Growth through Heterogeneous Convergence in Chinese Provinces[1]

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Abstract

Whether China pulls its thirty-one mainland Chinese provinces as it converges to the incomes of advanced economies matters as common prosperity guides its development since the economic reform in 1978. The literature does not agree on using pooled or fixed effects to measure convergence. There is also a question on the differences in the speed of convergence. This paper estimates income convergence in Chinese provinces from 1978 to 2018 using homogeneous and heterogeneous approaches. We empirically show the fixed effects estimator of convergence bias towards zero against the heterogeneous approach. The growth of China lifts its provinces, but growth has been uneven across provinces.

JEL: C33, O47

Keywords: economic growth, convergence, heterogeneity

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1. Introduction

Common prosperity has been an underlying tenet of Chinese development since its economic reform in 1978. Deng Xiaoping famously said in 1985, "let some regions and some people grow rich first, then help other regions gradually achieve common prosperity." The Chinese economy today differs from when Deng Xiaoping spoke these words four decades ago. Yet the 14th Five-Year Plan (2021-25) pitches common prosperity as a central theme. Between January and July 2021, according to Bloomberg, President Xi mentioned common prosperity 65 times in his speeches. In economic terms, common prosperity asks the convergence hypothesis if the growth of China has lifted its provinces. This paper examines the stylised facts of growth and convergence in Chinese provinces.

The literature disagrees with measuring convergence (NBER, 2022). Traditionally, the pooled approach—sigma or beta convergence—talks about economies converging to a common steady-state (Barro, 1991; Barro and Sala-i-Martin, 1992). But Mankiw et al. (1992) offer the insight that rather than converging to a common steady-state, countries converge to their own steady-state when allowed for Solow fundamentals or permanent differences like geography, culture and history, modelled via the fixed effects (Acemoglu et al., 2019). The latter seems to be the consensus of the literature in the cross-country context (Jones, 2016). But this debate on measuring convergence has no agreement at the NBER Macro meeting between (Kremer et al., 2022, henceforth, KWY) and Acemoglu and Molina (2022, hereafter, AM). KWY revisited cross-country growth, finding absolute convergence since the late 1980s, AM argued that the findings are driven by omitting countries' fixed effects, discussing conditional convergence instead.

The case for the fixed effects is if permanent differences matter and economies converge to different steady states, the pooled approach will miss or underestimate convergence when there is, in fact, one. However, the case against the fixed effects estimator is when the parameter of interest is not the convergence but conditional variables such as education that are persistent and become imprecisely estimated over a short data span. The second argument against it is that "convergence to different steady states is itself a puzzle" (KWY). There is no way of telling which approach is correct because, as Johnson and Papageorgiou (2020) put it, "we don't know whether economies converge to a common steady state before transitioning through multiple steady states."

There is also a question on the differences in the speed of convergence—the heterogeneous approach—where some economies may not converge at all. If economies converge to different steady states, the fixed effects approach by imposing all economies must converge or not and, at the same rate, is also biased against the heterogeneous panel approach. This is known as the heterogeneity bias in the literature (Pesaran and Smith, 1995). But like the efficiency argument against the fixed effects estimator vs the pooled estimator, estimating convergence estimates for each economy eat more degrees of freedom than the pooled approaches to measuring convergence.

Given the tension in measuring convergence in the literature, we use three approaches to estimate income convergence (real GDP per capita) in thirty-one Chinese provinces between 1978 and 2018. Our parameter of interest is convergence. The Chinese provinces provide an interesting context for the convergence debate because it is heterogenous with its scale[2] and land area but one country; therefore, we expect to find convergence where capital moves freer (Lucas, 1990). When we plot the distribution of cross-province incomes over time, no province is left behind in the forty years since the economic reform. We model this common factor with the Common Correlated Effects (CCE) estimator (Pesaran, 2007).

We contribute to the convergence debate by arguing that the fixed effects approach advocated by Acemoglu and Molina (2022) is insufficient. When comparing the parameter of interest—convergence—across three approaches, AM argument (the fixed effects approach) against the pooled approach holds out, and our argument (the heterogeneous approach) against AM also holds out. In the homogeneous approaches, the pooled estimate implies that provinces are converging to a common steady state at an annual rate of 0.04%, whilst the fixed effects estimate suggests that provinces are converging to their steady states at an annual rate of 4.1%, which is closer to Barro's iron law of convergence, 2%, in the cross-country context. When we use the heterogeneous approach, allowing some provinces to converge and others not, provinces converge at an annual rate of 13.6%, on average, to their steady states. The

[2] The OECD countries have a population of 1.36 billion compared to 1.39 billion in China in 2018 (World Bank). The population size of a province in 2018 ranges between 112.57 million (Guangdong) and 3.40 million (Tibet). The median province has a population of about 40 million. There are 14 provinces with population Compared with the cross-country context, the Guangdong province is larger than any country on continental Europe. The combined population of the largest three Chinese provinces (Guangdong, Shandong and Henan) is 308 million vs 326 million for the US.

estimates suggest that the fixed effects and the heterogeneous approaches seem more plausible in this context.

The heterogeneous convergence offers insights into income inequality across provinces over the homogeneous approaches. In equilibrium, the fixed effect estimate implies convergence in growth rates with the common factor. When the long-run elasticities to the common factor are parameterised in the heterogeneous case, the estimates suggest a divergence of growth rates. Despite common progress, growth and convergence have been uneven across provinces; there are two opposing forces to income inequality; the distance to Shanghai, the wealthiest province, has narrowed (income inequality reduces), but some provinces grow faster than others despite starting at similar income levels (income inequality widens).

This paper differs from the Chinese growth and convergence literature in two aspects. First, we use the heterogeneous convergence model that allows both steady-state and the transition towards the steady-state to differ across provinces, feasible only with sufficiently long time series, bringing the heterogeneity by the club- to province-level. The Chinese provincial convergence literature finds evidence for club convergence but no consensus on the clubs. Most papers (Herrerías and Monfort, 2015; Luintel et al., 2020) use regions to group the provinces as they are easy to interpret, and policy is typically framed in the region, but they do not fit the data. Using statistical procedures via Phillips and Sul (2007) and entropy, various papers (Maasoumi and Wang, 2008; Tian et al., 2016) have shown that convergence clubs do not show geographic regularity that fits the data but is harder to interpret; therefore less persuasive. The fixed effects and heterogeneous approaches could address this tension. By modelling heterogeneity at the province level, we provide better, i.e. less biased estimates of convergence and tell a narrative about income distribution within China.

Second, we model the common factor in the convergence model's long and short runs. Most Chinese growth and convergence studies have explored sigma and beta convergence but not pairwise convergence (Pesaran, 2007). By modelling that either the common factor or Shanghai provinces converge in the long run, we highlight that growth diffuses from either the growth of China or the technological frontier. We do not find evidence of convergence when we omit the common factor in the long run. Even without considering which of the three approaches is correct, we miss or underestimate convergence when we exclude the common factor. The growth of China (the tides) lifts its provinces (boats), which could be interpreted as a tendency toward common prosperity. Spillovers aid the convergence of provinces. Only Weeks and Yao (2003) have highlighted common technological progress among the Chinese provinces; they find incomes diverge during the reform period (1978-1997) because the coastal provinces do not share a common technology progress rate with the interior provinces. In contrast, we find some interior provinces grow faster than the coastal provinces because of two additional decades (1998-2018) and how we model spill-overs and heterogeneity in the convergence model.

This paper also extends cross-country convergence to income distribution within each country. Pande and Enevoldsen (2022) note that "from a development perspective, it is useful to link a narrative about country-level convergence to income distribution within countries: poor regions, communities, households, and individuals. [T]his, we argue, is critical if absolute convergence is to be the tide that lifts all boats." This paper sits at this extension: globally, China has been converging to the incomes of advanced economies since 1978; this paper shows whether converging at the country level translates to converging at the sub-national level.

This paper proceeds as follows. Section 2 relates the paper to the literature. Section 3 describes the data, and Section 4 sets out the multi-province growth diffusion model. Section 5 presents and discusses the results before concluding in Section 6.

2. Data and Descriptive Statistics

In this section, we describe incomes, the log of real GDP per capita, and growths across provinces between 1978 and 2018. We explore income distribution over provinces over four decades, sigma convergence and probe if there is a common trend in incomes and a common cycle of growth via principal components.

2.1 "Tides that lift all the boats"

We obtain the real GDP per person for 31 Chinese provinces between 1978 and 2018 from the EPS China Statistics database[3]. Real GDP per person is denominated in 1978 prices.

[3] https://www.epsnet.com.cn/

Figure 1 groups the 31 Chinese provinces by three regions - Coastal (11 provinces), Middle (8 provinces) and West (12 provinces) following the official classification. We present the descriptive statistics by regions as this connects to the literature, and policy is framed in regions (Ong et al., 2021).

[Insert Figure 1 here]

Shanghai has been the wealthiest province across four decades; therefore, we express the income of each province to Shanghai; all provinces but Beijing narrow their gap to Shanghai (see Table 1). Beijing's GDP per capita relative to Shanghai fell from 51- in 1978 to 45% in 2018, but other provinces see their incomes rise relative to Shanghai's. Averaging the ratios by the three regions, only the coastal region increases from 22- to 30% in the first two decades whilst the middle and west regions stagnate, from 13- to 14% and 12- to 12%, respectively. The coastal region led the uneven development strategy at the beginning of the reform (Ong et al., 2021). In the last two decades, however, all regions' incomes have risen relative to Shanghai, from 30- to 40% in the coastal region, 12- to 22% in the middle region and 12- to 22% in the western region. But the heterogeneity of growths across provinces shows when we compare the provincial with the regional ratios. Neimenggu, despite being in the western region that is the poorest of three regions, mustered 37% of Shanghai's income to the regional average of 22% in 2018, and higher than five coastal provinces (Shandong, Fujian, Liaoning, Hebei, Hainan). On the other spectrum in the west region, Guizhou, Guangxi, and Yunnan mustered 11-, 12- and 13% of Shanghai's income in 2018.

Table 1 GDP per Capita relative to Shanghai

	1978	1998	2018		1978	1998	2018
Coastal				Henan	0.09	0.13	0.20
Beijing	0.51	0.51	0.45	Hubei	0.13	0.16	0.28
Tianjin	0.46	0.46	0.68	Hunan	0.12	0.11	0.17
Hebei	0.15	0.19	0.24	*Average*	0.13	0.14	0.22
Liaoning	0.27	0.27	0.34				
Jiangsu	0.17	0.33	0.56	**West**			
Zhejiang	0.13	0.31	0.41	Neimenggu	0.13	0.16	0.37
Fujian	0.11	0.22	0.34	Guangxi	0.09	0.09	0.12
Shandong	0.13	0.22	0.35	Chongqing	0.11	0.14	0.27
Guangdong	0.15	0.30	0.37	Sichuan	0.11	0.13	0.21
Hainan	0.13	0.21	0.26	Guizhou	0.07	0.07	0.11

Average	0.22	0.30	0.40	Yunnan	0.09	0.10	0.13
				Tibet	0.15	0.14	0.21
Middle				Shannxi	0.12	0.12	0.23
Shanxi	0.15	0.14	0.18	Gansu	0.14	0.13	0.18
Jilin	0.15	0.17	0.27	Qinghai	0.17	0.14	0.20
Heilongjiang	0.23	0.17	0.23	Ningxia	0.15	0.12	0.16
Anhui	0.10	0.12	0.20	Xinjiang	0.13	0.15	0.15
Jiangxi	0.11	0.12	0.19	*Average*	0.12	0.12	0.20

Notes: The real GDP per capita is in 1978 prices. Source: EPS Database.

The income distribution across provinces over four decades tells the story of Chinese provincial growth in a picture (see Figure 2). In 1978, most provinces were poor, but few provinces were rich. The distribution is concentrated around the median - 330 yuan - but with a long tail to the right. In 1979, Deng Xiaoping launched economic reform, opening China to the world. In the two decades since 1978, the Special Economic Zones - i.e. vigorous industrial policies aimed at promoting investments and technology adoption in specific regions and industries and favouring the export sector - expanded in 1984. Deng's Southern Tour in 1992 affirmed the irreversible commitment to premarket reforms (Zilibotti, 2017).

In 1998, the income distribution across provinces levelled up; the median-province income grew from 330- to 1621 yuan (1978 prices). No province is left behind: the poorest provinces in 1998 enjoyed the incomes of the richest provinces in 1978. We interpret this as common prosperity. Relative to the distribution in 1978, the density grows to the right of the median: more provinces were prosperous in 1998 than in 1978.

Deng's celebrated Southern tour paved the way for the most important economic reforms introduced under Jiang Zemin's leadership: the pension reform, the housing market reform and, crucially, the large-scale privatisation of the industrial sector promoted by the 15th Congress of the Communist Party in 1997 (Zilibotti, 2017). China ascended to the World Trade Organization in 2001 and launched the Economic Stimulus Program in 2008 during the Great Recession. In 2018, the income distribution levelled up again; the median province income leaps from 1621 to 11509 yuan (1978 prices). The tides lift all the boats; the growth of China lifts its provinces.

[Insert Figure 2 here]

We draw two stylised facts from the income distribution across provinces over time. *First*, the income distribution levels up across four decades. No province is left behind; China pulls each province in its flight path of converging to the incomes of advanced economies. *Second*, most provinces narrow the gap to Shanghai, the richest province. The distribution's right tail shortens over four decades, motivating us to look at the dispersion of incomes over time - sigma convergence - with and without Shanghai, where falling dispersion implies sigma convergence and poor provinces catch up to rich provinces.

2.2 Sigma convergence

We compare sigma convergence with and without Shanghai to see if there is a catch-up to the frontier. We find sigma convergence with Shanghai across three regions but no sigma convergence without Shanghai between 2008 and 2018 (see Figure 3). The dispersion within the coastal region falls in the first two decades, but it stagnates just above 0.30 for the next two decades. But including Shanghai, the income dispersion has fallen in the last two decades. Some coastal provinces - Tianjin, for instance - closes the gap to Shanghai (see Figure 4). The slope of the log income in Tianjin is steeper than in Shanghai. Tianjin’s GDP per person grows from 46- to 68% of Shanghai’s income per person.

[Insert Figures 3 and 4 here]

The same pattern holds for the middle provinces. The dispersion within the region falls in the first two decades but stagnates in the next two decades. Including Shanghai, however, the dispersion has fallen in the last two decades. Middle provinces such as Hubei closes the gap to Shanghai. For instance, most provinces' growth rates are higher than Shanghai’s in the previous decade (see the fourth column of Table 2).

Table 2 Growth Rate of Real GDP per Capita

	1979-1988			1989-1998			1999-2008			2009-2018		
Coastal	Ave.	S.d.	C.V.	Ave.	S. d.	C.V.	Ave.	S. d.	C.V.	Ave.	S. d.	C.V.
Beijing	0.08	0.05	0.62	0.08	0.03	0.45	0.08	0.02	0.22	0.05	0.01	0.18
Tianjin	0.07	0.05	0.69	0.08	0.05	0.54	0.11	0.02	0.16	0.08	0.03	0.37
Hebei	0.07	0.04	0.60	0.10	0.04	0.44	0.10	0.02	0.18	0.07	0.02	0.24

Liaoning	0.08	0.05	0.67	0.07	0.04	0.56	0.10	0.02	0.18	0.07	0.05	0.67
Jiangsu	0.11	0.04	0.34	0.11	0.07	0.61	0.11	0.02	0.17	0.09	0.02	0.21
Zhejiang	0.12	0.04	0.34	0.12	0.07	0.58	0.10	0.02	0.20	0.07	0.01	0.13
Fujian	0.10	0.05	0.47	0.12	0.05	0.39	0.10	0.02	0.22	0.09	0.02	0.21
Shandong	0.09	0.03	0.37	0.11	0.05	0.47	0.11	0.02	0.17	0.08	0.02	0.22
Guangdong	0.11	0.04	0.34	0.11	0.04	0.40	0.10	0.03	0.25	0.07	0.01	0.16
Hainan	0.10	0.07	0.64	0.10	0.09	0.93	0.09	0.02	0.23	0.08	0.03	0.33
Shanghai	0.06	0.03	0.39	0.09	0.04	0.52	0.09	0.01	0.14	0.06	0.01	0.13
Average	0.09	0.04	0.50	0.10	0.05	0.54	0.10	0.02	0.19	0.07	0.02	0.26

	1979-1988			1989-1998			1999-2008			2009-2018		
Middle	Ave.	S. d.	C.V.	Ave.	S. d.	C.V.	Ave.	S. d.	C.V.	Ave.	S. d.	C.V.
Shanxi	0.07	0.06	0.80	0.08	0.03	0.43	0.10	0.03	0.26	0.07	0.03	0.42
Jilin	0.09	0.05	0.59	0.07	0.05	0.70	0.11	0.03	0.26	0.09	0.03	0.37
Heilongjiang	0.06	0.03	0.49	0.07	0.02	0.24	0.10	0.02	0.17	0.08	0.03	0.33
Anhui	0.09	0.05	0.63	0.09	0.06	0.76	0.10	0.02	0.22	0.10	0.03	0.33
Jiangxi	0.08	0.04	0.48	0.08	0.03	0.44	0.10	0.02	0.18	0.09	0.02	0.18
Henan	0.09	0.05	0.57	0.09	0.04	0.43	0.11	0.02	0.23	0.09	0.02	0.20
Hubei	0.09	0.05	0.55	0.08	0.04	0.45	0.11	0.02	0.22	0.10	0.02	0.26
Hunan	0.07	0.02	0.28	0.08	0.03	0.43	0.10	0.02	0.17	0.09	0.02	0.23
Average	0.08	0.004	0.55	0.08	0.003	0.49	0.10	0.001	0.21	0.09	0.004	0.29

	1979-1988			1989-1998			1999-2008			2009-2018		
West	Ave.	S. d.	C.V.	Ave.	S. d.	C.V.	Ave.	S. d.	C.V.	Ave.	S. d.	C.V.
Neimenggu	0.09	0.05	0.54	0.08	0.03	0.38	0.15	0.04	0.31	0.09	0.04	0.43
Guangxi	0.05	0.03	0.56	0.09	0.04	0.47	0.10	0.02	0.23	0.09	0.03	0.31
Chongqing	0.08	0.03	0.37	0.10	0.03	0.35	0.11	0.02	0.19	0.11	0.03	0.29
Sichuan	0.08	0.03	0.33	0.09	0.03	0.32	0.10	0.02	0.20	0.10	0.03	0.33
Guizhou	0.08	0.04	0.54	0.06	0.02	0.34	0.09	0.02	0.20	0.11	0.02	0.20
Yunnan	0.08	0.04	0.51	0.08	0.02	0.28	0.08	0.02	0.25	0.10	0.02	0.20
Tibet	0.05	0.11	2.13	0.09	0.05	0.53	0.10	0.01	0.11	0.09	0.01	0.16
Shannxi	0.09	0.06	0.68	0.07	0.03	0.48	0.11	0.02	0.16	0.10	0.03	0.27
Gansu	0.07	0.07	1.04	0.07	0.03	0.42	0.10	0.01	0.13	0.08	0.03	0.33
Qinghai	0.07	0.05	0.64	0.05	0.03	0.50	0.10	0.02	0.17	0.09	0.03	0.28
Ningxia	0.07	0.04	0.62	0.06	0.02	0.40	0.09	0.01	0.14	0.08	0.02	0.25
Xinjiang	0.09	0.03	0.32	0.07	0.02	0.29	0.08	0.01	0.18	0.07	0.02	0.30
Average	0.08	0.05	0.69	0.08	0.03	0.40	0.10	0.02	0.19	0.09	0.03	0.28

Note: The table summarizes the average (Ave.), standard deviation (S.d.) and coefficient of variation (C.V.) of GDP per capita growth rate for each province.

The pattern for the western provinces is different from the coastal and middle provinces: one misses sigma convergence if we do not consider the convergence to the frontier. The dispersion within the region does not fall but rises between 1998 and 2018, but the rise in dispersion excluding Shanghai mirrors the fall in including Shanghai. Provinces—Neimenggu, Chongqing, Sichuan and Shannxi—have grown rapidly in the last two decades and driven the rise in dispersion within the western region. Therefore, without considering convergence to the frontier, one finds no sigma convergence within the region, no convergence at all. This stylised fact where provinces across three regions catch up to the frontier motivates us to explore if provinces converge to Shanghai later; because sigma convergence has occurred, beta convergence must have occurred.

2.3 Growths

We draw the following observations on growths between 1978 and 2018 across provinces. *First*, growths are much more volatile in the first two decades (1979 - 1998) than in the last two decades (1999 - 2018). The coefficient of variation for the coastal provinces is 50- and 54% in the first two decades, compared with 19- and 20% in the last two decades (see Table 2). The same pattern holds for the central and western provinces, 55- and 49% (1979 - 1998) vs 21- and 29% (1999 - 2018); 69- and 40% vs 19- and 28%, respectively. *Second*, growth has slowed down in the last decade (2009-2018) for most provinces, notably for the coastal provinces - average growth falls from 10% (1999-2008) to 7% (2009-18). For the central and western provinces, average growth falls from 10- to 9% over the same decades. Four western provinces - Chongqing, Sichuan, Guizhou and Yunnan - buck the trend are Western provinces. *Third*, the time series of growth shows common movement and highlights sharp fluctuations: Hainan in 1992 and Tianjin in 1984[4], for instance (see Figure 5).

[Insert Figure 5 here]

There is a lack of absolute convergence across all provinces (see Figure 6). Plotting average growth over four decades against income in 1978, Shanghai, the richest province, grows between 7 and 8 per cent, while 13 poor provinces - less than 1000 yuan in 1978 - grow faster, i.e. between 9 and 11 per cent, 15 other poor provinces of similar initial income, however, grow between 7 and 9 per cent. The salience from the cross-section plot reveals

[4] 1992 positive shock in Hainan when it separated from Guangdong and made a Special Economic Zone to increase investment in 1988. 1984 positive shock in Tianjin when it is listed as one of the 14 coastal open cities by the State Council at the beginning of economic reform.

heterogeneities of growth across provinces, a recurrent theme of this paper. Despite sharing incomes in 1978, growths ranged between 7 and 11 per cent across the provinces.

[Insert Figure 6 here]

How much do common co-movements account for variation in income and growth across provinces? Using principal components, the first factor—made up of almost equal loadings for all provinces, which we interpret as the China factor—accounts for 99.5% of the variation of incomes across provinces (see Table 3). In contrast, the first factor, also made up of almost equal loadings for all provinces, accounts for half of the variation of growths across provinces; up to 10 factors are needed to describe growths. In short, incomes are dominated by a common stochastic trend, but growths are much less correlated.

Table 3 Principal Components on Log and Growth of Real GDP per Capita

	Log of Real GDP per Capita		Growth of Real GDP per Capita	
	Cumulative explained variation (%)	Classification	Cumulative explained variation (%)	Classification
Principal component 1	99.5	China	50.3	China
Principal component 2	99.8	Regional	61.2	Regional
Principal component 3	99.9	Regional	68.5	Regional
Principal component 4	100	Regional	74.5	Regional

Note: The first principal component is made up of equal weight from each province.

The descriptive statistics sets the context for the modelling in the following section. *First*, from the principal component finding, we model a common stochastic trend via the Pesaran (2006) estimator driving incomes in the long run as “the tides lifting the boats”. Second, given the growth heterogeneity across provinces, we set out a heterogeneous beta convergence model. Third, the stylised fact where provinces catch up to the frontier motivates us to consider Shanghai as the long-run provinces converge.

3. Modelling

3.1 Heterogeneous beta convergence

Acemoglu and Molina (2022) argue that the lack of fixed effects in convergence models, to control for unobserved determinants of GDP per capita across countries, will bias convergence coefficients towards zero. But the fixed effect estimator by imposing common convergence coefficients also biases the estimate towards zero relative to the heterogeneous mean group estimator. The fixed effect model also has each country converging to different levels of steady state income.

Following Pesaran (2007, 2006), suppose that log per capita GDP, y_{it}, in each Chinese province is adjusting towards a common stochastic trend, f_t:

$$\Delta y_{it} = \alpha_i + \beta_i y_{i,t-1} + \gamma_i f_t + u_{it} \tag{1}$$

Averaging over provinces and noting if β_i and y_{it} are uncorrelated, the last term below goes to zero as N gets large

$$\Delta \bar{y}_t = \bar{\alpha} + \bar{\beta}\bar{y}_{t-1} + \bar{\gamma} f_t + \left(\sum_{i=1}^{N}(\beta_i - \bar{\beta})\Big/N\right)$$

we can proxy the factor as

$$f_t = \bar{\gamma}^{-1}(\Delta \bar{y}_t - \bar{\alpha} - \bar{\beta}\bar{y}_{t-1})$$

and inserting this factor into (1) gives an estimating equation for heterogeneous convergence:

$$\Delta y_{it} = a_i + b_i y_{i,t-1} + c_i \Delta \bar{y}_t + d_i \bar{y}_{t-1} + \varepsilon_{it} \tag{2}$$

where one would expect $b_i < 0$ if there is convergence.

The static long-run relationship when $\Delta y_{it} = \Delta \bar{y}_t = 0$ is

$$y_i = -\left(\frac{a_i}{b_i} + \frac{d_i}{b_i}\bar{y}\right)$$

where $-d_i/b_i$ is the long-run elasticity to the common factor.

If $\frac{d_i}{b_i} = -1$ then (2) is

$$\Delta y_{it} = a_i + b_i(y_{i,t-1} - \bar{y}_{t-1}) + c_i \Delta \bar{y}_t + \varepsilon_{it} \tag{3}$$

with long run relationship

$$y_i = -\frac{a_i}{b_i} + \bar{y}$$

In the long run, each province would then be proportional to the average $Y_i = A_i \bar{Y}$ where $A_i = \exp\left(-a_i/b_i\right)$. To get $Y_i = A_i \bar{Y}$, full convergence, we require $a_i = 0$, since for convergence we need $b_i \neq 0$.

A convenient way to test $d_i = -b_i$ is to write (2) as

$$\Delta y_{it} = a_i + b_i\left(y_{i,t-1} - \bar{y}_{t-1}\right) + c_i \Delta \bar{y}_t + (d_i + b_i)\bar{y}_{t-1} + \varepsilon_{it}, \tag{4}$$

and do a *t* test on the coefficient of $\bar{y}_{t-1}$.

This does not work when the target is growing, since you would only make up a proportion of the difference between where the target was in the last period and by then the target would have moved on. You will always be behind. To allow for that consider a steady state $\Delta y_{it} = \Delta \bar{y}_t = g$

$$\mathrm{g} = a_i + b_i(y - \bar{y}) + c_i \mathrm{g};$$

$$y = b_i^{-1}[g(1 - c_i) - a_i] + \bar{y} \tag{5}$$

So $A_i = \exp(b_i^{-1}[g(1 - c_i) - a_i])$ and depends on the rate of growth. $A_i = 1$ if $g(1 - c_i) = a_i$, the intercept exactly offsets the growth, to stop you always being behind.

3.2 Homogenous beta convergence

We also consider homogeneous beta convergence where we first allow the steady states to differ across provinces via fixed effects as in Acemoglu and Molina (2022) and Acemoglu et al. (2019), then do not allow for fixed effects as in Kremer et al. (2022), because of the tension whether to use or not to use fixed effects in convergence model.

3.2.1 The Fixed Effects Approach

From (2), we consider homogeneous convergence where we model provinces heterogeneity only with province fixed effects:

$$\Delta y_{it} = a_i + by_{i,t-1} + c\Delta\bar{y}_t + d\bar{y}_{t-1} + u_{it} \tag{6}$$

Acemoglu and Molina (2022) show that the lack of fixed effects in convergence models, to control for unobserved determinants of GDP per capita across economies, will bias convergence coefficient towards zero. The static long-run relationship is

$$y_i = -\frac{a_i}{b} + \frac{d}{b}\bar{y}$$

In the long run, each province would be proportional to the average $Y_i = A_i\bar{Y}^{-\frac{d}{b}}$ where A_i is exp $(-\,a_i/b)$. Unlike the heterogeneous panel, the long-run elasticity to the common factor, $-\,d/b$, is equivalent across provinces. By construction, all provinces grow with the same rate as the common factor in the long-run. But A_i allows for different steady states for each province.

3.2.2 The Pooled Approach

By not including fixed effects, we would use the pooled OLS model where we replace fixed effects with an intercept:

$$\Delta y_{it} = a + by_{i,t-1} + c\Delta\bar{y}_t + d\bar{y}_{t-1} + u_{it} \tag{7}$$

The static long-run relationship when $\Delta y_{it} = \Delta\bar{y}_t = 0$ is

$$y = -\left(\frac{a}{b} + \frac{d}{b}\bar{y}\right)$$

In equilibrium, all provinces would converge to a common steady state $Y_i = A\bar{Y}^{-\frac{d}{b}}$ where A is exp $(-\,a/b)$.

3.2.3 The Pooled Approach without The Common Factor

Model (7) implies that each province would converge to a common steady state that is a function of the common factor. We want to compare convergence coefficient b, with and without the common factor therefore we impose $c = d = 0$ on (4):

$$\Delta y_{it} = a + b y_{i,t-1} + u_{it} \tag{8}$$

The static long-run relationship is

$$y_i = -\frac{a}{b}$$

Each province would converge to a common steady state that is not a function of the common factor.

4. Results

4.1 Main Findings

Do the provinces converge to a common factor? When the year effects are excluded, the convergence estimate is 0.1% and t-stats of nearly 1 (column 1 of Table 4); when the year effects are included, the convergence estimate is 0.4% and t-stats of almost 4 (column 2 of Table 4). The provinces are converging to a flexible time trend in China at a rate of 0.4% yearly, i.e. very slow. Instead of using the year effects, we could model the convergence to a common factor with the Pesaran CCE estimator. We compare the convergence coefficient when the common factor is present in the short-run vs when the common factor is present in both the short- and long-run. The contrast between the estimates is similar to the difference between the estimates with and without year effects; the convergence is both economically and statistically significant when the long-run trend is specified. The BIC prefers the common factor model to the model with year effects, as the common factor model is more parsimonious. In summary, convergence suffers from an omitted variable bias: it biases towards zero (no convergence) in the absence of a long-run trend. We find strong evidence of convergence to a common factor without entering a debate between pooled and fixed effects estimates.

Table 4 Beta convergence to Common Factor

	Dependent variable: Annual growth of real GDP per capita					
	(1)	(2)	(3)	(4)	(5)	(6)
	Pooled	Pooled	Pesaran_SR	Pesaran_SLR	Prov.Eff	Mean group
Lag income	-0.001	-0.004	-0.001	-0.004	-0.041	-0.136
	(0.001)	(0.001)	(0.001)	(0.002)	(0.010)	(0.036)
Lag Com				0.003	0.040	0.135
				(0.002)	(0.010)	(0.037)
L.r. elasticity				0.79	0.99	1.02
				0.53	0.69	
Annual Com			0.834	0.833	0.862	0.87
			(0.039)	(0.039)	(0.039)	(0.042)
R-squared	0.250	0.534	0.506	0.507	0.533	
BIC	-4699	-5077	-5183	-5180	-5324	-5314
SER	0.0326	0.0261	0.0265	0.0264	0.0249	

Notes: All models include a constant and two lags of dependent variables. Standard errors in parentheses. We test the hypothesis if the long-run elasticity equals 1. Columns (1) and (2) are the pooled OLS estimates of the homogeneous beta convergence. Column (3) is the province fixed effects estimates of the homogeneous beta convergence. Column (4) is the mean group estimates of the heterogeneous beta convergence. The number of observations and provinces in each column are 1,178 and 31.

The case against the pooled estimate—column 1 to 4 of Table 4—is that the convergence suffers a bias towards zero (no convergence) in the absence of province-fixed effects, as AM argue against KWY. Do we find bias in the Chinese provinces? Building on the common factor model in column (4), the inclusion of province effects changes the convergence estimate from 0.4% to 4.1% (t-stat of 2), closer to Barro’s iron law of convergence, 2% annually, in the cross-country context. The bias is as large as 4.06%. We also plot the fixed effects with their standard errors of equation (6). Because they are statistically different from one another, provinces are converging to their steady states.

[Insert Figure 7 here]

Because the long-run elasticity to the common factor is unity (statistically insignificant from one), therefore, at equilibrium, we could interpret Ai as the long-run coefficient of proportionality to the geometric average. Since the long-run elasticity is homogeneous across provinces and equal to one, at equilibrium, the estimates imply convergence in growth rates and divergence in levels given different Ais.

We obtain convergence and long-run elasticities for each province using the heterogeneous approach. Does convergence bias towards zero when we pool convergence across provinces? The mean group estimate of convergence is 13.6%, which is higher than the fixed effects estimate of 4.1%. The average long-run elasticities are similar to other estimates, 1.02. This validates empirically the Pesaran and Smith (1995) argument that the estimate is biased when we pool a dynamic coefficient such as convergence.

Do some provinces converge and others do not? What is the evidence of convergence based on the heterogenous estimate? Figure 7 plots the histogram of t-stats of convergence. All but three estimates imply convergence. The speed of convergence ranges between 0.02 (Guizhou) and -1 (Henan). Henan sees instantaneous adjustment because it is close to its steady state. The histogram indicates they are more likely to converge than not. Taking -1.5 as a threshold, 17/31 provinces lap the threshold.

In equilibrium, the growth rates are equivalent to the common factor in the fixed effects model; the growth rates could differ from the common factor in the heterogeneous convergence (Table 5).

Most long-run elasticities are close to one and insignificantly different from one. If the elasticity is not one, the equilibrium growth rate of the province is the long-run elasticity time of the average, so they are diverging. However, it may take some time for the divergence to be apparent, and the parameters may not be stable over the long run. For long-run elasticities less than one and statistically different from one, from the smallest to highest, the provinces are Xinjiang, Shanghai, Hainan, Heilongjiang, and Liaoning. For long-run elasticities of more than one and statistically different from one, from the smallest to highest, the provinces are Henan, Sichuan, Neimenggu, and Chongqing.

Table 5. Long-run Coefficient of Proportionality to The Exponential of Average Log

Provinces	d_i Fixed Effects	d_i/-a F.E. in S.S.	exp (d_i/-a)	Provinces	d_i Fixed Effects	d_i/-a F.E. in S.S.	exp (d_i/-a)

				L.r. coeff proport.					L.r. coeff proport.
1	Shanghai	0.056	1.362	3.91	17	Heilongjiang	-0.009	-0.218	0.80
2	Tianjin	0.036	0.893	2.44	18	Anhui	-0.011	-0.269	0.76
3	Jiangsu	0.035	0.868	2.38	19	Sichuan	-0.011	-0.271	0.76
4	Zhejiang	0.025	0.622	1.86	20	Henan	-0.011	-0.275	0.76
5	Beijing	0.025	0.604	1.83	21	Shanxi	-0.015	-0.368	0.69
6	Guangdong	0.021	0.507	1.66	22	Tibet	-0.016	-0.382	0.68
7	Fujian	0.014	0.338	1.40	23	Jiangxi	-0.017	-0.415	0.66
8	Shandong	0.014	0.336	1.40	24	Qinghai	-0.017	-0.425	0.65
9	Neimenggu	0.014	0.334	1.40	25	Gansu	-0.018	-0.451	0.64
10	Liaoning	0.012	0.285	1.33	26	Xinjiang	-0.018	-0.452	0.64
11	Hainan	0.009	0.232	1.26	27	Hunan	-0.021	-0.517	0.60
12	Jilin	0.001	0.035	1.04	28	Ningxia	-0.023	-0.565	0.57
13	Hubei	0.001	0.018	1.02	29	Yunnan	-0.029	-0.705	0.49
14	Hebei	-0.002	-0.059	0.94	30	Guangxi	-0.034	-0.828	0.44
15	Chongqing	-0.003	-0.075	0.93	31	Guizhou	-0.039	-0.964	0.38
16	Shannxi	-0.008	-0.190	0.83					

[Insert Figure 8 here]

Plotting the long-run elasticities against initial income (Figure 8), we see two opposing forces on the income gap across Chinese provinces (see Figure 8). *First*, the gap between the 23 provinces and Shanghai, the richest province, narrows. As China grows by 1%, Shanghai, the richest province, grows by 0.83% in the long run. But 22 provinces grow faster to the common factor than Shanghai in the long run, from 0.89 (Ningxia) to 1.17 (Chongqing). Xinjiang (0.80) grew slower than Shanghai. Therefore, the gap between Shanghai and Xinjiang widens. *Second*, provinces with similar initial income are growing at different rates to the common factor in the long run, which widens the income gap across provinces. For instance, Yunnan and Chongqing were similarly poor in 1978, but while Chongqing grew by 1.17% to the common factor in the long run, Yunnan only increased by 0.93%. Even when the tide carries all boats, the boats rise at different heights to the tide, which widens the income gap across provinces.

Despite the heterogeneity, there is a tendency toward common prosperity; each province grows as China grows. Take an analogy of 31 runners starting at different positions akin to the position of incomes in 1978. Shanghai starts at the front. As China began its economic reform in 1978, most provinces except Xinjiang grew faster than the leader; the distance to Shanghai therefore shortened. But sprinters starting similar positions are running at different paces - Neimenggu and Chongqing run faster than Ningxia and other provinces, for instance - widening the gap between provinces. Nonetheless, all provinces move forward.

4.2 Shanghai

Because sigma convergence to Shanghai has occurred, beta convergence would occur too. We replace the common factor with Shanghai as the long-run provinces converge. The interpretation changes: in the common factor diffusion model, growth diffuses to provinces as China grows; spill-overs aid convergence in incomes; in the Shanghai diffusion model, growth diffuses to provinces from Shanghai, our proxy of the economic frontier.

First, the evidence of convergence is weaker than the common factor in the long run. Figure 8 plots the histogram of t-stats of convergence. All but three estimates (Guizhou, Shandong and Beijing) imply convergence. Still, if we were to use a 1.5 as the critical value of significance, seventeen vs seven provinces lap the threshold in the common factor than the Shanghai models (Figure 9). We see a few instances where the short-run estimates are insensible, but the long-run estimates are (Jiangsu, Guangdong); that is due to the high covariance typical in the heterogeneous panel approach (Baltagi et al., 2008).

Table 6. Speed of convergence and long-run elasticities from the heterogeneous convergence (common factor as the long-run)

	Provinces	beta	t-stat	theta	p-val		Provinces	beta	t-stat	theta	p-val
1	Beijing	0.01	0.20	1.40	0.90	17	Hubei	-0.05	-0.53	1.11	0.45
2	Tianjin	-0.12	-2.23	1.02	0.52	18	Hunan	-0.08	-1.80	1.05	0.31

3	Hebei	-0.03	-0.62	0.89	0.66	19	Guangdong	-0.01	-0.40	0.22	0.73
4	Shanxi	-0.22	-2.11	0.91	0.00	20	Guangxi	-0.16	-2.63	1.00	0.91
5	Neimenggu	-0.06	-1.25	1.14	0.12	21	Hainan	-0.17	-3.01	0.90	0.06
6	Liaoning	-0.23	-2.38	0.95	0.00	22	Chongqing	-0.09	-1.68	1.17	0.00
7	Jilin	-0.23	-1.91	1.03	0.25	23	Sichuan	-0.12	-1.72	1.09	0.01
8	Heilongjiang	-0.08	-2.36	0.93	0.06	24	Guizhou	0.02	0.50	0.63	0.51
9	Shanghai	-0.08	-1.61	0.83	0.00	25	Yunnan	-0.12	-1.75	0.93	0.01
10	Jiangsu	-0.05	-0.96	1.00	1.00	26	Tibet	-0.11	-1.56	1.07	0.55
11	Zhejiang	-0.03	-0.82	0.63	0.57	27	Shannxi	-0.07	-0.85	1.08	0.20
12	Anhui	-0.24	-1.95	1.03	0.11	28	Gansu	-0.60	-4.55	0.96	0.00
13	Fujian	-0.03	-0.61	0.96	0.91	29	Qinghai	-0.02	-0.64	1.38	0.65
14	Jiangxi	-0.05	-0.84	1.16	0.47	30	Ningxia	-0.08	-1.15	0.89	0.02
15	Shandong	0.01	0.10	2.39	0.91	31	Xinjiang	-0.11	-2.98	0.80	0.00
16	Henan	-1.00	-5.00	1.06	0.00		**Average**	-0.14	-1.58	1.02	0.35

Note: The model is estimated from heterogeneous convergence on equation (x). All models include a constant and two lags of dependent variables. We test the hypothesis if the long-run elasticity (theta) equals 1; p-value reports the result. The number of observations and provinces in each row are 1,178 and 40.

[Insert Figure 9 here]

Second, the long-run elasticities are higher than unity, highlighting the provinces that narrow their gap to Shanghai. Figure 9 also plots the long-run elasticities to Shanghai (we plot estimates where t-stats is more than one in absolute terms); two things stand out: one, all estimates are more than one (echoing the previous finding that the income gap to the frontier is narrowing). The long-run elasticities range from 1.04 (Shanxi) to Jiangsu (1.58). Two, the coastal provinces—Jiangsu and Guangdong— grow faster than the northeast and western provinces, which underlie uneven growth rates across provinces. The elasticities are higher than the common factor diffusion model because Shanghai grows slower than the common factor. The catch-up speed ranges between 3- (Xinjiang) and 16% (Shanxi), much slower than the growth diffusing from China.

5. Discussion and Conclusion

Whether China pulls the thirty-one mainland provinces as it converges to the incomes of advanced economies matters, "achieving common prosperity is not only an economic issue but also a significant political issue," said President Xi in January 2021, citing the Analects of Confucius, "where there is contentment, there will be no upheavals." (The Economist, 2021) Because there is no agreement on measuring convergence in the literature, we estimate convergence using the pooled, fixed effects and heterogeneous panel approaches. In the Chinese provinces, we find strong evidence of converging to the common factor; without accounting for the diffusion of growth across provinces via the common factor, one would omit an important driver of convergence. This fact, combined with the heterogenous estimates, tells the narrative that the gap between most provinces and the frontier narrows. Despite the unevenness of growth across provinces, there is progress. We also find evidence of growth diffusing to provinces from the technological frontier, albeit slower than growth diffusing from China. The empirical results confirm the bias towards zero in the convergence parameter that AM argue against the pooled approach. Still, the fixed effects approach also suffers from bias towards zero against the heterogeneous panel approach (heterogeneity bias), the argument of this paper.

The China story of convergence - about one-sixth of the world's population - differs from the global story of convergence. Deaton (2013) surmises globally that despite progress, it has been uneven. Globally, some economies grow rapidly and close the gap with the rich economies. Still, the rapid progress these economies have made creates a gap between them and other economies that are left behind. Within China, despite unevenness, there is progress. No province is left behind as China grows across four decades. Income trickles down: as China grows by 1%, each province would increase by 0.80% in the short-run, the cyclical component but 1% in the long run. This is in line with the expectation of convergence, where capitals can move freer within a country (Lucas, 1990).

We agree with Acemoglu and Molina (2022) that we should use fixed effects to account for heterogeneities across economies in the long run. Still, we argue that fixed effects do not allow for enough heterogeneity. Both fixed effects and heterogeneous panel approaches imply that each province converges to different steady states, but the fixed effects approach imposes homogeneity on the transition to a steady state. Each province converges to the steady states with the same speed, but pooling a dynamic coefficient yields inconsistent and biased estimates towards zero (Pesaran and Smith, 1995); therefore, one would underestimate convergence. Whilst we cannot tell which approach is correct if convergence is the parameter of interest, the estimates suggest that the fixed effects and heterogeneous approaches seem more plausible.

There are two main explanations for convergence, one based on the diminishing returns (Barro and Sala-i-Martin, 2003; Solow, 1956) and another based on the technological catch-up (Aghion and Howitt, 1992). Our evidence of where less-advanced provinces catch up to advanced provinces supports the paradigm where growth diffuses from the technology frontier (Acemoglu et al., 2006; Zilibotti, 2017).

This paper can be extended in two ways. First, the growth diffusion model via the common factor representation is a coarse model relative to a more granular spatial model. Given the scale of China both in terms of population and land area, it is plausible that there could be more than one dominant province - we use Shanghai as a proxy of technological frontier, but Beijing could be the dominant province in the north while Guangdong—Guangzhou and Shenzhen—could be the dominant province in the south. Second, this paper has cemented that diffusion has occurred within China: understanding the institutions and policies that help diffuse wealth is a useful research avenue— what works and does not—to ensure greater domestic redistribution and that the tides continue lifting the boats.

References

Acemoglu, D., Aghion, P., Zilibotti, F., 2006. Distance to frontier, selection, and economic growth. J. Eur. Econ. Assoc. 4, 37–74.

Acemoglu, D., Molina, C., 2022. Comment. NBER Macroecon. Annu. 36, 425–442. https://doi.org/10.1086/718674

Acemoglu, D., Naidu, S., Restrepo, P., Robinson, J.A., 2019. Democracy Does Cause Growth. J. Polit. Econ. 127, 47–100.

Aghion, P., Howitt, P., 1992. A Model of Growth Through Creative Destruction. Econometrica 60, 323–351. https://doi.org/10.2307/2951599

Baltagi, B.H., Bresson, G., Pirotte, A., 2008. To Pool or Not to Pool?, in: The Econometrics of Panel Data. Springer Berlin Heidelberg, Berlin, Heidelberg, pp. 517–546. https://doi.org/10.1007/978-3-540-75892-1_16

Barro, R.J., 1991. Economic growth in a cross section of countries. Q. J. Econ. 106, 407–443. https://doi.org/10.2307/2937943

Barro, R.J., Sala-i-Martin, X.I., 2003. Economic growth. MIT press.

Barro, R.J., Sala-i-Martin, X.I., 1992. Convergence. J. Polit. Econ. 100, 223–251. https://doi.org/10.1086/261816

Deaton, A., 2013. The Great Escape : Health, Wealth, and the Origins of Inequality. Princeton University Press, Princeton, New Jersey.

Herrerías, M.J., Monfort, J.O., 2015. Testing stochastic convergence across Chinese provinces, 1952--2008. Reg. Stud. 49, 485–501.

Johnson, P., Papageorgiou, C., 2020. What Remains of Cross-Country Convergence? J. Econ. Lit. 58, 129–175. https://doi.org/10.1257/jel.20181207

Jones, C.I., 2016. The Facts of Economic Growth. Handb. Macroecon. 2, 3–69. https://doi.org/10.1016/BS.HESMAC.2016.03.002

Kremer, M., Willis, J., You, Y., 2022. Converging to Convergence. NBER Macroecon. Annu. 36, 337–412. https://doi.org/10.1086/718672

Lucas, R.E., 1990. Why Doesn’t Capital Flow from Rich to Poor Countries? Am. Econ. Rev. 80, 92—96.

Luintel, K.B., Matthews, K., Minford, L., Valentinyi, A., Wang, B., 2020. The role of Provincial Government Spending Composition in growth and convergence in China. Econ. Model. 90, 117–134. https://doi.org/10.1016/j.econmod.2020.04.024

Maasoumi, E., Wang, L., 2008. Economic reform, growth and convergence in China.

Econom. J. 11, 128–154. https://doi.org/10.1111/j.1368-423X.2008.00233.x

Mankiw, N.G., Romer, D., Weil, D.N., 1992. A Contribution to the Empirics of Economic Growth. Q. J. Econ. 107, 407–437. https://doi.org/10.2307/2118477

NBER, 2022. Discussion of "Converging to Convergence." NBER Macroecon. Annu. 36, 443–444. https://doi.org/10.1086/718675

Ong, K., Matthews, K., Wang, B., 2021. Growth versus Equity: The Effects of Centralised Fiscal Transfers on Provincial Economies in China, Cardiff-Fudan Working Paper 22/02.

Pande, R., Enevoldsen, N., 2022. Comment. NBER Macroecon. Annu. 36, 413–424. https://doi.org/10.1086/718673

Pesaran, M.H., 2007. A pair-wise approach to testing for output and growth convergence. J. Econom. 138, 312–355. https://doi.org/10.1016/j.jeconom.2006.05.024

Pesaran, M.H., 2006. Estimation and inference in large heterogeneous panels with a multifactor error structure. Econometrica 74, 967–1012. https://doi.org/10.1111/j.1468-0262.2006.00692.x

Pesaran, M.H., Smith, R., 1995. Estimating long-run relationships from dynamic heterogeneous panels, Journal of Econometrics. https://doi.org/10.1016/0304-4076(94)01644-F

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

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

The Economist, 2021. Xi Jinping's talk of "common prosperity" spooks the prosperous. Econ.

Tian, X., Zhang, X., Zhou, Y., Yu, X., 2016. Regional income inequality in China revisited: A perspective from club convergence. Econ. Model. 56, 50–58. https://doi.org/10.1016/j.econmod.2016.02.028

Weeks, M., Yao, J.Y., 2003. Provincial conditional income convergence in China, 1953--1997: a panel data approach. Econom. Rev. 22, 59–77.

Zilibotti, F., 2017. Growing and slowing down like China. J. Eur. Econ. Assoc. 15, 943–988. https://doi.org/10.1093/jeea/jvx018

Figure 1. Chinese Provinces

Notes: Shanghai is the economic frontier. The ten Coastal provinces are Beijing, Tianjin, Hebei, Liaoning, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong and Hainan. The eight Middle provinces are Shanxi, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei and Hunan. The twelve West provinces are Neimenggu, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Tibet, Shannxi, Gansu, Qinghai, Ningxia and Xinjiang.

Figure 2. Per capita Income Distribution across Provinces (in logarithms)

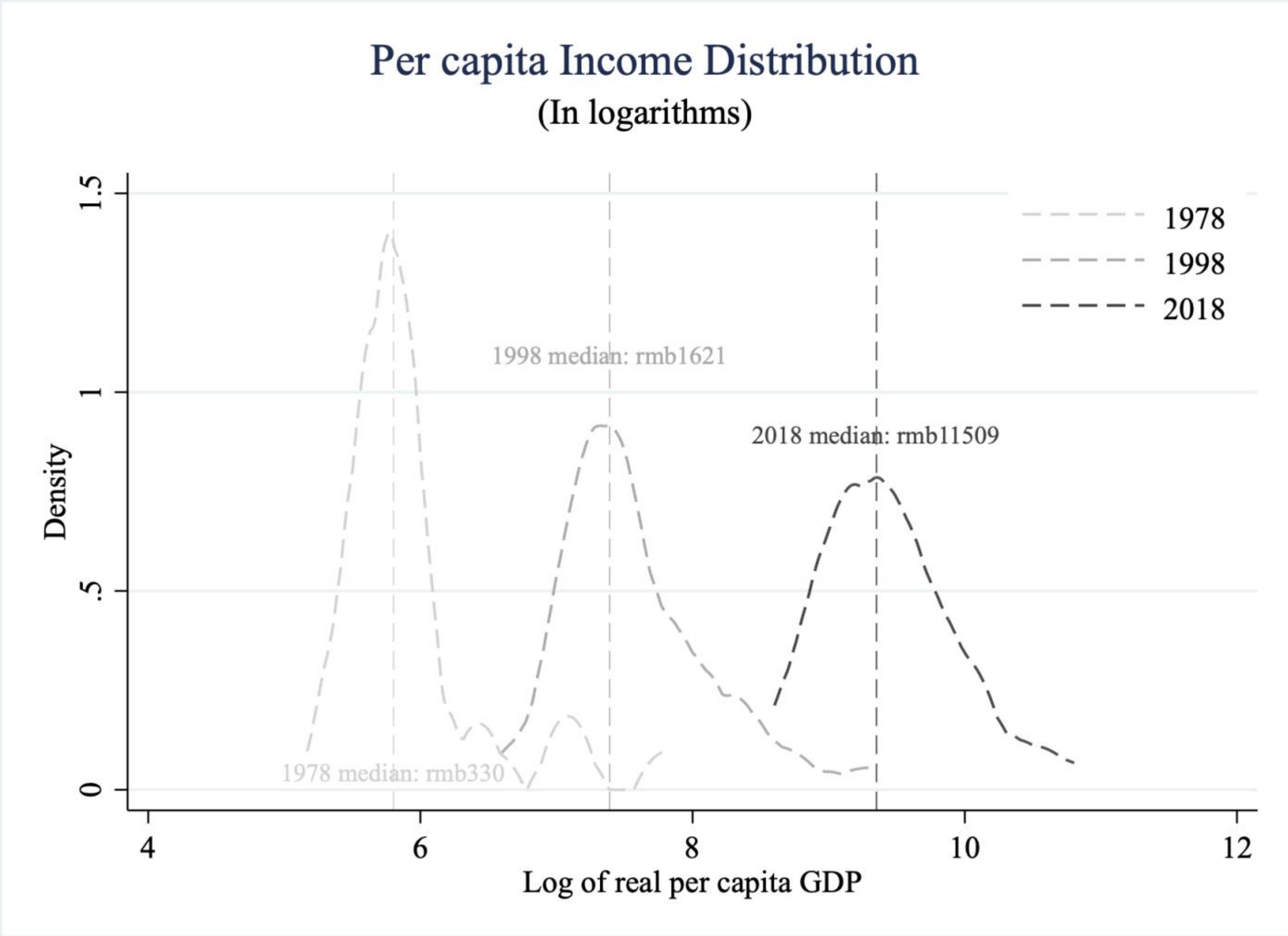


Figure 3a. Logarithms of Real GDP per capita in the Coastal Region

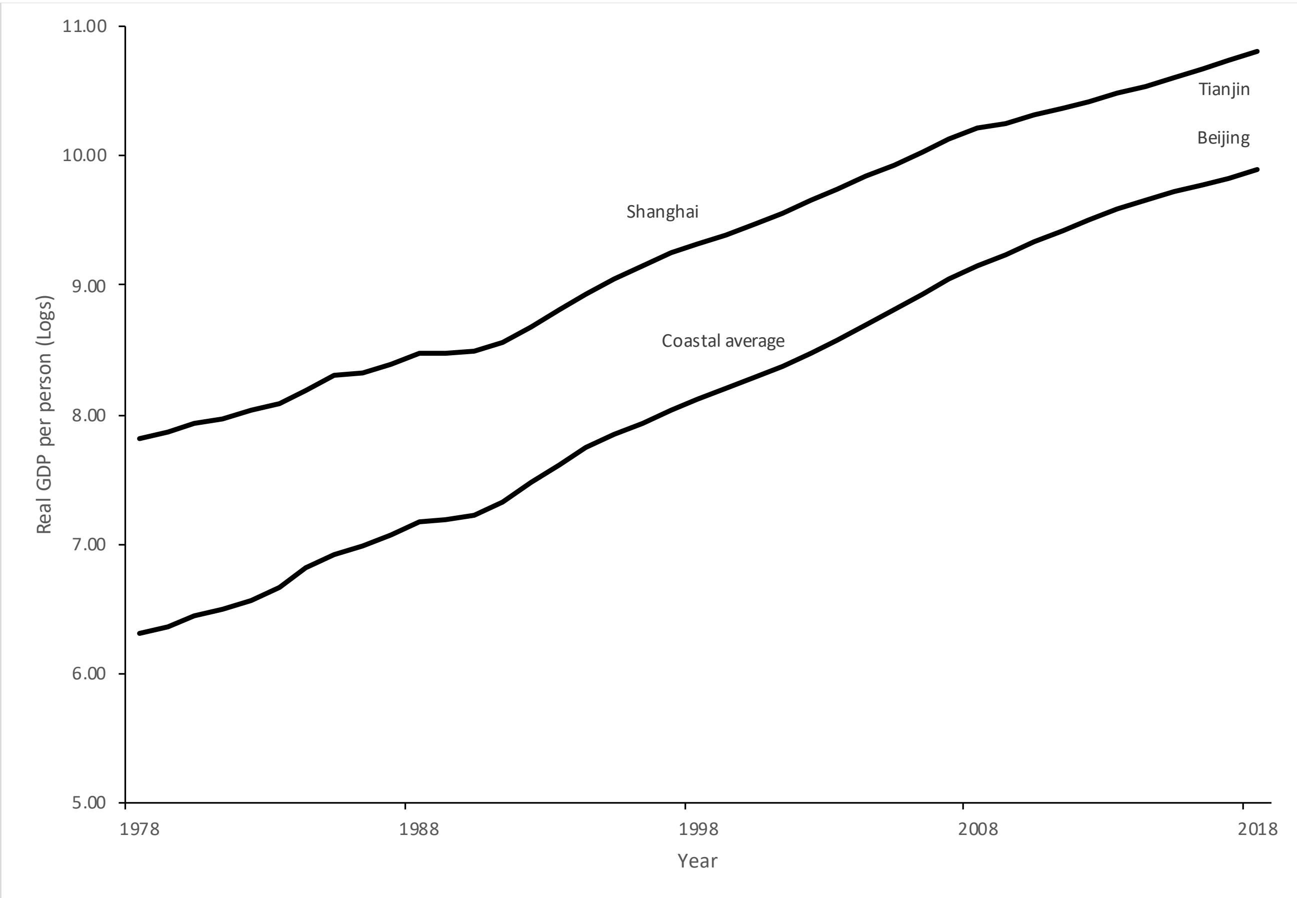


Figure 3b. Logarithms of Real GDP per capita in the Middle Region

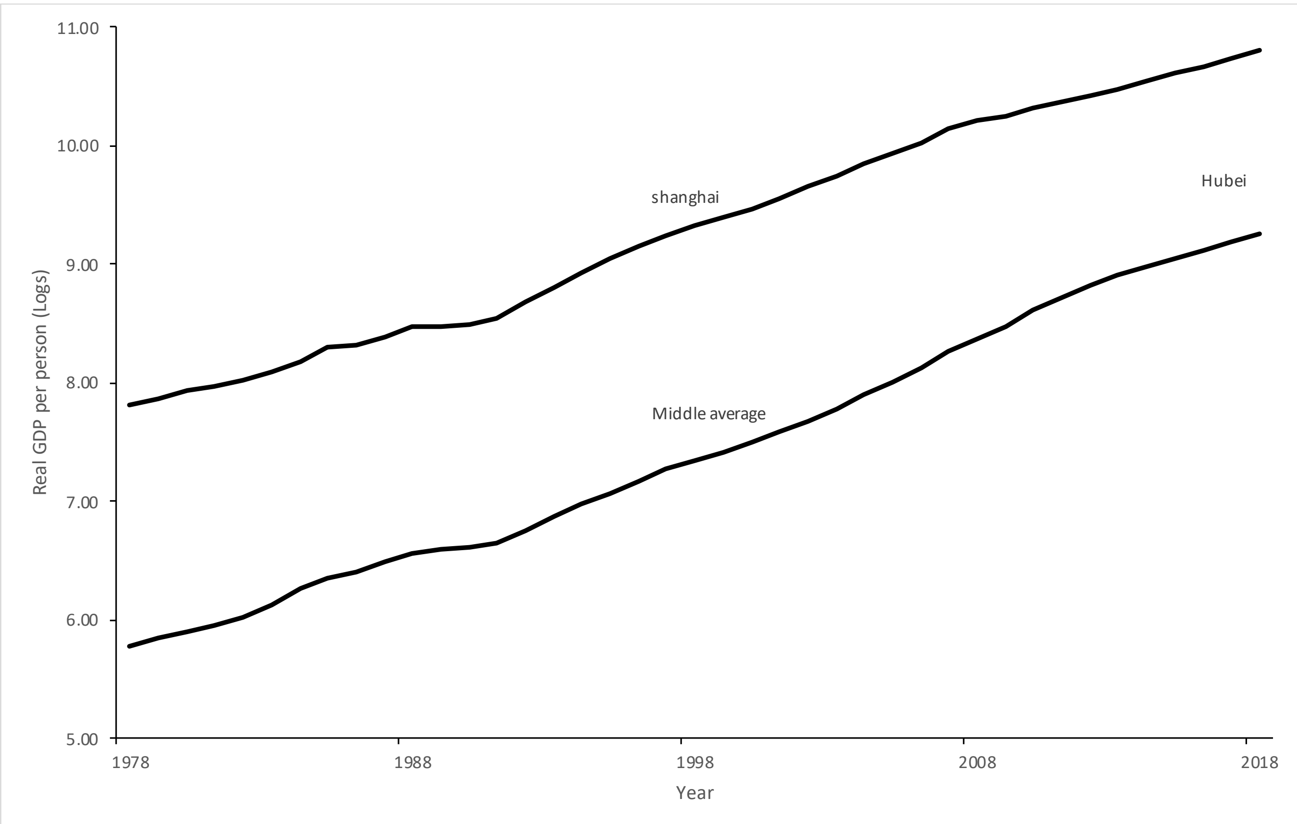


Figure 3c. Logarithms of Real GDP per capita in the West Region

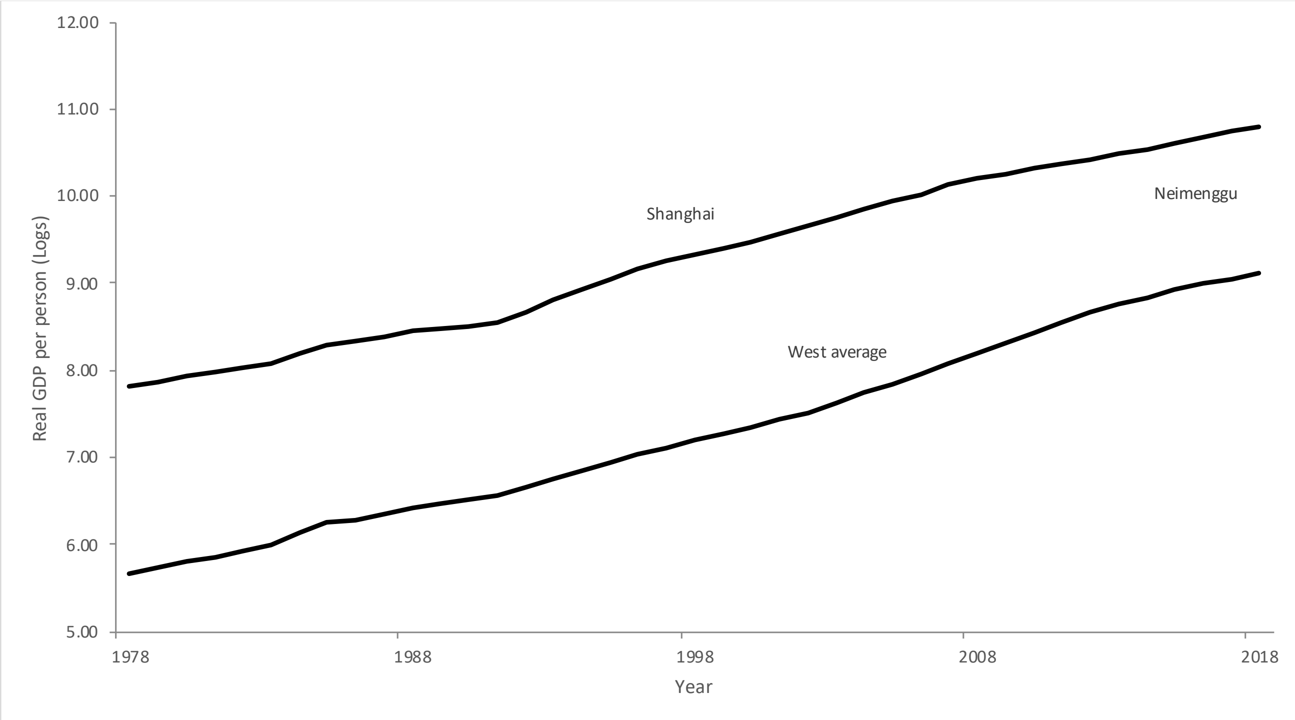


Figure 4a. Sigma Convergence with and without Shanghai in the Coastal Region

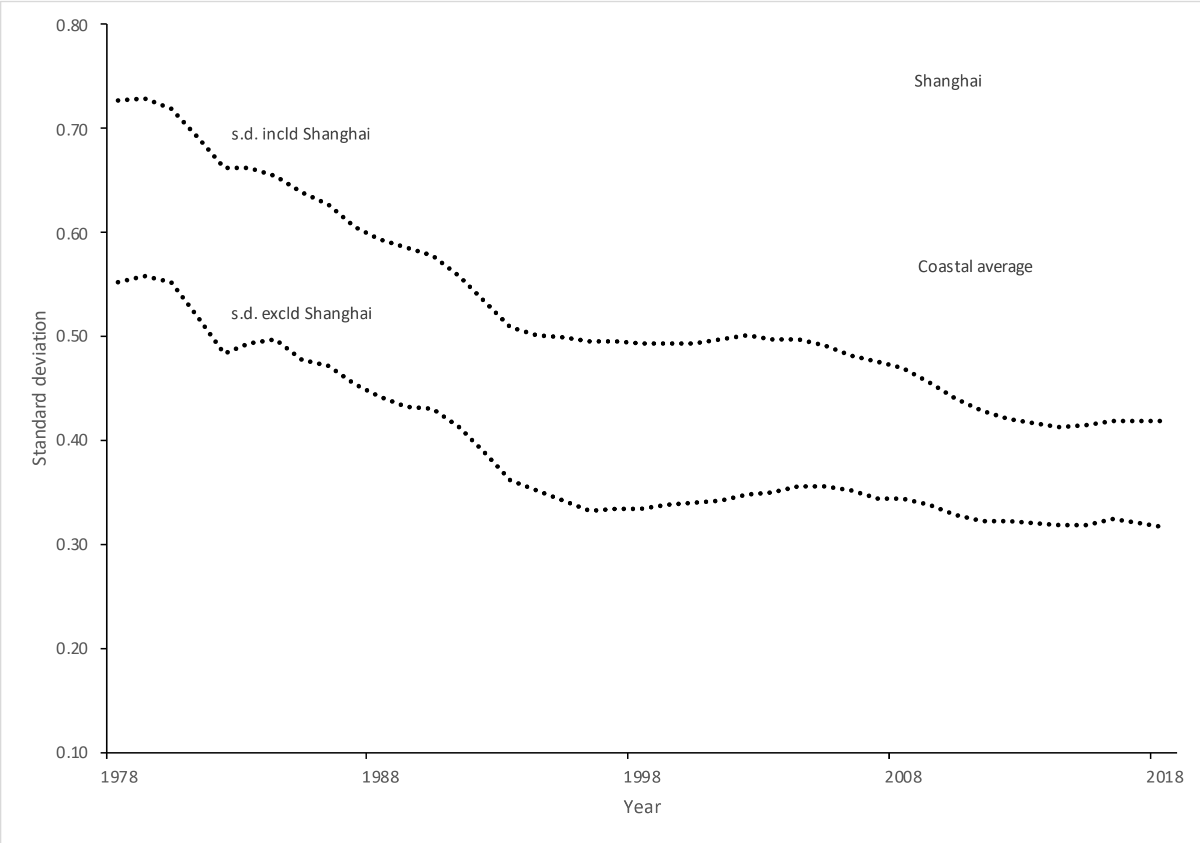


Figure 4b. Sigma Convergence with and without Shanghai in the Middle Region

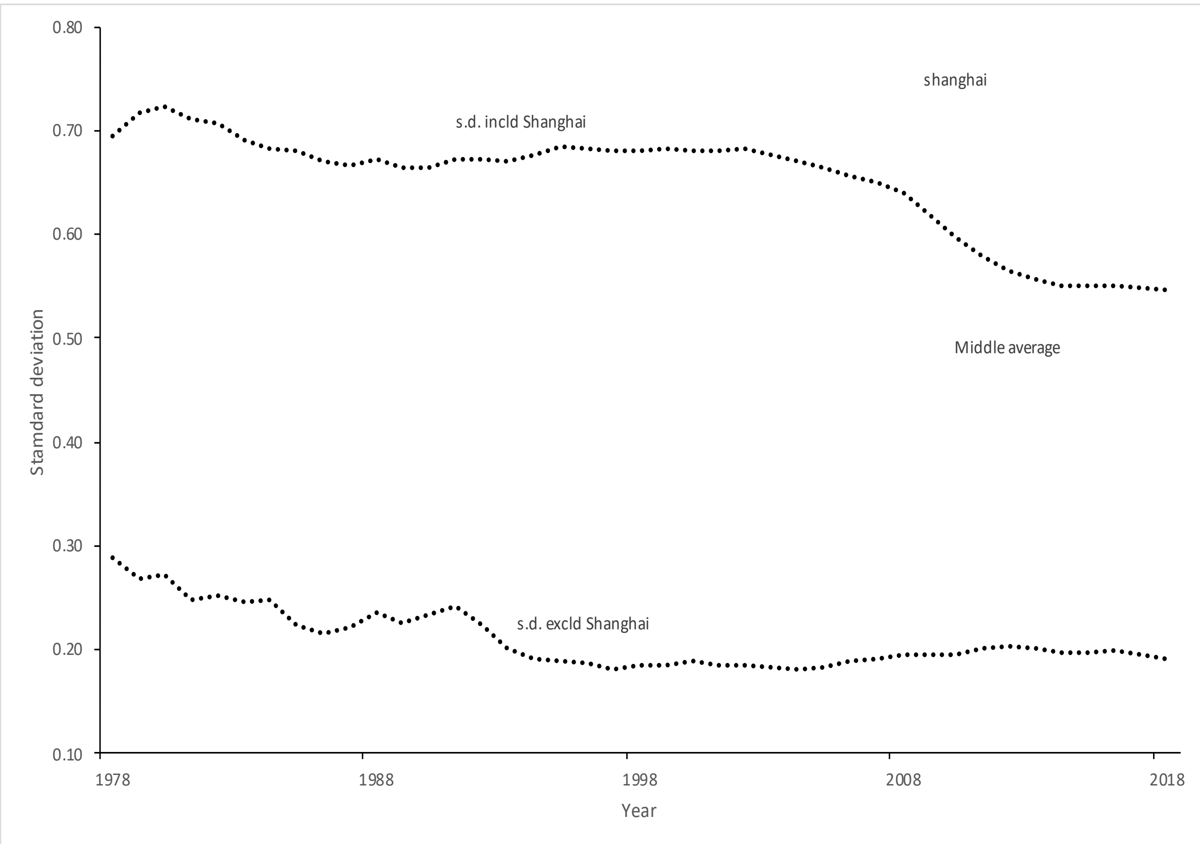


Figure 4c. Sigma Convergence with and without Shanghai in the West Region

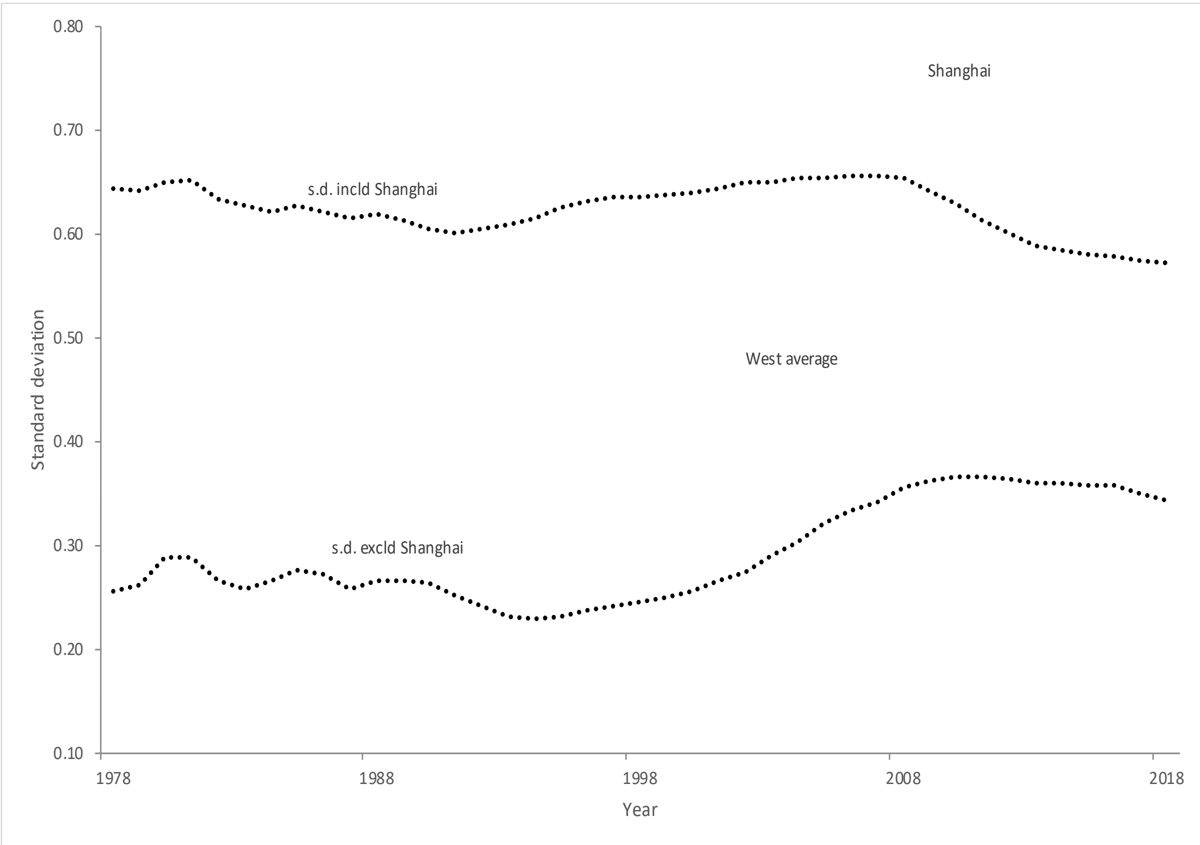


Figure 5a Annual Growth of Real GDP per Person in the Coastal region

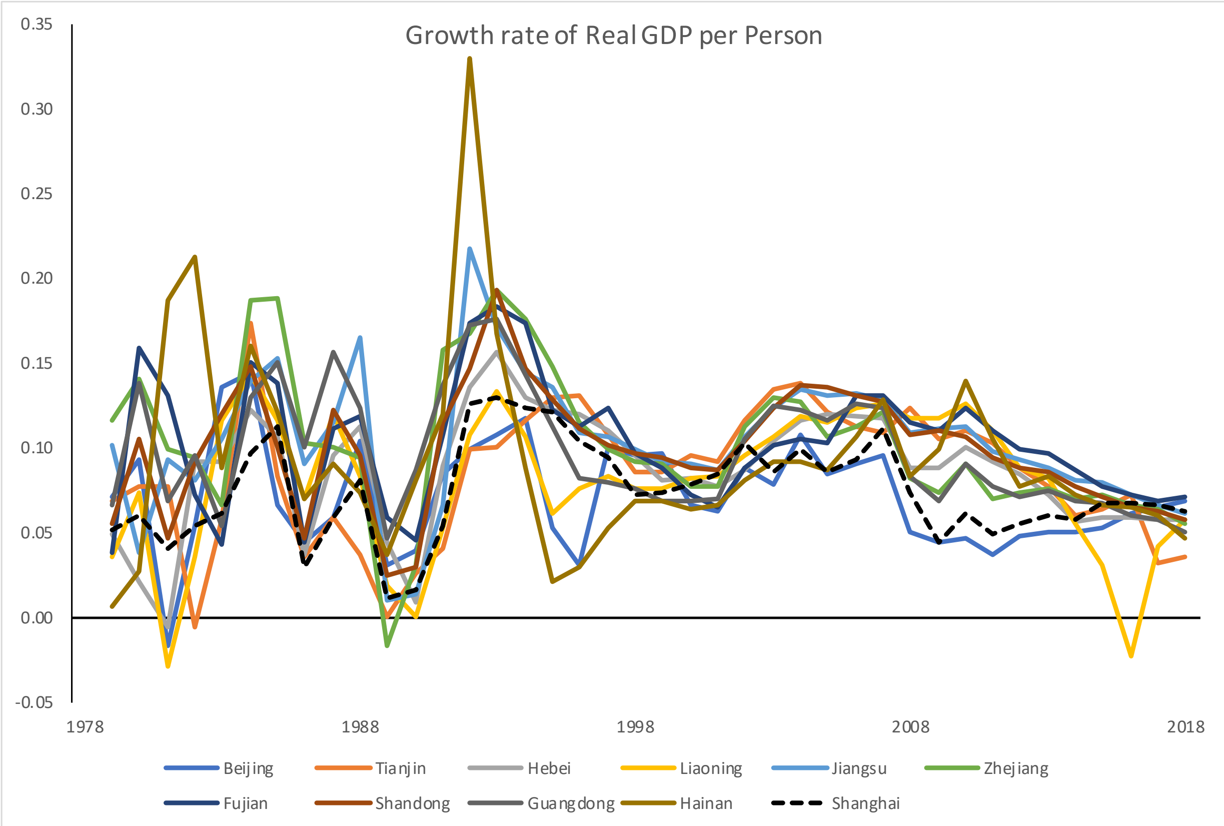


Figure 5b Annual Growth of Real GDP per Person in the Middle region

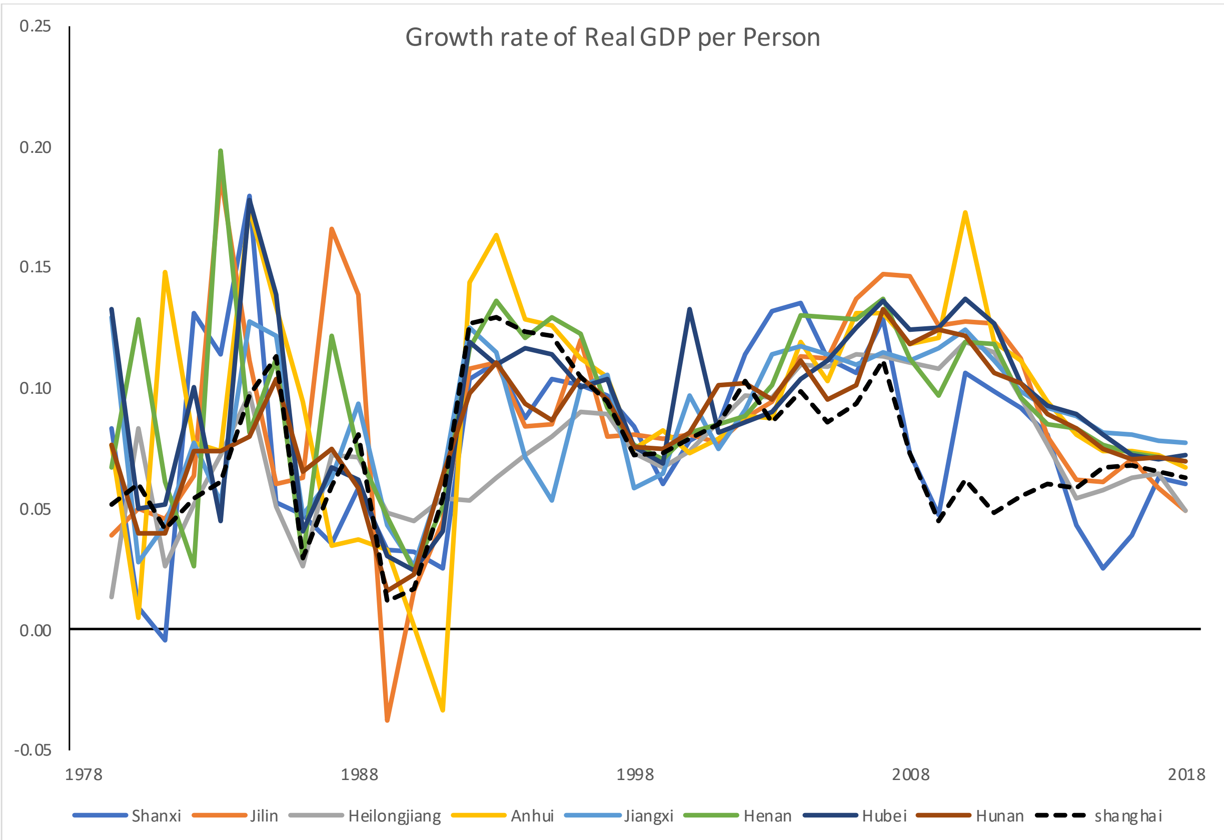


Figure 5c Annual Growth of Real GDP per Person in the West region

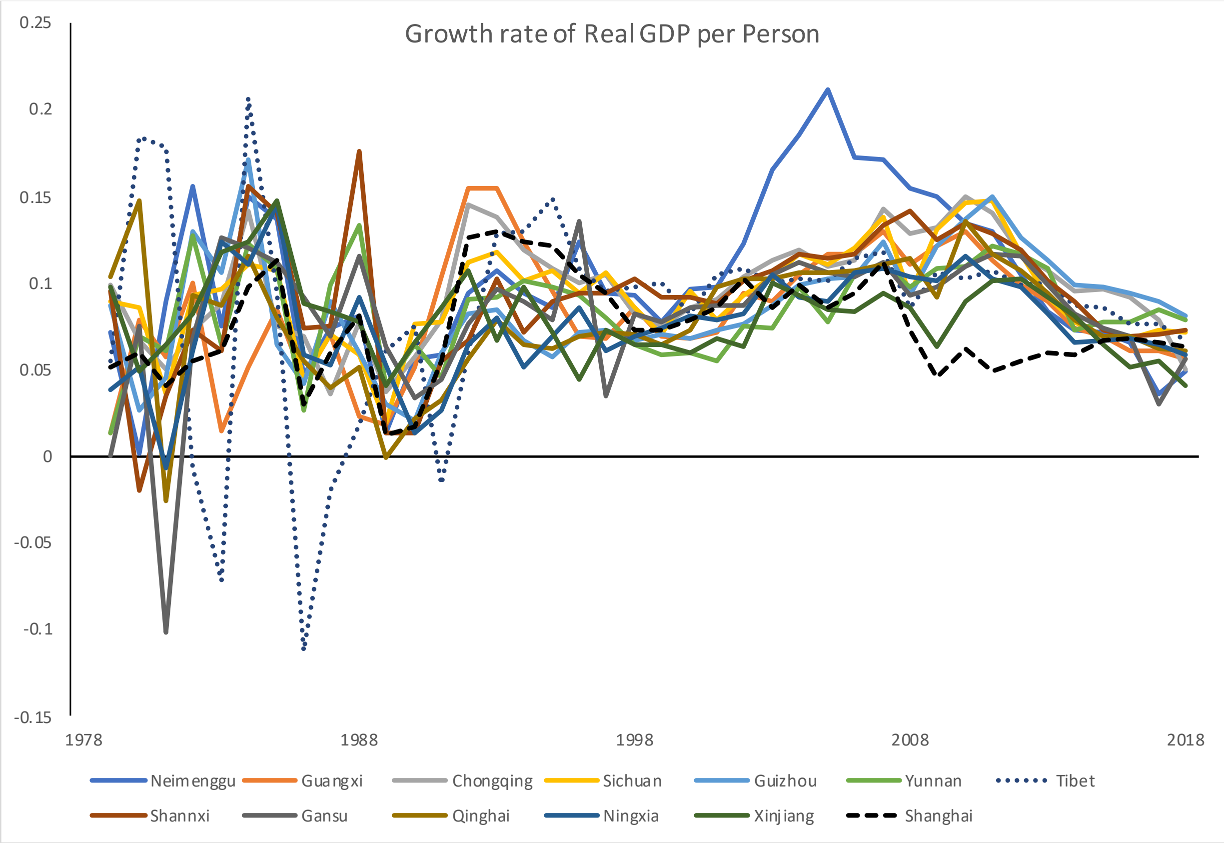


Figure 6 Convergence (Growth against initial GDP per person)

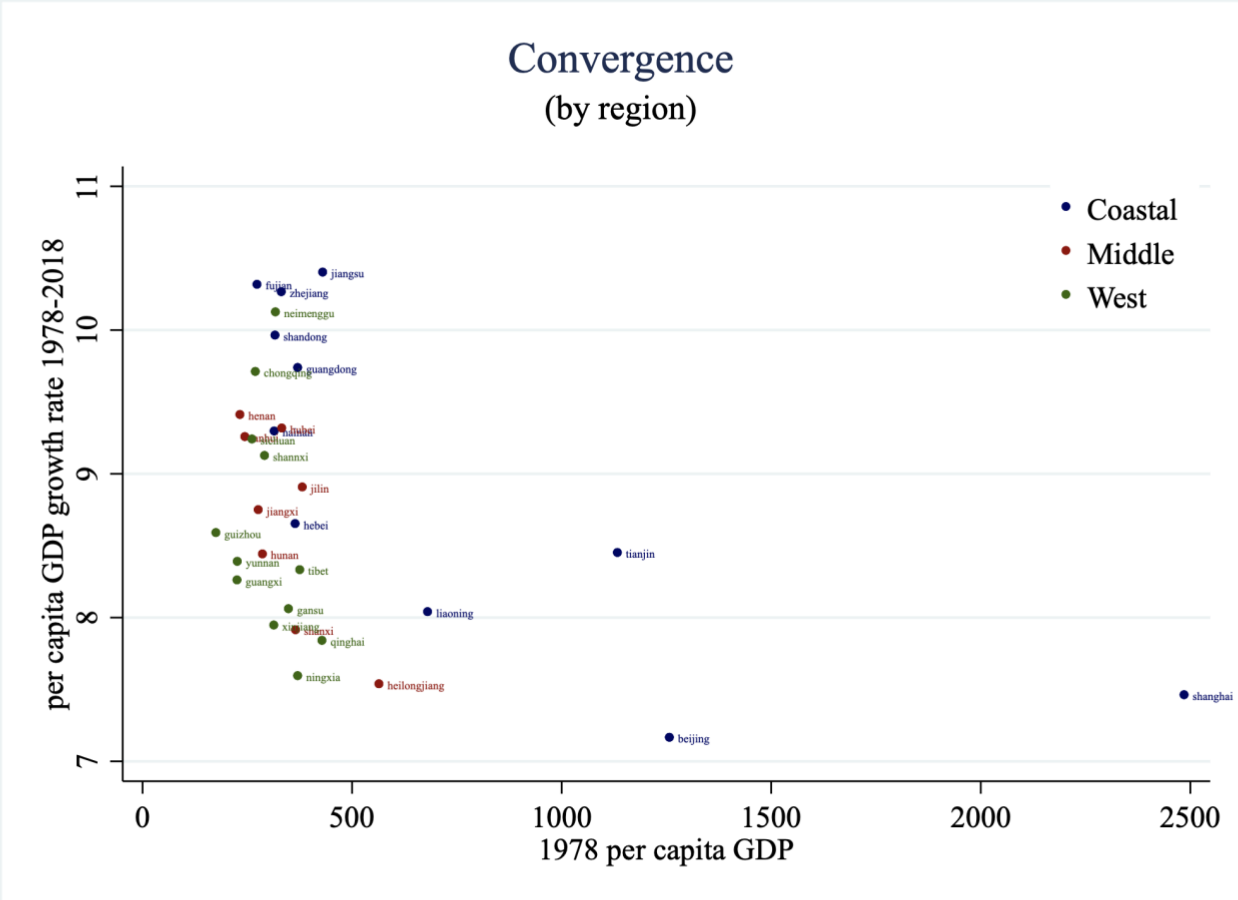
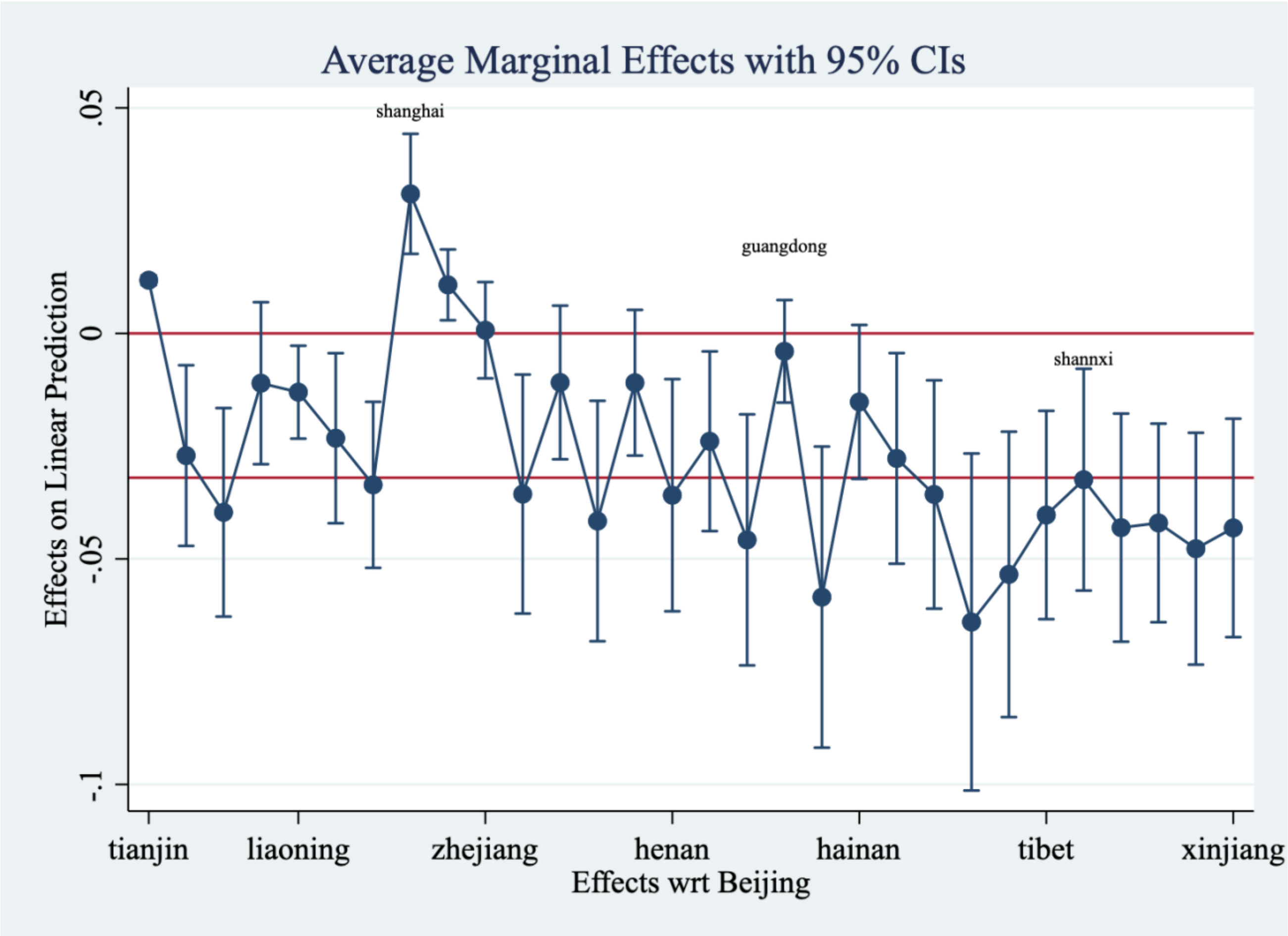
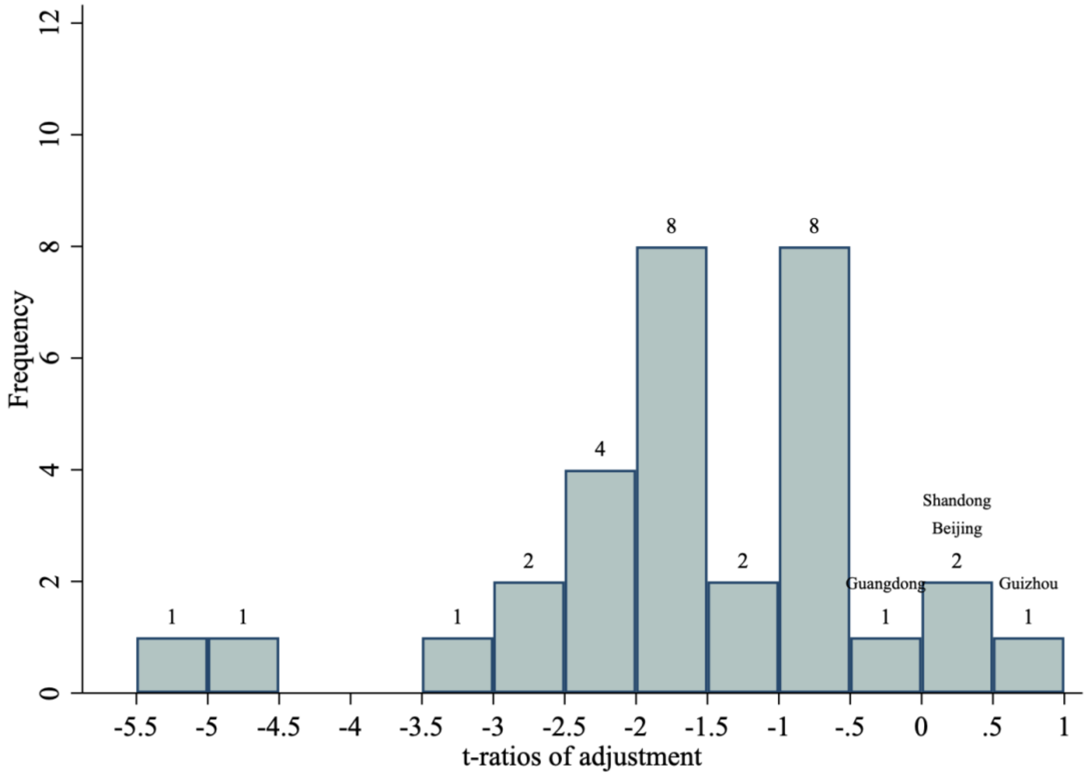


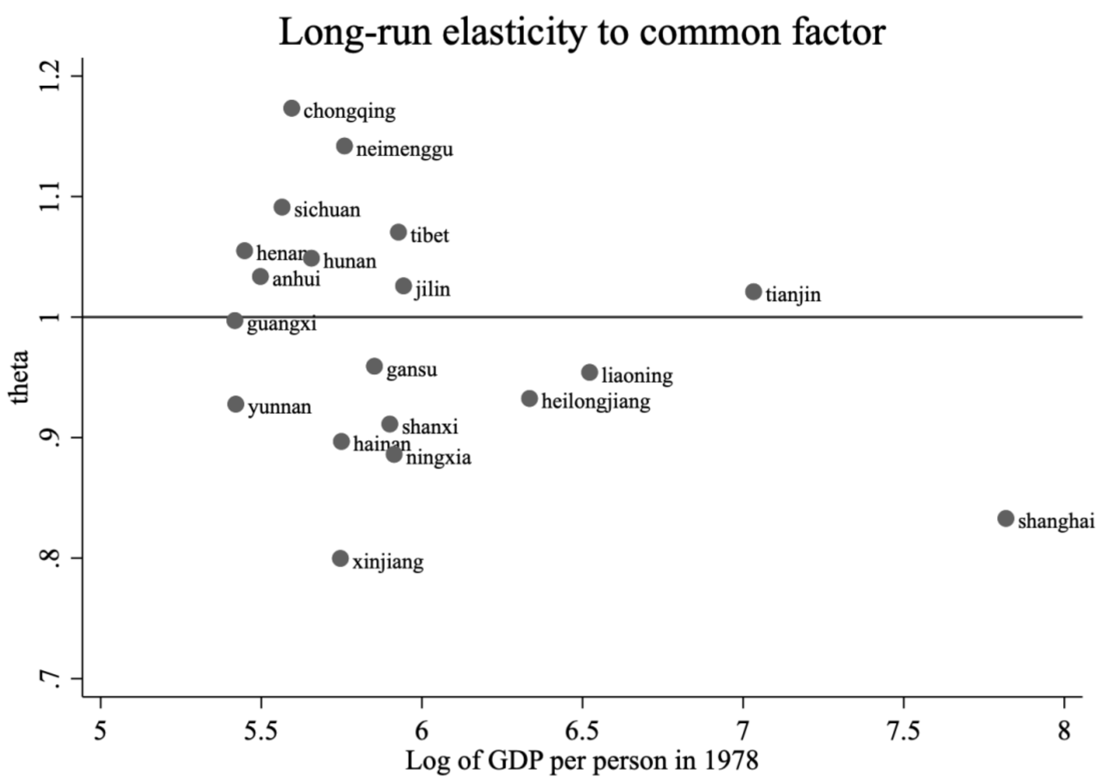
Figure 7 Province Fixed Effects



Note: we plot the province fixed effects (relative to Beijing on equation (4).

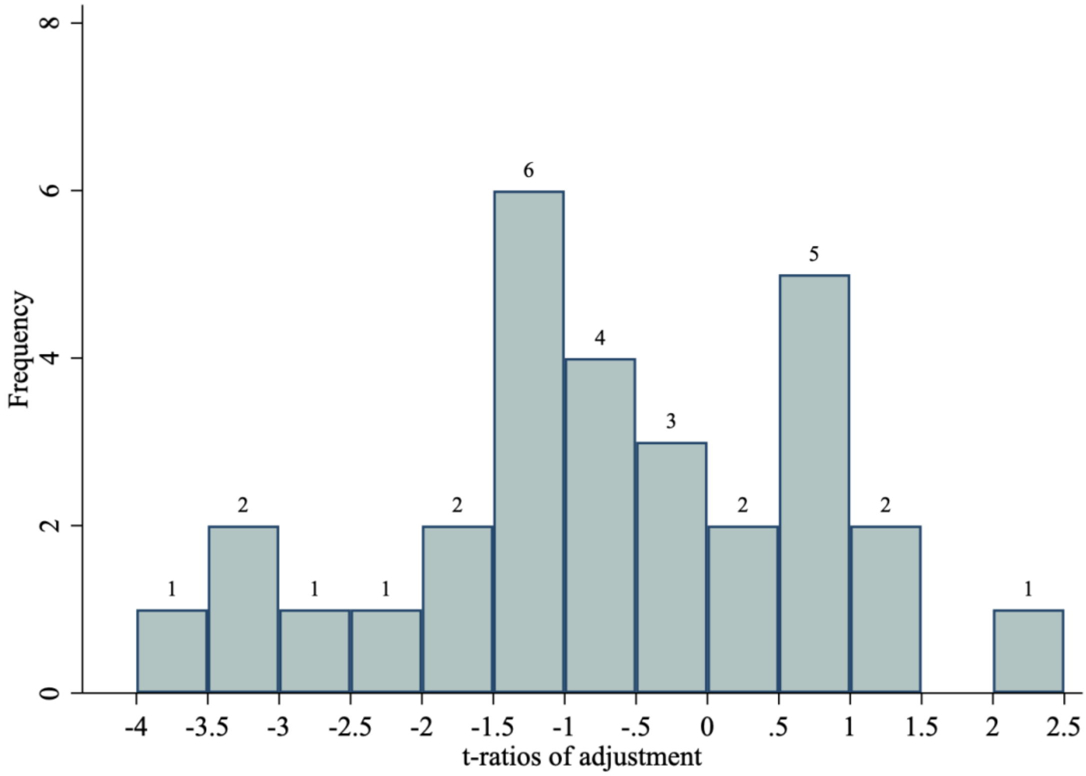
Figure 8 Heterogeneous beta convergence (common factor in the long run)

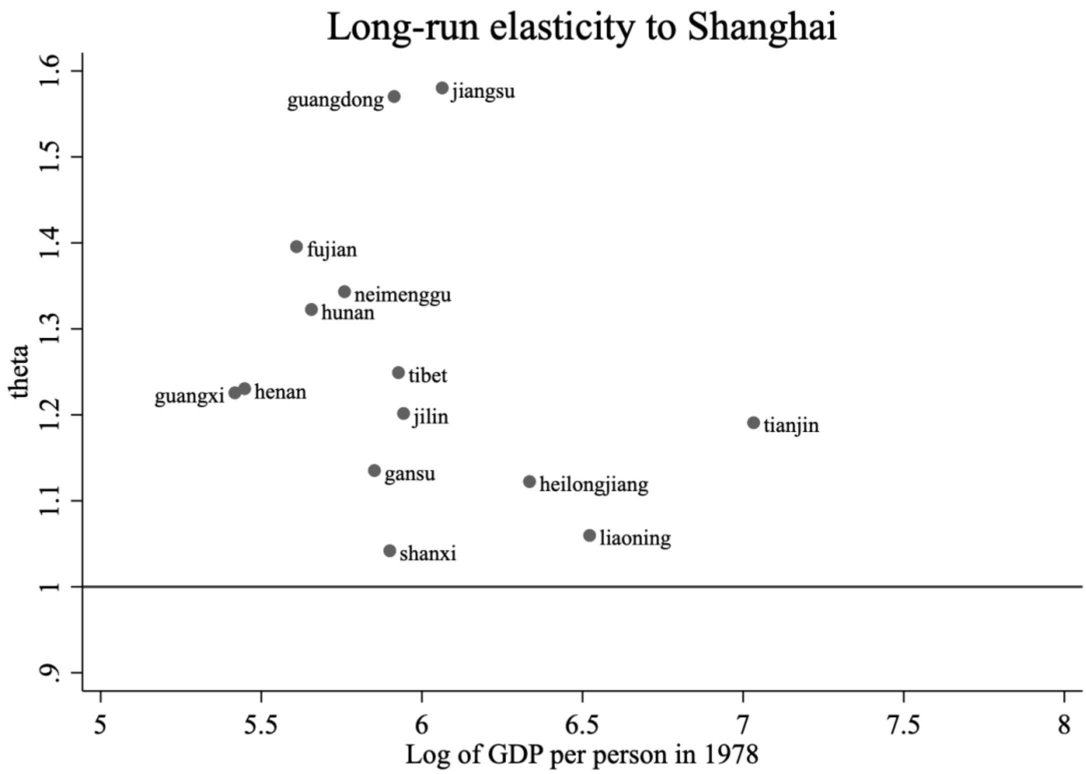




Notes: the speed of convergence and long-run elasticity is estimated from the heterogenous panel model on equation (2). For the long-run elasticities, we plot the cases where the absolute t-stats for lag income and common factor are at least one.

Figure 9 Heterogeneous beta convergence (Shanghai in the long run)





Notes: the speed of convergence and long-run elasticity is estimated from the heterogenous panel model on equation (2), but the long-run is Shanghai. For the long-run elasticities, we plot the cases where the absolute t-stats for lag income and Shanghai are at least one.