studies for other countries and regions, the results of this paper show that Chinese provinces have revealed clear tendency to converge into a few clubs in terms of average income levels.

The current study produces a number of meaningful empirical findings in this direction. Firstly, as expected, it is observed that Chinese GDP per capita series contain significant nonlinear components as validated by Phillips and Sul's (2007) approach. Secondly, it is found that there are two or three significant convergence clusters based on the GDP per capita data in China's 31 inland provinces. Although the clustering results vary somewhat depending on starting years (1952, 1962, 1973, or 1978) or initial conditions, in general the two or three convergence clubs are relatively similar in membership structures, indicating an important evidence for the conditional or club convergence of Chinese average income at provincial level. These results can help local and central governments implement different economic growth policies for different groups of provinces.

Economic convergence studies as this paper need data over longer time period to get more stable and convincing results, which can be expected to be conducted with the availability of more recent and future GDP per capita data at China's provincial level. To support policy analysis for different convergence clubs, future studies can be suggested to directly link GDP per capita to such more controllable variables as tax rates on labor and consumption using econometric models in a more general convergence clustering framework (Donath & Mura, 2019). In the future it is also meaningful

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to extend the current study to some other important economic variables such as income-consumption ratios, inflation rates, unemployment rates, industrial output, fixed-asset investments, monetary aggregates, and interest rates as once examined by, e.g., Brada et al. (2005), Kutan and Yigit (2005, 2007), Chow (1985, 2010, 2011, 2016), Chow and Wang (2010), Nagayasu (2011), Tillmann (2013), and Zhang (2011, 2013a, 2013b). This can be expected to produce more comprehensive and reliable results in grouping Chinese provinces into more specific convergence clusters to help promote China's economic growth and structural change more effectively. It is also expected that, applying the same club convergence and clustering procedure of Phillips and Sul (2007), internationally comparable studies can be done with other developing countries with available long-period data in average income (and inflation, consumption and unemployment rates) to further validate the ideas and results of (conditional) economic convergence from a broader perspective in the future.

Last but not the least, this paper suggests and actually uses some necessary simplifications of the popular convergence clustering algorithm of Phillips and Sul (2007) which usually involves many rounds of complex and cumbersome calculations on different groups of provinces. It is hoped that more simplifying efforts, including validations of these simplifications, can be done in the future to make the algorithm more welcome in economic growth convergence studies.

References

Barro, R. J., & Sala-i-Martin, X. X. (1992). Convergence. *Journal of Political Economy*, *100*(2), 223-251. https://doi.org/10.1086/261816

Bartkowska, M., & Riedl, A. (2012). Regional convergence clubs in Europe: Identification and conditioning factors. *Economic Modelling*, *29*(1), 22-31. https://doi.org/10.1016/j.econmod.2011.01.013

Baumol, W. J. (1986). Productivity growth, convergence, and welfare: What the long-run data show. *The American Economic Review*, *76*(5), 1072-1085.

Bernard, A. B., & Durlauf, S. N. (1995). Convergence in international output. *Journal of Applied Econometrics*, *10*(2), 97-108. https://doi.org/10.1002/jae.3950100202

Bernard, A. B., & Durlauf, S. N. (1996). Interpreting tests of the convergence hypothesis. *Journal of Econometrics*, *71*(1-2), 161-173. https://doi.org/10.1016/0304-4076(94)01699-2

Borsi, M. T., & Metiu, N. (2015). The evolution of economic convergence in the European Union. *Empirical Economics*, *48*(2), 657-681. https://doi.org/10.1007/s00181-014-0801-2

Brada, J. C., Kutan, A. M., & Zhou, S. (2005). Real and monetary convergence between the European Union's core and recent member countries: A rolling cointegration approach. *Journal of Banking*

& Finance, *29*(1), 249-270. https://doi.org/10.1016/j.jbankfin.2004.06.024

Canova, F. (2004). Testing for convergence clubs in income per capita: A predictive density approach. *International Economic Review*, *45*(1), 49-77. https://doi.org/10.1111/j.1468-2354.2004.00117.x

Cavenaile, L., & Dubois, D. (2011). An empirical analysis of income convergence in the European Union. *Applied Economics Letters*, *18*(17), 1705-1708. https://doi.org/10.1080/13504851.2011.560104

Cheong, T. S., & Wu, Y. (2013). Regional disparity, transitional dynamics and convergence in China. *Journal of Asian Economics*, *29*(December), 1-14. https://doi.org/10.1016/j.asieco.2013.08.007

Cheong, T. S., & Wu, Y. (2014). The impacts of structural transformation and industrial upgrading on regional inequality in China. *China Economic Review*, *31*(December), 339-350. https://doi.org/10.1016/j.chieco.2014.09.007

Chow, G. C. (1985). A model of Chinese national income determination. *Journal of Political Economy*, *93*(4), 782-792. https://doi.org/10.1086/261330

Chow, G. C. (2010). Note on a model of Chinese national income determination. *Economics Letters*, *106*(3), 195-196. https://doi.org/10.1016/j.econlet.2009.11.018

Chow, G. C. (2011). Lessons from studying a simple macroeconomic model for China. *Economics Letters*, *112*(3), 233-235. https://doi.org/10.1016/j.econlet.2011.05.004

Chow, G. C. (2016). Important laws governing China's macro-economy. *Journal of Comparative Economics*, *44*(2), 289-294. https://doi.org/10.1016/j.jce.2015.10.011

Chow, G. C., & Wang. P. (2010). The empirics of inflation in China. *Economics Letters*, *109*(1), 28-30. https://doi.org/10.1016/j.econlet.2010.07.009

Corrado, L., Martin, R., & Weeks, M. (2005). Identifying and interpreting regional convergence clusters across Europe. *The Economic Journal*, *115*(502), C133-C160. https://doi.org/10.1111/j.0013-0133.2005.00984.x

Diaz del Hoyo, J. L., Dorrucci, E., Heinz, F. F., & Muzikarova, S. (2017). *Real convergence in the Euro area: A long-term perspective* (ECB Occasional Paper). Retrieved from https://www.ssrn.com/abstract=3082205

Donath, L. E., & Mura, P-O. (2019). The looming Central and Eastern European real convergence club: Do implicit tax rates play a part? *DANUBE: Law, Economics and Social Issues Review*, *10*(1), 67-89.

Fritsche, U., & Kuzin, V. (2011). Analysing convergence in Europe using the nonlinear single factor model. *Empirical Economics*, *41*(2), 343-369. https://doi.org/10.1007/s00181-010-0385-4

Greasley, D., & Oxley, L. (1997). Time-series based tests of the convergence hypothesis: Some positive results. *Economics Letters*, *56*(2), 143-147. https://doi.org/10.1016/S0165-1765(97)81892-7

Herrerias, M. J., & Monfort, J. O. (2015). Testing stochastic convergence across Chinese provinces, 1952-2008. *Regional Studies*, *49*(4), 485-501. https://doi.org/10.1080/00343404.2013.786825

Herrerias, M. J., & Ordóñez, J. (2012). New evidence on the role of regional clusters and convergence in China (1952-2008). *China Economic Review*, *23*(4), 1120-1133. https://doi.org/10.1016/j.chieco.2012.08.001

Herrerias, M. J., Orts, V., & Tortosa-Ausina, E. (2011). Weighted convergence and regional clusters across China. *Papers in Regional Science*, *90*(4), 703-734. https://doi.org/10.1111/j.1435-5957.2010.00339.x

Ho, C-Y., & Li, D. (2010). Spatial dependence and divergence across Chinese cities. *Review of Development Economics*, *14*(2), 386-403. https://doi.org/10.1111/j.1467-9361.2010.00560.x

Hodrick, R. J., & Prescott, E. C. (1997). Postwar U.S. business cycles: An empirical investigation. *Journal of Money, Credit and Banking*, *29*(1), 1-16. https://doi.org/10.2307/2953682

Islam, N. (2013). What have we learnt from the convergence debate? *Journal of Economic Surveys*, *17*(3), 309-362. https://doi.org/10.1111/1467-6419.00197

Knight, J. (2014). Inequality in China: An overview. *The World Bank Research Observer*, *29*(1), 1-19. https://doi.org/10.1093/wbro/lkt006

Kutan, A. M., & Yigit, T. M. (2005). Real and nominal stochastic convergence: Are the new EU members ready to join the Euro zone? *Journal of Comparative Economics*, *33*(2), 387-400. https://doi.org/10.1016/j.jce.2005.03.001

Kutan, A. M., & Yigit, T. M. (2007). European integration, productivity growth and real convergence. *European Economic Review*, *51*(6), 1370-1395. https://doi.org/10.1016/j.euroecorev.2006.11.001

Lau, C. K. M. (2010). New evidence about regional income divergence in China. *China Economic Review*, *21*(2), 293-309. https://doi.org/10.1016/j.chieco.2010.01.003

Lucas, R. E. (1988). On the mechanics of economic development. *Journal of Monetary Economics*, *22*(1), 3-42. https://doi.org/10.1016/0304-3932(88)90168-7

Lyhagen, J., & Rickne, J. (2014). Income inequality between Chinese regions: Newfound harmony or continued discord? *Empirical Economics*, *47*(1), 93-110. https://doi.org/10.1007/s00181-013-0745-y

Maddison, A. (1982). *Phases of Capitalist Development*. New York: Oxford University Press.

Maddison, A. (1991). *Dynamic Forces in Capitalist Development*. New York: Oxford University Press.

Maddison, A. (2007). *Contours of the World Economy 1-2030 AD: Essays in Macroeconomic History*. New York: Oxford University Press.

Mankiw, N. G., Romer, D., & Weil, D. N. (1992). A contribution to the empirics of economic growth. *Quarterly Journal of Economics*, *107*(2), 407-437. https://doi.org/10.2307/2118477

Mora, T. (2005). Evidencing European regional convergence clubs with optimal grouping criteria. *Applied Economics Letters*, *12*(15), 937-940. https://doi.org/10.1080/13504850500119120

Nagayasu, J. (2011). Heterogeneity and convergence of regional inflation (prices). *Journal of Macroeconomics*, *33*(4), 711-723. https://doi.org/10.1016/j.jmacro.2011.07.002

Phillips, P. C. B., & Sul, D. (2007). Transition modeling and econometric convergence tests. *Econometrica*, *75*(6), 1771-1855. https://doi.org/10.1111/j.1468-0262.2007.00811.x

Quah, D. T. (1996). Empirics for economic growth and convergence. *European Economic Review*. *40*(6), 1353-1375. https://doi.org/10.1016/0014-2921(95)00051-8

Ramajo, J., Márquez, M. A., Hewings, G. J., & Salinas, M. M. (2008). Spatial heterogeneity and interregional spillovers in the European Union: Do cohesion policies encourage convergence across regions? *European Economic Review*, *52*(3), 551-567. https://doi.org/10.1016/j.euroecorev.2007.05.006

Romer, P. M. (1986). Increasing returns and long run growth. *Journal of Political Economy*, *94*(5), 1002-1037. https://doi.org/10.1086/261420

Sakamoto, H., & Islam, N. (2008). Convergence across Chinese provinces: An analysis using Markov transition matrix. *China Economic Review*, *19*(1), 66-79. https://doi.org/10.1016/j.chieco.2006.07.002

Sala-i-Martin, X. (1996). Regional cohesion: Evidence and theories of regional growth and convergence. *European Economic Review*, *40*(6), 1325-1352. https://doi.org/10.1016/0014-2921(95)00029-1

Simionescu, M. (2015). About regional convergence clubs in the European Union. *Proceedings of Rijeka Faculty of Economics*, *33*(1), 67-80.

Solow, R. M. (1956). A contribution to the theory of economic growth. *Quarterly Journal of Economics*, *70*(1), 65-94. https://doi.org/10.2307/1884513

Tillmann. P. (2013). Inflation targeting and regional inflation persistence: Evidence from Korea. *Pacific Economic Review*, *18*(2), 147-161. https://doi.org/10.1111/1468-0106.12016

Zhang, C. (2011). Inflation persistence, inflation expectations, and monetary policy in China. *Economic Modelling*, *28*(1-2), 622-629. https://doi.org/10.1016/j.econmod.2010.06.009

Zhang, C. (2013a). Inflation dynamics and an extended new Keynesian Phillips curve for China. *Emerging Markets Finance and Trade*, *49*(5), 82-98. https://doi.org/10.2753/REE1540-496X490505

Zhang, L. (2013b). Revisiting the empirics of inflation in China: A smooth transition error correction approach. *Economics Letters*, *119*(1), 68-71. https://doi.org/10.1016/j.econlet.2013.01.014