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China's Economic Growth: Some Stylized Facts

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Abstract

This paper proposes a set of stylized facts about Chinese economic growth. Using kernel density estimation, China is found to belong to the group of low-income countries in a sample of 124 countries. While mainland China has not yet made the transition to the group of high-income countries, Hong Kong joined the group of high-income countries in 1990 and Taiwan in 2000 while Singapore has belonged to the high-income group since 1980. The only other transitions observed in the data were those of Malta joining the high-income group in 2000 and the Czech Republic and South Korea in 2010. Within China, the distribution of GDP per capita has one mode with Beijing, Shanghai and Tianjin being the leaders in the right-hand tail of the distribution, these three provinces approaching the threshold separating low-income and high-income groups. Economic growth in China cannot be explained fully by investment: instead an explanation for rapid labor productivity growth is needed.

JEL codes: O4, O5.

Keywords: Kernel density estimation, growth accounting, economic growth.

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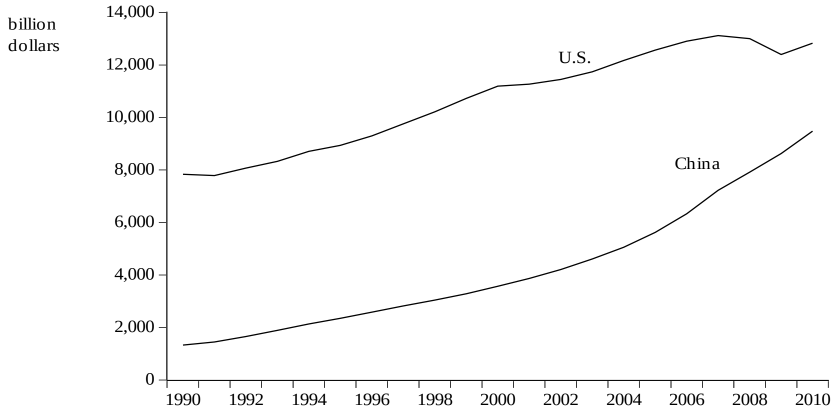
The rise of China is perhaps the single most important economic development in the latter part of the 20th century and the beginning of the 21st. China's economic success has brought hundreds of millions of people out of poverty and contributed to a more equal distribution of world income. According to the World Bank, China reduced its poverty rate from 84% of its population to 14% in 1981 to less than 12% in 2009 (poverty defined as survival on less than $1.25 per day). More symbolically, China may soon become the world's largest economy. But where does this place China in the family of nations? And what is the source of its increased prosperity?

1. Introduction

Rapid economic growth in China can be traced back to the introduction of market-oriented policies at the end of the 1970s. The third plenum of the Central Committee of the Eleventh National Party Congress in 1978, under the leadership of Deng Xiaoping, marked a sea change in economic policy in China. From this point on policy aimed to enhance the role of markets, increase competition and import foreign technologies. The scope of the public sector was reduced and laws and regulations changed so as to make it easier for entrepreneurs to set up new firms. Incentive systems were introduced in the public sector. Special economic zones were established to create a competitive environment for the export industries. Low interest rates generated private savings which were used to finance investment in manufacturing. As a result, China may soon become the world's largest economy as shown in Figure 1 below. In a second phase of reforms, started in the 1990s, new measures included fiscal consolidation, the establishment of a modern central bank, reforms of the banking sector and corporate governance, the establishment of a stock market and membership in the World Trade Organisation.

In spite of its economic successes, China remains, as we will document below, a low-income country on a per-capita basis. Nevertheless, due to its large population, the economic impact of Chinese economic growth on the world economy is significant. Table 1 shows the population of China's 31 provinces at the end of 2011 and that of a few comparator countries belonging to the European Union in addition to the largest U.S. states. Fourteen Chinese provinces have more people than California, the most populous U.S. state; the provinces of Shandong, Guangdong and Sichuan all have larger populations than Germany, the most populous EU member state; and the provinces of Hebei, Jiangsu and Hunan have populations that are close to that of Germany.

Figure 1. Real GDP in China and the U.S. in 2005 dollars



Source: Penn World Tables (2012).

Weaknesses have become apparent in recent years. Private savings are disproportionately allocated to state-owned enterprises while new entrepreneurial enterprises have to rely more on retained earnings.[1] Also, very low interest rates and capital rationing foster corruption when firms are allocated capital based on political considerations[2]. State-owned firms have lower returns to capital than privately-owned firms,[3] and consistently lower returns to capital in some regions and sectors indicate the existence of capital market imperfections. The rapidly expanding capital stock, especially in recent years, is indicative of a monetary disequilibrium, as described by Robert Aliber (2013), taking the form of capital rationing, corruption and real estate bubbles.

2. Distribution of world GDP per capita

China's position within the distribution of world GDP per capita has changed over time. The evolution of the world income distribution in a cross-section of countries and the mobility of individual countries within the distribution can be studied using kernel density estimation. Denote by y_i the GDP per capita in 2005 dollars for each of 124 countries (taken from the Penn World tables[4]) and transform the variable so that x_i denotes the country's per capita GDP relative to the sum of GDP per capita across all 124 countries:

$$x_i = {}^{y_i}\!/\!_{\sum_{i=1}^{n} y_i} \cdot 100 \qquad (1)$$

[1] See Hsieh and Klenow (2007), Dollar, and Jin Wei (2007) and Song and Storesletten (2008).
[2] See Wang (2013).
[3] See Dollar and Wei (2007) and Kwan (2006).
[4] Revisions of China's output figures suggested by Madison (1998) have been incorporated into the Penn-World tables (November 2012). For criticism of this approach, see Holtz (2006) and also Young(2000) on the limitations of official Chinese data.

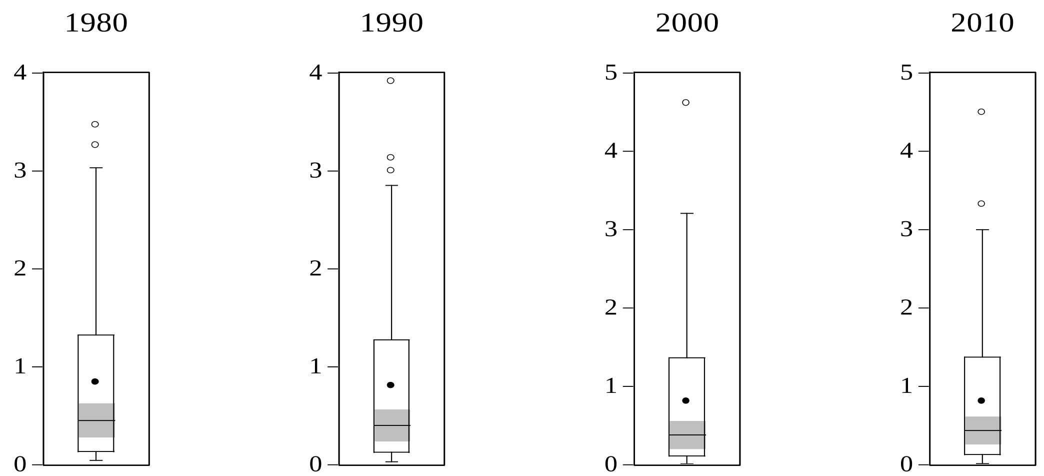
Table 1. Population of Chinese provinces in millions of people (end of 2011) and a sample of European countries and U.S. states

China												Europe and the U.S. states			
Beijing area		North-east		East coast		South coast		Interior		West		Europe*		U.S. states**	
Beijing	20.2	Liaoning	43.8	Shanghai	23.5	Henan	93.9	Chongqing	29.2	Shaanxi	37.4	Germany	81.1	California	38.0
Tianjin	13.6	Jilin	27.5	Jiangsu	79.0	Hubei	57.6	Sichuan	80.5	Gansu	25.6	France	66.0	Texas	26.1
Hebei	72.4	Heilongjiang	38.3	Zhejiang	54.6	Hunan	66.0	Guizhou	34.7	Qinghai	5.7	U.K	63.4	New York	19.6
Shanxi	35.9			Anhui	59.7	Guangdong	105.1	Yunnan	46.3	Ningxia	6.4	Italy	61.5	Florida	19.3
Mongolia	24.8			Fujian	37.2	Guangxi	46.5	Tibet	3.0	Xinjiang	22.1	Spain	47.4	Illinois	12.9
				Jiangxi	44.9	Hainan	8.8					Poland	44.6	Pennsylvania	12.8
				Shandong	96.4							Netherlands	16.8	Ohio	11.5

*) July 1st 2013, **) July 1st 2012. Source: China Statistical Yearbook (2012) and the OECD.

The transformation has a natural interpretation as a fraction of total world income contributed by the i^{th} country if all the countries had the same populations so that one abstracts from the size of the different countries.[5] This normalization makes it easier to compare the densities between any two periods. The boxplot in Figure 2 describes the distribution of the data for the 124 countries in each of four years; 1980, 1990, 2000 and 2010. The box represents the middle 50 percent of the data with the horizontal line through the box showing the median and the mean drawn using a symbol.

Figure 2. Boxplots for GDP per capita in the country sample



The box portion represents the middle 50 percent of the data. The median is depicted using a line though the center of the box while the mean is drawn using a symbol. The shaded box shows a confidence interval for the median. The inner fences – represented by the line above and below the box – show a distance of 1.5 times the length of the box on top of the box and below it. Data points further away are considered to be outliers.

The boxplots all indicate skewness around the median as well as the presence of outliers with high relative income.

Following Bianchi (1997) we estimate the density distribution $f(x_i)$ in order to identify the location of China within the estimated distribution. There may be different groups of countries, such as the group of low-income and the group of high-income countries. In this case the density distribution of the data is a mixture of distributions described by

$$f(x) = \sum_{j=0}^{m-1} p_j g_j\left(x; \mu_{j,}\sigma_j\right) \quad p_j \geq 0 \tag{2}$$

where p_j's are mixing proportions with

$$\sum_{j=0}^{m-1} p_j = 1 \tag{3}$$

[5] This transformation was proposed by Canova and Marcet (1995) to correct for potential problems of cross correlation for the countries, such as expansions and contractions of the world economy.

and g_j are densities with first and second moments μ_j and σ_j. If the gap in the μ_j's is large relative to the σ_j's the modes in the distribution are said to be well separated and *f(x)* is multimodal with *m* modes. If the gap is small relative to the variances the mixture components in the density are not well separated.

The density can be estimated non-parametrically by the method of kernels. Given a sample of *n* independent and identically distributed observations, a kernel density estimator of *f(x)* is constructed as (see Silverman, 1986)

$$\widehat{f_h}(x) = (nh)^{-1} \sum_{i=1}^{n} K\left(\frac{x-x_i}{h}\right) = (nh)^{-1} \sum_{i=1}^{n} K(u) \quad (4)$$

where $h > 0$ is the bandwidth and $K(u) = 1/\sqrt{2\pi}\ exp(-1/2u^2)$ is the Gaussian kernel. The bandwidth h determines the degree of smoothness of the density estimate, with larger values of h producing a smoother density estimate.

A critical bandwidth h_m, is defined as the smallest possible h producing a density with, at most, *m* modes.[6] If the true underlying density has two modes, a large value of h_1 is expected because a considerable amount of smoothing is required to obtain a unimodal density estimate from a bimodal density. A large value of h_m would then indicate the presence of more than *m* modes. Table 2 has the critical bandwidths for one, two and three modes.

Table 2. Critical bandwidths for 124 OECD countries

	One mode	Two modes	Three modes
1980	0.0070	0.0025	0.0015
1990	0.0075	0.0025	0.0015
2000	0.0080	0.0020	0.0015
2010	0.0075	0.0020	0.0015

Since the critical bandwidth for one mode is higher in 1990, 2000 and 2010 than it was in 1980 it follows that more smoothing is required in the three latter years to eliminate the second mode in the density. In the case of two modes in the distribution (see Appendix I), the mode of the low-income group falls in 2000 and 2010 while the mode for the high-income group becomes more distinct. The gap between the two modes appears to become smaller.

The bandwidths proposed by Silverman (1986) fall between the critical bandwidths for one and two modes in the distribution. The estimated densities using these bandwidths are shown in Figure 3. Several observations can be made about the estimated densities. First, the densities are bimodal which implies the existence of two groups of countries in the data; a

[6] See Silverman (1981, 1983, and 1986).

group of low-income countries and another of high-income countries. This distinction becomes more pronounced over time, especially between the years 1980 and 1990. Second, as shown in Table 3, there is a tendency for the gap between the two groups to narrow over time. The difference between the mean values of x_i in the two groups when the trough in the distribution is used to separate the two distributions rose slightly in the 1980s, remained constant in the 1990s and fell in the 2000s. The gap is around 9% smaller in 2010 than it was in 1980 and this is all due to a fall between 2000 and 2010.

Table 3. Group means and standard deviations (x_i) for the two country groups

	Mean			Peak of distribution		
	L-income	H-income	Difference	L-income	H-income	Difference
1980	0.42	2.32	1.90	0.20	2.30	2.10
1990	0.44	2.36	1.92	0.20	2.20	2.00
2000	0.35	2.27	1.92	0.20	2.10	1.90
2010	0.36	2.09	1.73	0.20	1.90	1.70

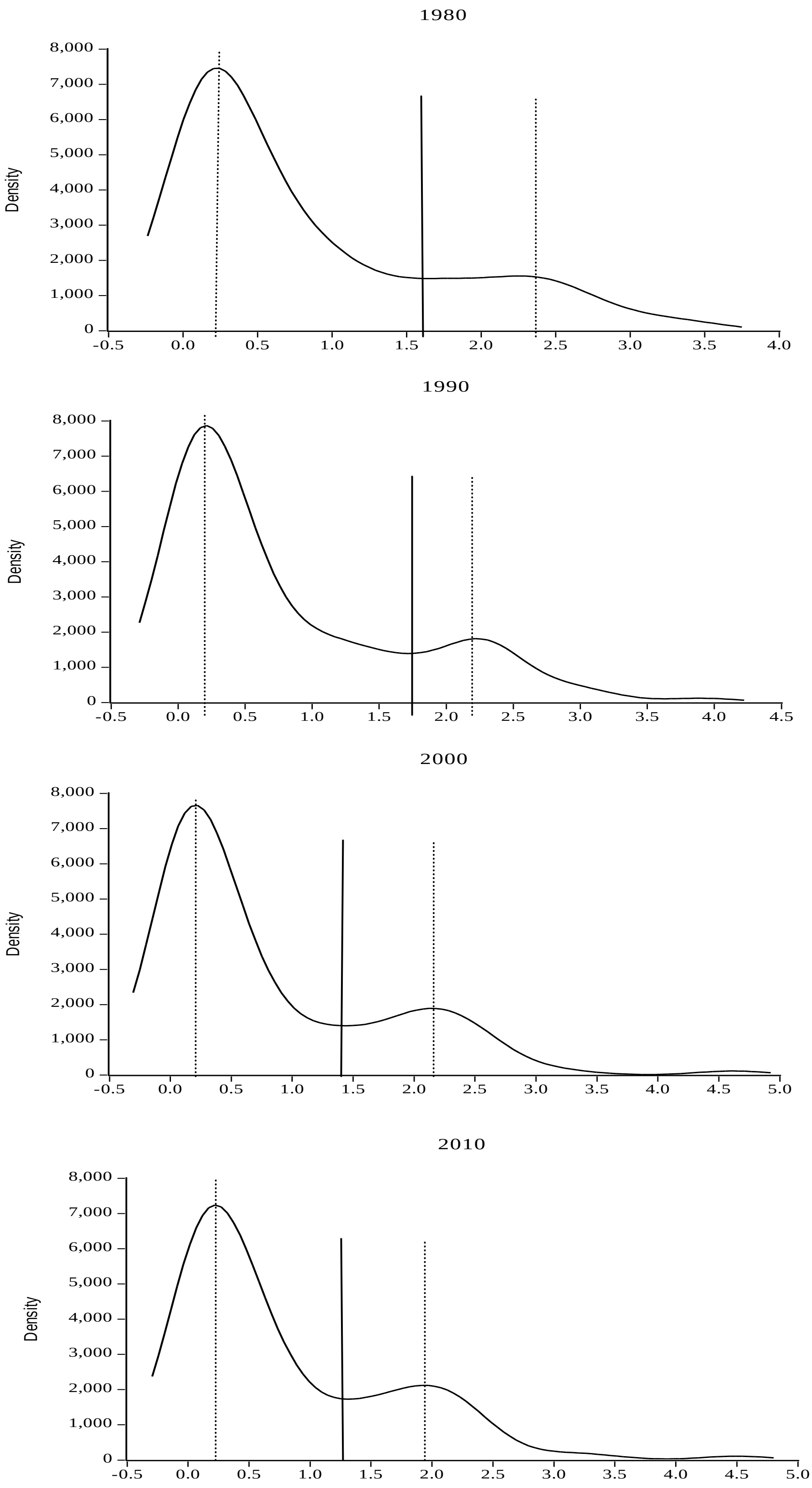
The difference between the peaks of the two modes of the distribution – shown by broken lines in Figure 3 – fell in the last two decades while it is difficult to detect what happened in the 1980s because of the flatness of the high-income mode. In contrast, Bianchi (1997) found a widening of the gap between the modes in the 1970s and 1980s.

We can also analyze the inter-distribution dynamics within the estimated densities in Figure 3. Then each country is allocated to the low-income group if the country has a value of x to the left of the threshold separating the two modes – this is the value of x at which the estimated density has a local minimum, see solid lines in Figure 3. Table 4 lists the countries that moved between the low-income and the high-income groups between 1980 and 2010. Of the five, South Korea and Taiwan are the greatest success stories, starting with the lowest values of x_i and ending with the highest ones.

Table 4. Movements between the group of low-income and high-income countries

	1980	1990	2000	2010
Czech Rep.		Low-income (1.38% <1.75%)	Low-income (1.18% <1.40%)	High-income (1.39%>1.30%)
Malta	Low-income (0.99%<1.60%)	Low-income (1.15% <1.75%)	High-income (1.41%>1.40%)	High-income (1.30%>1.30%)
South Korea	Low-income (0.57%<1.60%)	Low-income (1.02%<1.75%)	Low-income (1.33%<1.40%)	High-income (1.58%>1.30%)
Taiwan	Low-income (0.81%<1.60%)	Low-income (1.19% <1.75%)	High-income (1.63%>1.40%)	High-income (1.91% >1.30%)
Tri. & Tob.	High-income (2.09%>1.60%)	Low-income (0.93% <1.75%)	Low-income (1.12%<1.40%)	High-income (1.83%>1.30%)

Figure 3. The density for world GDP per capita



The densities are estimated using bandwidths recommended by Silverman (1986).

Both South Korea and Taiwan started as above-average income countries in the low-income group in 1990, although from the midpoint between the low-income and the high-income groups. Taiwan joined the high-income group in 2000 and South Korea in 2010. Taiwan subsequently moved up the distribution of high-income countries. The Czech Republic hovered around the midpoint between the two groups, starting in 1990 below, then falling further into the low-income group and then joining the high-income group in 2010. Malta rose from being a low-income country and joining the high-income group in 2000. Trinidad and Tobago left the high-income group in 1990 and then rejoined it in 2010, reflecting movements in the price of oil.

3. China in the family of nations

Table 5 shows the values of x_i for China, Hong King, Singapore and Taiwan in addition to three other fast-growing Asian economies; Indonesia, Malaysia and Thailand.

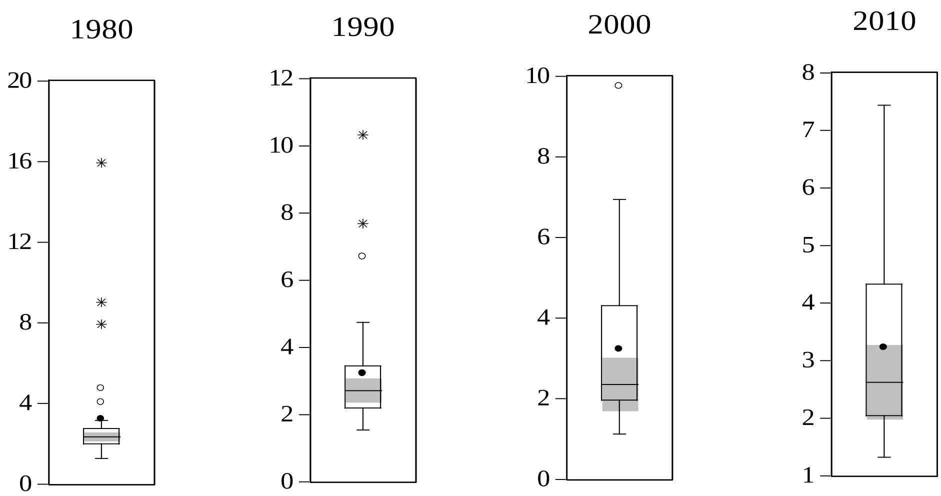
Table 5. Chinese speaking countries and a selection of Asian economies

Country	1980	1990	2000	2010
China	Low-income (0.06%<1.60%)	Low income (0.10%<1.75%)	Low income (0.20%<1.40%)	Low income (0.42%<1.30%)
Hong Kong	Low-income (1.49%<1.60%)	Low-income (1.95>1.75%)	High-income (1.98%>1.40%)	High-income (2.30%>1.30%)
Singapore	High-income (1.67%>1.60%)	High-income (2.06%>1.75%)	High-income (2.62%>1.40%)	High-income (3.32%>1.30%)
Taiwan	Low income (0.81%<1.60%)	High-income (1.19%<1.75%)	High-income (1.63%>1.40%)	High-income (1.91%>1.30%)
Indonesia	Low income (0.16%<1.60%)	Low income (0.19%<1.75%)	Low income (0.19%<1.40%)	Low income (0.24%<1.30%)
Malaysia	Low income (0.46%<1.60%)	Low income (0.51%<1.75%)	Low income (0.67%<1.40%)	Low income (0.71%<1.30%)
Thailand	Low income (0.26%<1.60%)	Low income (0.38%<1.75%)	Low income (0.40%<1.40%)	Low income (0.48%<1.30%)

Of the four Chinese-speaking regions and countries, Singapore already belonged to the high-income group in 1980 and then rose through its ranks over the next 30 years. Hong Kong was close to the border of the high-income club in 1980 and joined it in 1990 and has continued its ascent within the group. Taiwan joined the high income group in 2000 and has improved its position within the high-income group. Mainland China has belonged to the low-income group throughout this period although rising rapidly within the low-income group. Thus China is now above the mean of the low-income group but started out in the 1980s far below the mean, while Taiwan is getting closer to the mean of the high-income group. The three comparator countries, Indonesia, Malaysia and Thailand, belong to the low-income group. Malaysia has around twice the mean income level in the group while Thailand is just above the mean level and Indonesia below the mean in 2010. All three have grown and moved within the group of low-income countries.

Each of the 31 Chinese provinces has population numbers similar to those of European countries. Using equation (1) above one can construct time series for Chinese regions for real GDP per capita (Source: China Data Online) normalized by the sum of real GDP per capita in all the provinces for each of the 31 provinces from 1980-2010. Boxplots of the data are shown below.

Figure 4. Boxplots for GDP per capita in the Chinese provinces



The box portion represents the middle 50 percent of the data. The median is depicted using a line though the center of the box while the mean is drawn using a symbol. The shaded box shows a confidence interval for the median. The inner fences – represented by the line above and below the box – show a distance of 1.5 times the length of the box on top of the box and below it. Data points further away are considered to be outliers.

The boxplots all indicate a distribution that is skewed to the right. The first plot for 1980 shows that half the provinces have GDP per capita in the small box in the lower part of the plot, the distribution is thus compressed with a few large outliers; Shanghai, Beijing and Tianjin. The distribution then becomes less compressed in 1990, 2000 and 2010 and the outliers gradually disappear. The plots thus depict China having been overwhelmingly poor by the standards of developed countries with a handful of better off provinces in 1980 to having more widespread prosperity in 2010. The critical bandwidths shown in Table 6 confirm this conclusion. Much less smoothing is required in 2010 to get a unimodal distribution than is required in 1980. The unimodal densities are shown in Appendix I. A unimodal density becomes clearer over time.[7]

Table 6. Critical bandwidths for 31 Chinese regions

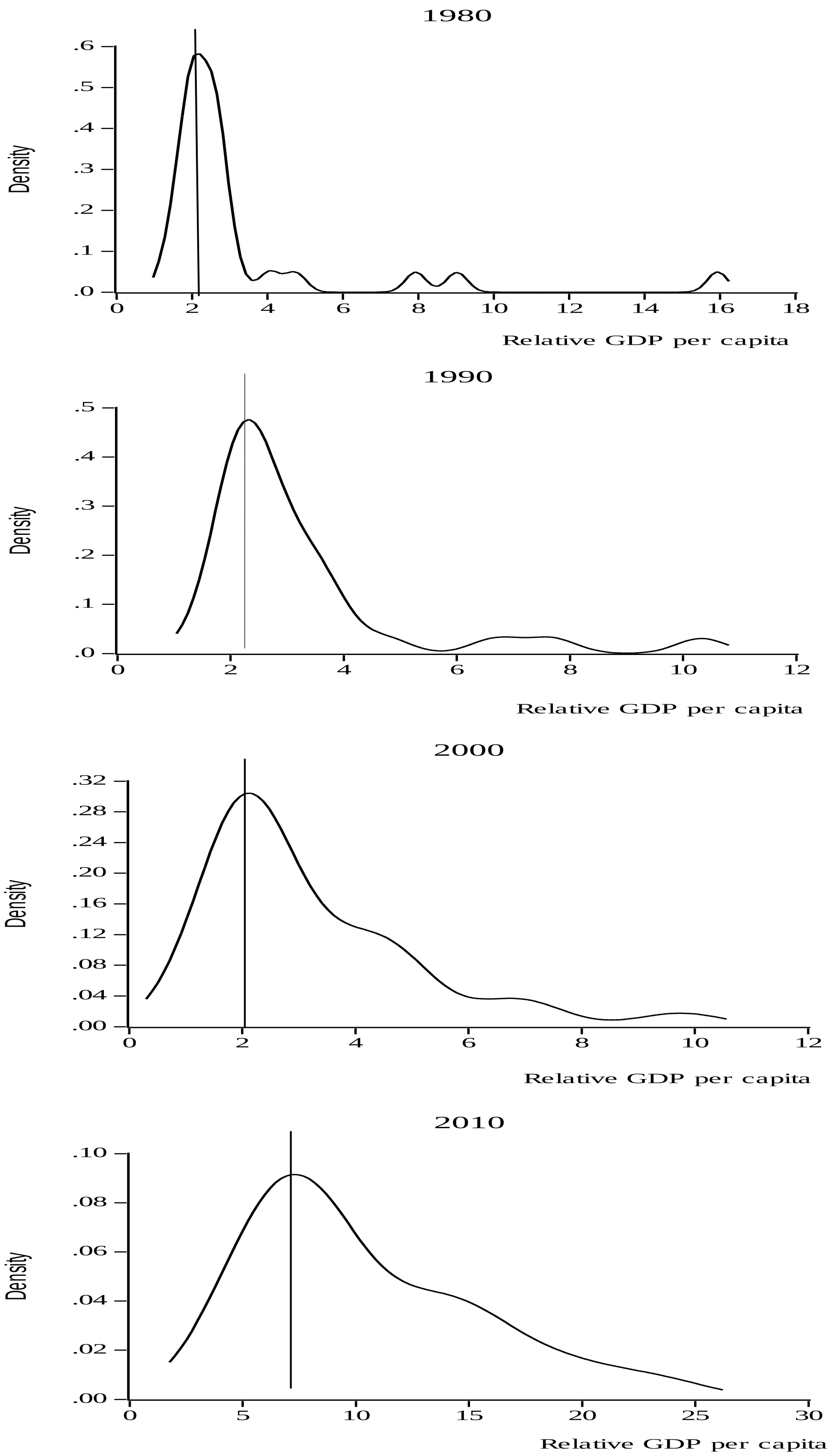
	One mode	Two modes	Three modes
1980	0.030	0.020	0.0065
1990	0.015	0.010	0.0045
2000	0.015	0.0095	0.009
2010	0.009	0.0055	0.0035

The estimated distributions for 1980, 1990, 2000 and 2010 using the bandwidth recommended by Silverman (1986) are shown in Figure 5 below. The densities have one mode in contrast to those for the cross-country sample in the figures above.[8] The distribution changes somewhat over the years. In 1980 the bulk of the provinces are poor and only three – Shanghai, Beijing and Tianjin – are comparatively well off although poor by western standards. These three remain in the lead in the other three years but the distribution of the remaining regions changes drastically. The distribution in 2010 is nevertheless skewed to the right and has a fat tail (skewness = 1.02 and kurtosis = 3.22). The estimated distribution functions show that more provinces now enjoy a relatively higher standard of living than in 1980 – welfare is becoming more widespread. In addition, the per capita GDP in all the regions is growing, a development which is hidden by the normalisation behind the distribution functions.

As shown in Appendix II, the Heilongjiang province which borders Russia in the north-east part of China is falling behind the other provinces, as are some western regions such as Gansu, Tibet and Qinghai in addition to Hunan in the middle of the country. The most upwardly mobile are Shandong, a coastal province south of Beijing and north of Shanghai, Fujian, a coastal region north of Guangdong, Henan, which borders Shandong inland, and Mongolia. Overall the provinces of Shanghai, Beijing and Tianjin are top of the list. The two coastal regions that boarder Shanghai – Jiangsu to the north and Zhejiang to the south – gradually attain fourth and fifth place at the expense of Liaoning and Heilongjiang, the last two the home of old industry originating in Japan’s pre-war occupation.

[7] Due to the limited number of observations it is difficult to detect three or more modes.
[8] These results are consistent with those of Herzfeld (2006) who also found a unimodal distribution of GDP per capita across Chinese provinces.

Figure 5. The density for GDP per capita in Chinese provinces



The densities are estimated using bandwidths recommended by Silverman (1986).

Guangdong remains in the top league in all years. Thus the coastal regions have benefited most from the economic development of the past thirty years although the interior regions have also grown significantly.

One can estimate whether relatively low income provinces have a tendency to catch up with the better off. To test for what is called *β-convergence* one estimates the following equation where *i* is an index for regions in the cross section of provinces:

$$log(y_{it}/y_{i0}) = g - \left[\left(1 - e^{-\beta t}\right)/T\right]log(y_{i0}) + \varepsilon_{i0T} \qquad (5)$$

A positive and significant value of β indicates β-convergence in the data. Recent studies for European regions, U.S. states and Japanese prefectures have revealed convergence within these economically homogenous areas.[9] The estimated speed of convergence turns out to be surprisingly similar across data sets: regions tend to converge at a speed of approximately 2% per year. The estimates are reported in Table 7, first when *g* – which is growth due to other factors than catching up – is constrained to take the same value for all provinces and the other when each province is allowed to have its own value. The equation is estimated for the whole period 1980-2010 as well as for each decade.

Table 7. β - Convergence for Chinese provinces

	Basic equation			Equation with regional dummies		
	g	β	R^2	β	R^2	Obs.
1980-2010	0.100 (17.1)	0.016 (2.7)	0.29	0.027 (3.34)	0.60	31
1980-1990	0.086 (12.2)	0.025 (4.4)	0.47	0.030 (4.26)	0.56	31
1990-2000	0.050 (3.2)	-0.008 (1.1)	0.04	0.001 (0.10)	0.40	31
2000-2010	0.145 (9.0)	0.014 (2.1)	0.15	0.027 (2.9)	0.37	31

The results come from the estimation of equation (2) using cross sectional data.
Estimation method: weighted least squares. t-statistics in parentheses.

[9] European regions that were low-income in 1960 turned out to grow faster than the high-income ones in the decades that followed. In the United States the South started out being low-income at the end of the Civil War and then experienced faster growth than the better off northern states. In Japan studies have also documented such convergence of productivity across prefectures. See Sala-I-Martin (1996).

For the whole period the value for β is 0.016 – implying that the rate of convergence is 1.6% per year. This rises to 2.7% when each region is allowed to have its own value of autonomous growth *g*, allowing, for example, for differences in the pace of deregulation across provinces.[10] Convergence was more rapid in the 1980s and the 2000s than in the 1990s when the estimated β was not statistically significant from zero. The values of *g* for the provinces are shown in Table 8 below.

Table 8. Dummy variables (*g*) for provinces

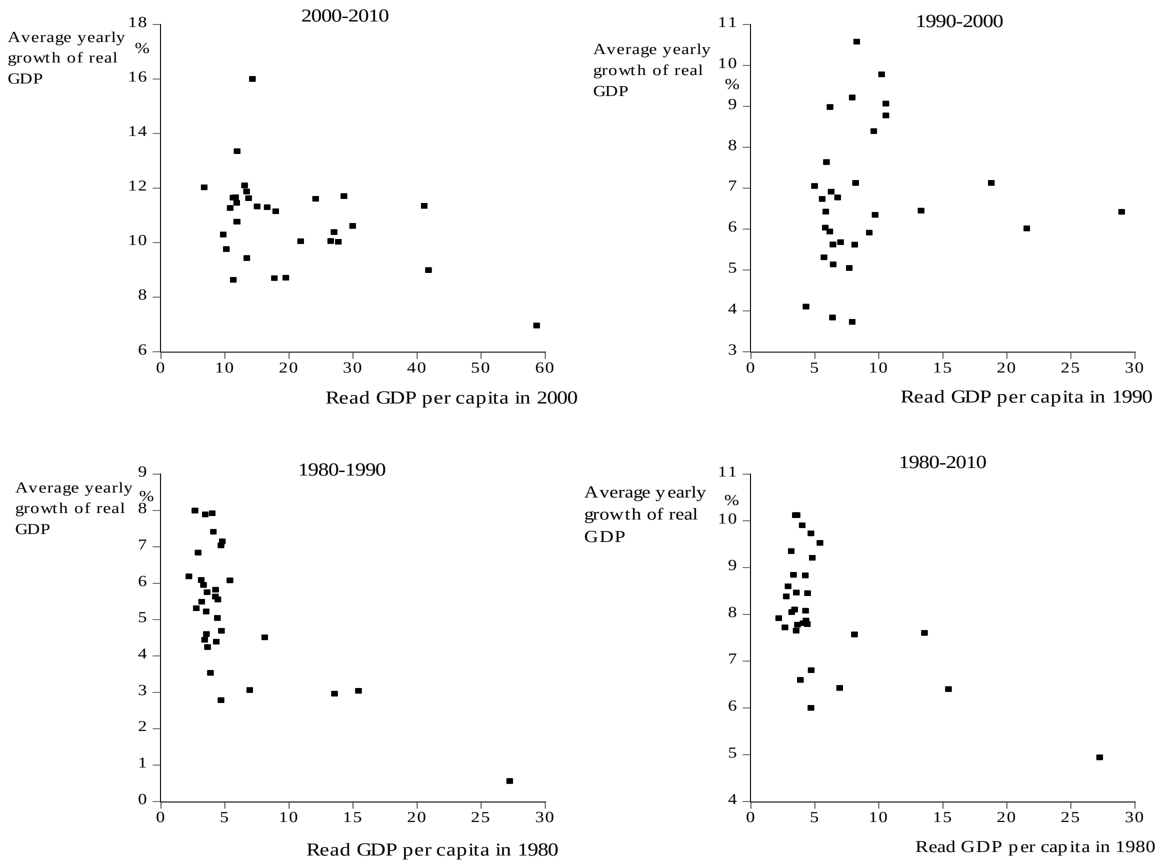
Regions	1980-2010	1980-1990	1990-2000	2000-2010
Beijing	0.116 (15.04)	0.094 (8.34)	0.070 (3.57)	0.191 (8.28)
North East	0.108 (13.27)	0.091 (7.65)	0.068 (3.44)	0.173 (7.52)
East coast	0.117 (17.69)	0.101 (10.42)	0.083 (4.51)	0.181 (7.88)
South coast	0.108 (18.71)	0.090 (10.69)	0.074 (4.63)	0.172 (8.66)
Middle	0.097 (17.37)	0.084 (10.25)	0.055 (3.71)	0.162 (9.17)
West	0.101 (16.21)	0.088 (9.65)	0.054 (3.26)	0.170 (8.92)

The table has estimation results for the coefficient g in equation (2).
t-statistics in parentheses.

The autonomous rate of growth (*g*) is highest on the east coast and in the Beijing area and slowest in the middle of the country and in the western provinces. Figure 6 below shows the relationship between average rate of growth of real GDP per capita and initial real GDP per capita for the Chinese provinces.

[10] Démurger et al. (2006) find that the coastal regions grew more rapidly between 1996 and 1999 due to greater deregulation.

Figure 6. Convergence of Chinese regions



A downward-sloping relationship – indicating β convergence – is found in all charts in the figure except the 1990-2000 one.[11]

Splitting the sample into two with the coastal provinces (Beijing, the north east, the east coast and the south coast), on the one hand, and the central and westerns provinces on the other hand, shows that the catching up process is much stronger on the coasts than in the centre or the western part of the country. The convergence coefficient β is statistically not significant in the centre and the western provinces while convergence on the coasts is estimated to be 2.2% per year. See Table 9.

[11] Cai et al. (2002), Demurger et al. (2002) and Weeks and Yao (2003) also find beta-convergence for Chinese regions.

Table 9. β - Convergence for coastal and interior provinces

	g	β	R^2	Obs.
Coastal provinces	0.109 (19.7)	0.022 (3.5)	0.51	31
Central and western regions	0.099 (6.7)	0.026 (1.0)		

The results come from the estimation of equation (5) using cross sectional data.
Estimation method: weighted least squares. t-statistics in parentheses.

4. The sources of growth

Two main explanations have been proposed for rapid growth in China, as well as the earlier growth episodes in South Korea, Taiwan, Singapore and Hong Kong. One emphasizes factor accumulation (see, among others, Young (1995)) while the other emphasizes technology catch-up (see Nelson and Pack (1999)) or assimilation. According to the first approach, growth in China can be explained by its high rates of investment and the migration of workers from rural areas to the cities. The assimilation approach, in contrast, attributes growth to technological progress driven by the adoption of foreign technologies and their adaption to local circumstances.

These arguments can be formalized with a few equations. Assume, for the sake of illustration, the existence of two sectors in the economy, primary industry and an expanding manufacturing industry. Output in the manufacturing industry is given by the following equation.

$$Y_1 = K_1^{\alpha}(A_1 L_1)^{1-\alpha} \tag{6}$$

where Y denotes output, K is the capital stock, A technology and L labor and the subscript 1 denotes manufacturing while the subscript 2 indicates the primary industry whose output is given by a Leontief production function so that

$$Y_2 = A_2 L_2 \tag{7}$$

Assume technological progress in both sectors and also assume that technology grows more rapidly in the manufacturing sector

$$g_1 = \frac{\dot{A_1}}{A_1} > \frac{\dot{A_2}}{A_2} = g_2 \tag{8}$$

A faster rate of technical progress in the manufacturing sector than in the primary sector will draw labor into manufacturing.[12] Employment in the manufacturing sector can then be made a function of the level of productivity in both sectors and the stock of capital in manufacturing by equalizing the marginal product of labor between the two sectors:

$$L_1 = (1-\alpha)^{1/\alpha} A_1^{(1-\alpha)/\alpha} A_2^{-1/\alpha} K_1 \qquad (9)$$

Taking logs of equation (9) gives the rate of growth of manufacturing employment;

$$g_{L_1} = \frac{1-\alpha}{\alpha} g_1 - \frac{1}{\alpha} g_2 + g_k \qquad (10)$$

From equations (6) and (10) it follows that

$$g_{Y_1} = g_{K_1} + \frac{(1-\alpha)}{\alpha}(g_1 - g_2) \qquad (11)$$

Using the production function (6) and equation (9) and assuming a fixed saving rate *s* gives;

$$g_{K_1} = sK_1 \left(\frac{A_1}{A_2}\right)^{\frac{1-\alpha}{\alpha}} (1-\alpha)^{1-\alpha/\alpha} \qquad (12)$$

Inputting (12) into (11) gives

$$g_{Y_1} = sA_1^{\frac{1-\alpha}{\alpha}} (1-\alpha)^{\frac{1-\alpha}{\alpha}} + \frac{1-\alpha}{\alpha}(g_1 - g_2) \qquad (13)$$

Growth of manufacturing output can thus be caused by investment and technical progress. The former can propel growth without hitting diminishing returns since labor migrates from the primary sector.[13] The growth rate of total output, $Y_1 + Y_2$ is then

$$g_Y = \left[sA_1^{\frac{1-\alpha}{\alpha}} (1-\alpha)^{\frac{1-\alpha}{\alpha}} + \frac{1-\alpha}{\alpha}(g_1 - g_2) \right] \frac{Y_1}{Y_1 + Y_2} \qquad (14)$$

as long as agricultural output remains constant, that is $g_2 = -g_{L_2}$, agricultural workers manage to increase productivity to offset any loss of workers to the expanding manufacturing sector.

Following Nelson and Pack (1999), we regress the average rate of growth of real GDP per capita from 1990 to 2010 in 124 countries on the initial level of real GDP per capita in 1990, the average rate of growth of the population and the average share of investment of GDP in

[12] Cai et al. (2002) finds that industrial productivity has grown more rapidly than agricultural productivity in China since the mid-1980s. This is most pronounced in the eastern provinces and less so in the central and western provinces, although very clearly present in the data in those provinces also

[13] According to Bosworth and Collins (2007) 1.2% of Chinese growth can be attributed to the reallocation of workers from agriculture to industry and services.

order to test whether China's growth performance is accounted for by its low initial level of GDP as well as the high rate of investment.[14] If not, the residual from this regression will be high for China. The investment variable is a proxy for the rate of growth of the capital stock since differences in the output-capital ratio in 1990 will be dwarfed by investment data covering twenty years.[15] The estimation results are shown in the second column of table below while the third column shows the results of the same regression using data from the 31 Chinese provinces.

Table 10. Growth between 1990 and 2010 explained

(1)	(2) 124 countries		(3) Chinese regions	
	Coefficient	t-ratio	Coefficient	t-ratio
Constant	1.70	1.93	52.46	5.60
Initial GDP	-0.001	2.55	-0.23	0.67
Population growth	-0.61	2.75	-1.21	0.76
Investment	11.50	3.17	-45.14	2.10
	Observations: 124 R-squared:0.21, adj.-squared: 0.19		Observations: 31 R-squared: 0.17, adj. R-squared: 0.08	

The table has the results for a cross section of countries in column (2) and Chinese provinces in column (3). The estimated equation is: $\frac{\Delta(Y/L)}{Y/L} = \alpha_0 + \alpha_1 (Y/L)_0 + \alpha_1 \frac{\Delta L}{L} + \alpha_2 \frac{I}{Y} + \varepsilon$ where output growth and population growth (in per cent) is measured as average annual growth from 1990 to 2010 and initial output per capita is the 1990s value.

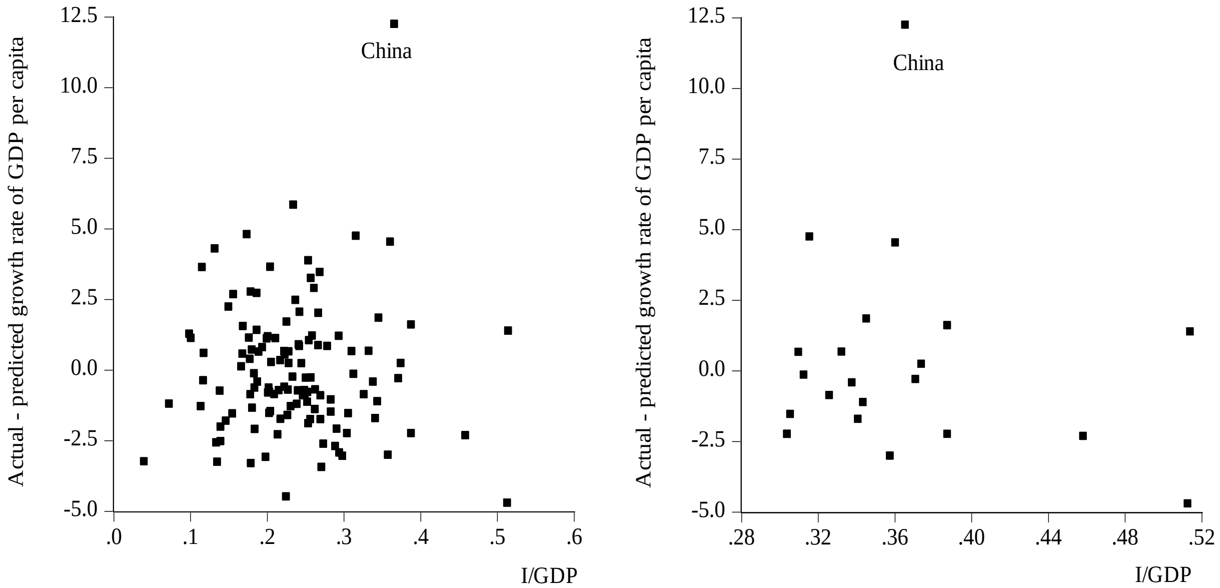
The results for the sample of 124 countries show, as expected, that the higher the initial level of GDP, the lower the average rate of growth in the subsequent twenty years; that the higher the rate of population growth the lower the average growth rate of output per capita; and that the higher the level of investment the higher the rate of growth of output.

The third column of Table 10 has results for the Chinese provinces for the same period. The results are not nearly as good as those for the countries in the second column. First, the level of convergence is not nearly as strong. Second, the coefficient of population growth is not significantly different from zero. And, finally, the coefficient of the investment to output ratio is both negative in sign and significantly different from zero, indicating that high investment and low growth are correlated across the provinces.

[14] The evolution of capital-output ratios for the 31 provinces is shown in Appendix III. A notable increase in this ratio occurs in many provinces after 2005 which indicates that investment has increased.
[15] This equation was estimated by Levine and Renelt (1992) who also found a negative effect of initial income and population growth on output growth and a positive effect of investment.

A plot of the difference between actual average rate of growth of real GDP per capita and the predicted rate of growth for the 124 countries in column (2) of the table, on the one hand, against the investment variable, on the other hand, can be used to assess whether the equation accounts for China's growth performance, in particular whether the high investment rates in China help explain its stellar growth performance. In the left-hand panel we show the relationship for all 124 countries while in the right-hand panel only countries where investment exceeds 30% of GDP are included.

Figure 7. Actual minus predicted GDP growth rates 1990-2010



The vertical axes measure the difference between actual average annual growth from 1990 to 2010 and the predicted value from Table 10. The horizontal axis has the average value of the ratio of gross capital formation to GDP over the same period.

Clearly, China stands out as a good performer even after adjusting for the low level of initial GDP, investment and population growth. Investment in physical capital is not sufficient to explain either the high growth experienced in China between 1990 and 2010 or the differences in observed growth rates across the provinces. Also, differences in the initial level of real GDP per capita cannot explain differences in growth either. Instead one must turn elsewhere.

5. More on productivity growth

The approach of Hall and Jones (1999) can be used to calculate the relative importance of productivity and capital in explaining differences in output per employed worker across countries and provinces. Starting with the Cobb-Douglas production function for the whole economy

$$Y = K^{\alpha} (AN)^{1-\alpha} \tag{15}$$

where N denotes the number of employed workers and K is calculated from investment data.[16] Now taking logs gives;

$$\log Y = \alpha \log K + (1-\alpha)\log A + (1-\alpha)\log N \tag{16}$$

Finally, rearranging gives a solution for A which can be calculated by assuming that the share of capital in national income is 1/3 (as in Hall-Jones and derived using Chinese data by Chow and Li (2002)):

$$\log A = \log Y - \frac{1}{2}\log\frac{K}{Y} - \log N \tag{17}$$

Before analyzing productivity growth we can take a look at the value of the different terms in equation (17) in 1980 and 2010. Table 11 has the values of the log of output per employed worker $log(Y/N)$ and $0.5log(K/Y)$ for China, France and the United States.

Table 11. China, France and the United States compared

	China		United States		France	
	1980	2010	1980	2010	1980	2010
0.5*log(*K/Y*)	0.603	0.498	0.364	0.500	0.480	0.527
log(*Y/N*)	3.501	4.693	5.432	5.659	5.405	5.566

China had a higher capital-output ratio in 1980 than the United States and almost as high in 2010. France had a higher ratio in both years. But the level of output is much higher in the U.S. than in China in both years and also higher than in France. The difference in the log of output per capita between the U.S. and China was 1.93 in 1980 and 0.97 in 2010. The differences in the log of productivity A were 2.2 and 1.0 in these same years. For the U.S. and France the differences in log output per capita were 0.03 and 0.09 and in log productivity 0.14

[16] K is calculated by using data on gross capital formation in 1970, assuming that the rate of depreciation is 0.06 and calculating the rate of growth of output for the next ten years. Assuming that the K/Y ratio was stable one can then calculate the level of K in 1970. Then using data on investment and the assumed depreciation rate K, the series is extended until 2010.

and 0.12. Therefore, the observed differences in the level of output per capita can be traced to differences in the level of productivity A.[17]

A similar pattern emerges when the Chinese provinces are compared as shown in Table 12. The growth of output per employed worker is explained by increased productivity for each of the provinces and differences across provinces in output per worker are explained by differences in productivity. Thus the difference between the log of output per employed worker in the highest income province in 2010 (Shanghai) and the lowest income province (Guizhou) is 2.114, while the difference between log of the capital-output ratio multiplied by 0.5 is -0.135, that is Guizhou has a higher capital-output ratio so that all of the difference in output per employed worker can be attributed to differences in productivity.

The growth of labor productivity in China in the past three decades is very impressive. Following decades of zero technological change from 1950 to 1980 a period of rapid growth of technology and productivity followed (see Chow (1993) and Chow and Li (2002)). Figure 8 shows the evolution of labor productivity in the G7 countries in addition to China based on equation (17). Note the rapid rise of China but, since Chinese productivity started at a very low level, it is still only a fraction of that found in the G7 countries. In contrast, productivity in Japan has been stagnant for the whole period since 1990. Also, note how productivity growth appears to peter out in the other G7 countries after year 2000.

The level of productivity varies greatly between Chinese provinces, with the provinces in the western part of the country and in the interior having much lower levels than those on the coasts, in the Beijing region and in the north east. Some provinces managed to narrow the gap with Shanghai – which is the highest productivity region throughout the period 1990-2010. This applies to Beijing, Tianjin and Mongolia in the Beijing region but particularly to the coastal regions of Jiangsu and Zhejiang. In the south the province of Guangdong also managed to narrow the gap with Beijing.[18]

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[17] These results are similar to those of Zhu (2012) who found that China's capital-output ratio is higher than that of the U.S. and that the growth of its relative GDP per capita is mainly driven by the growth of China's relative total factor productivity. Bloom et al. (2005) find that most of Chinese productivity growth occurs within sector rather than due to changes in sector shares.

[18] See Appendix IV.

Table 12. Provinces compared

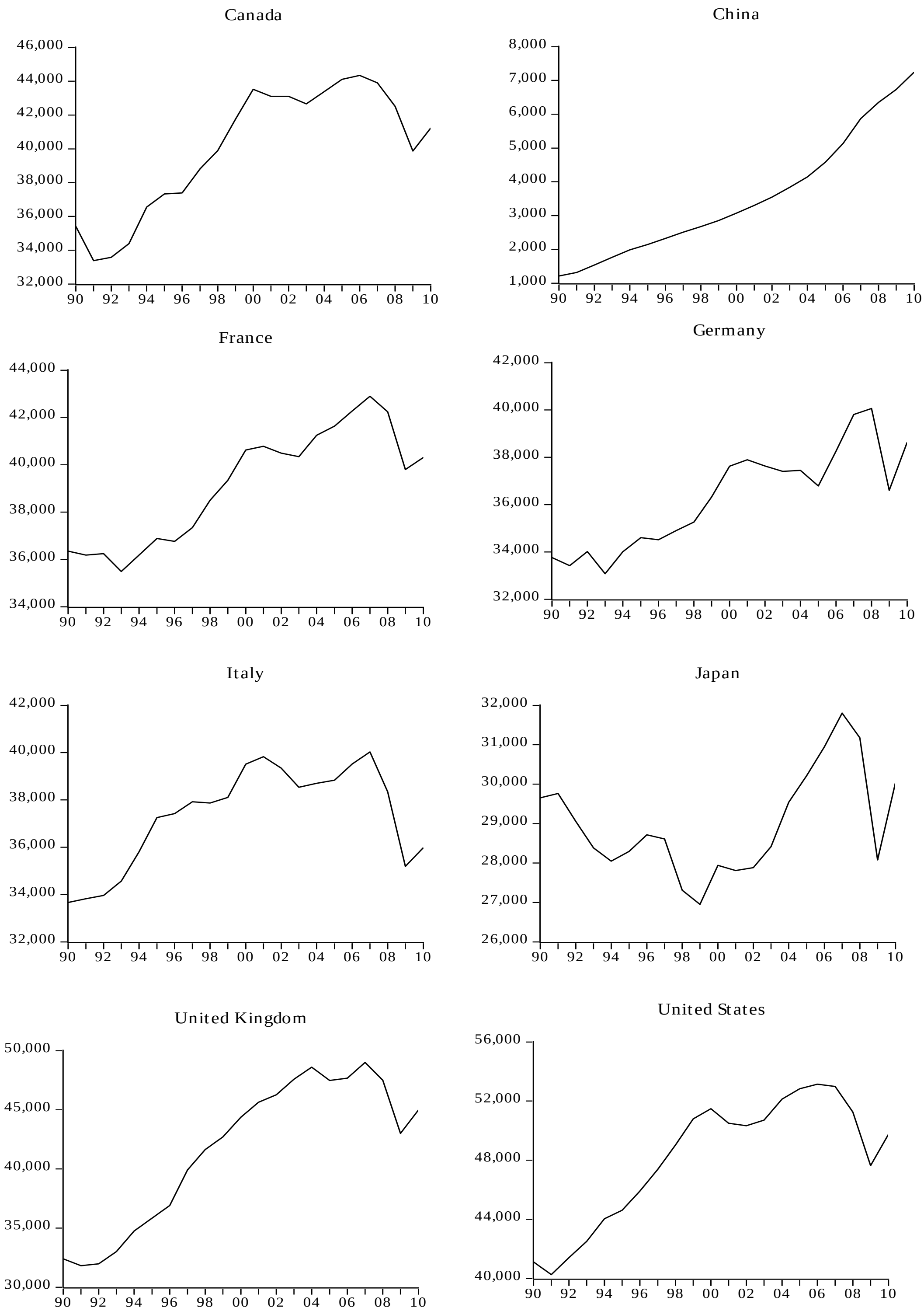
1990	Beijing	Tianjin	Hebei	Shanxi	Mongolia	Liaoning	Jilin	Heilongjiang
*00.5*log(K/Y)*	0.454	0.471	0.241	0.409	0.251	0.306	0.255	0.342
log(Y/N)	3.615	3.574	2.799	2.808	2.765	3.319	2.837	3.172
2010								
*0.5*log(K/Y)*	0.376	0.448	0.535	0.479	0.519	0.591	0.605	0.463
log(Y/N)	5.093	5.851	4.810	4.628	5.152	5.097	4.899	4.703

1990	Shanghai	Jiangsu	Zheijiang	Anhui	Fujian	Jiangxi	Shandong	Henan
*0.5*log(K/Y)*	0.442	0.236	0.174	0.157	0.145	0.169	0.237	0.192
log(Y/N)	3.885	2.989	2.829	2.505	2.902	2.451	2.985	2.563
2010								
*00.5*log(K/Y)*	0.374	0.432	0.430	0.597	0.40704	0.579	0.468	0.501
log(Y/N)	5.729	5.146	4.862	4.164	4.908	4.398	4.983	4.499

1990	Hubei	Hunan	Guangdong	Guangxi	Hainan	Chongqing	Sichuan	Guizhou
*0.5*log(K/Y)*	0.182	0.183	0.156	0.071	0.269	0.140	0.158	0.214
log(Y/N)	2.863	2.413	3.056	2.298	2.605	2.349	2.367	2.129
2010								
*0.5*log(K/Y)*	0.451	0.415	0.268	0.481	0.475	0.580	0.545	0.509
log(Y/N)	4.565	4.179	4.990	4.088	4.302	4.304	4.125	3.615

1990	Yunnan	Tibet	Shaanxi	Gansu	Qinghai	Ningxia	Xinjiang	
*0.5*log(K/Y)*	0.102	0.397	0.326	0.310	0.564	0.429	0.398	
log(Y/N)	2.514	2.555	2.587	2.281	2.847	2.738	3.131	
2010								
*0.5*log(K/Y)*	0.571	0.711	0.527	0.535	0.575	0.606	0.536	
log(Y/N)	3.864	3.925	4.585	3.981	4.308	4.532	4.766	

Figure 8. Labor productivity *A* for China and the G7 countries



The figure shows calculated labor productivity from equation (17). Vertical axes measure dollars at 2005 prices.

One can estimate the Nelson-Phelps (1966)[19,20] equation to get an estimate of the average rate of catching up to the technology leader;

$$\frac{\dot{A}_i}{A_i} = c_0 + c_1\left(\frac{A_S - A_i}{A_i}\right) \tag{18}$$

where A_S is the level of productivity in the leading province, Shanghai, and A_i is productivity in the other 30 provinces. The results are shown below.

Table 12. Estimated Nelson-Phelps equations

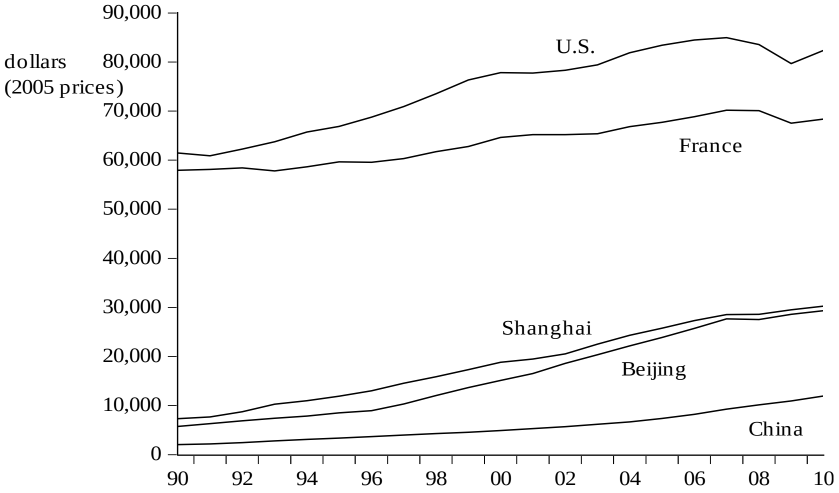
Constant: c_0	-0.07 (2.32)
Log(A^*/A): c_1	0.14 (4.87)
R-squared	0.35
Observations	620 (31*20)
Time period	1999-2010

The table has the results of estimating equation (17) in a panel of observations where Shanghai is taken to be the leading region. t-statistics in parentheses.

The results show that the rate of catching up to Shanghai is on average 14% per year. However, in spite of very rapid productivity growth in recent decades, the level of labor productivity in the leading Chinese regions is still significantly lagging behind productivity in the developed world as can be seen in Figure 9 below, which shows real GDP per working individual in China, France and the U.S. and in the leading provinces of Beijing and Shanghai.[21]

[19] For empirical studies using this approach, see, amongst others, Acemoglu et al. (2010) and Vandenbussche et al. (2006).
[20] A paper by Yifu Lin (2013) describes how industrial policy can be used to facilitate the acquisition of foreign technology.
[21] The Beijing and Shanghai levels of productivity were calculated by first calculating the ratio of their GDP per worker in renminbi to overall Chinese productivity and then multiplying with the dollar value of Chinese productivity taken from the Penn World tables.

Figure 9. Output per worker



Source: China Statistical Yearbook and the Penn-World Table.

In terms of its relative output per capita – x_i from equation (1) – each of the provinces is rapidly advancing within the group of low income "countries."[22]

6. Summary

We have established a set of stylized facts about economic growth in China.

- There are two statistically-distinguishable groups of countries in the world defined by GDP per capita; a low-income and a high-income group.
- There is a tendency for the two groups of countries to converge over time since 1980, which is a reversal of the trend in previous decades as described by Bianchi (1997).
- There are also few instances of countries graduating from the low-income group and joining the high-income group. Hong Kong joined the high-income group in 1990, Taiwan and Malta joined the group in 2000, as did South Korea and the Czech Republic in 2010.
- Mainland China is still in the group of low-income countries although it has moved rapidly through their ranks. The most advanced Chinese regions, Shanghai, Tianjin and Beijing, are currently approaching the border between the low-income and the high-income groups. Nevertheless, productivity per employed worker in these regions is still less than 50% of U.S. productivity.

[22] Appendix V has the value of for each of the 31 Chinese provinces when these are treated as if they were independent countries.

- Economic growth in China appears to be driven by technological progress rather than rising capital-output ratios. Thus differences in investment to GDP ratios across provinces are negatively correlated with economic growth and China remains an outlier in terms of the growth of GDP per employed worker in a cross section of countries after controlling for investment, population growth and initial income.
- Differences in productivity explain differences in output per capita between China and the United States as well as between Chinese provinces. Labor productivity has grown rapidly in each of China's provinces.
- Within China, the distribution of GDP per capita has one mode with Beijing, Shanghai and Tianjin being the leaders in the right-hand tail of the distribution.
- Some provinces managed to narrow the gap with Shanghai between 1990 and 2010. This applies to Beijing and Tianjin in the Beijing region but particularly to the coastal regions of Jiangsu and Zhejiang. In the south the province of Guangdong managed to narrow the gap with Beijing.
- Due to the size of the Chinese population, a continued convergence of Chinese productivity to U.S. productivity levels will make Chinese GDP exceed U.S. GDP. Weaknesses may prevent this from happening: inefficient allocation of capital; corruption; a monetary disequilibrium and real estate bubbles.

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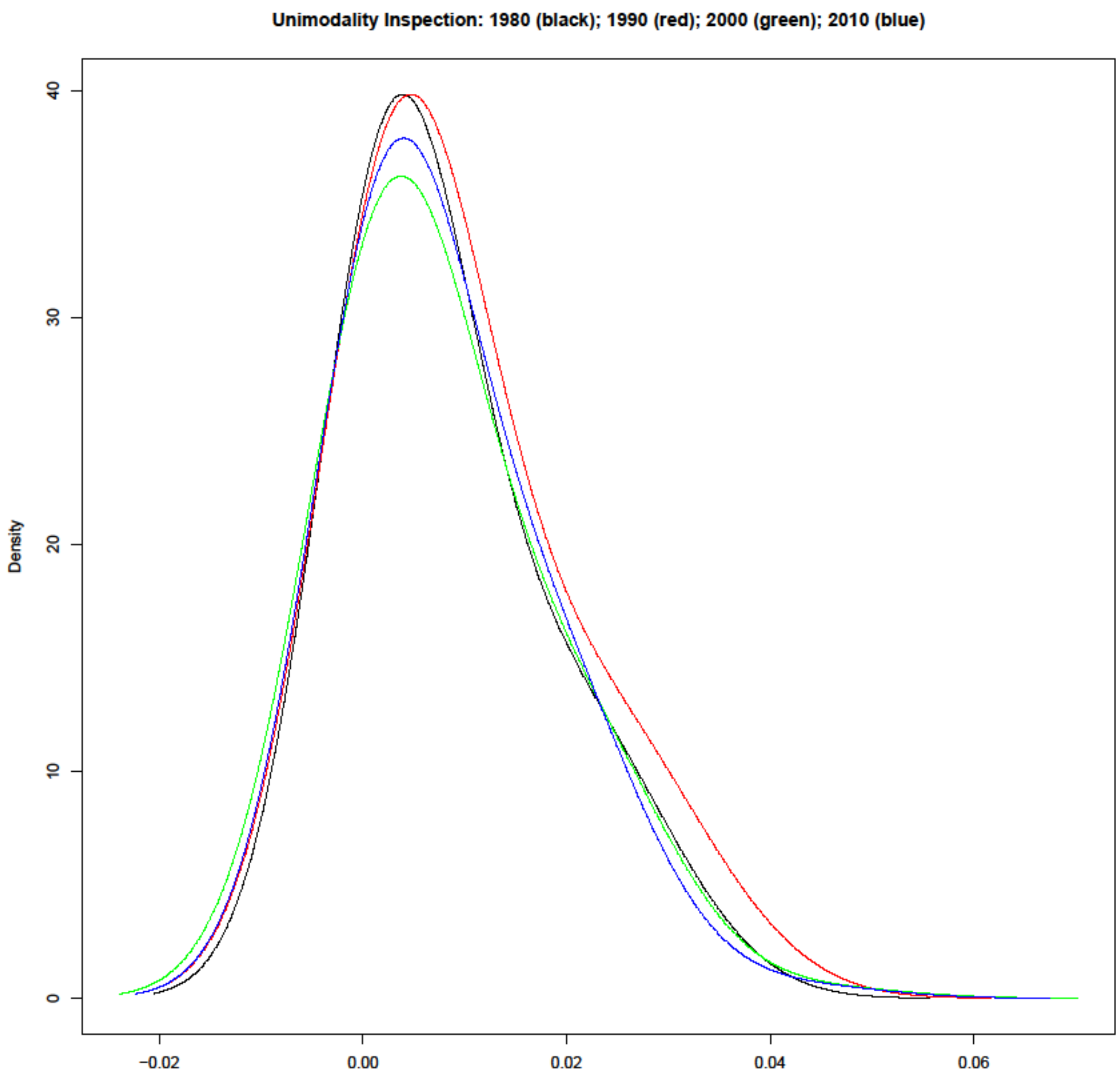
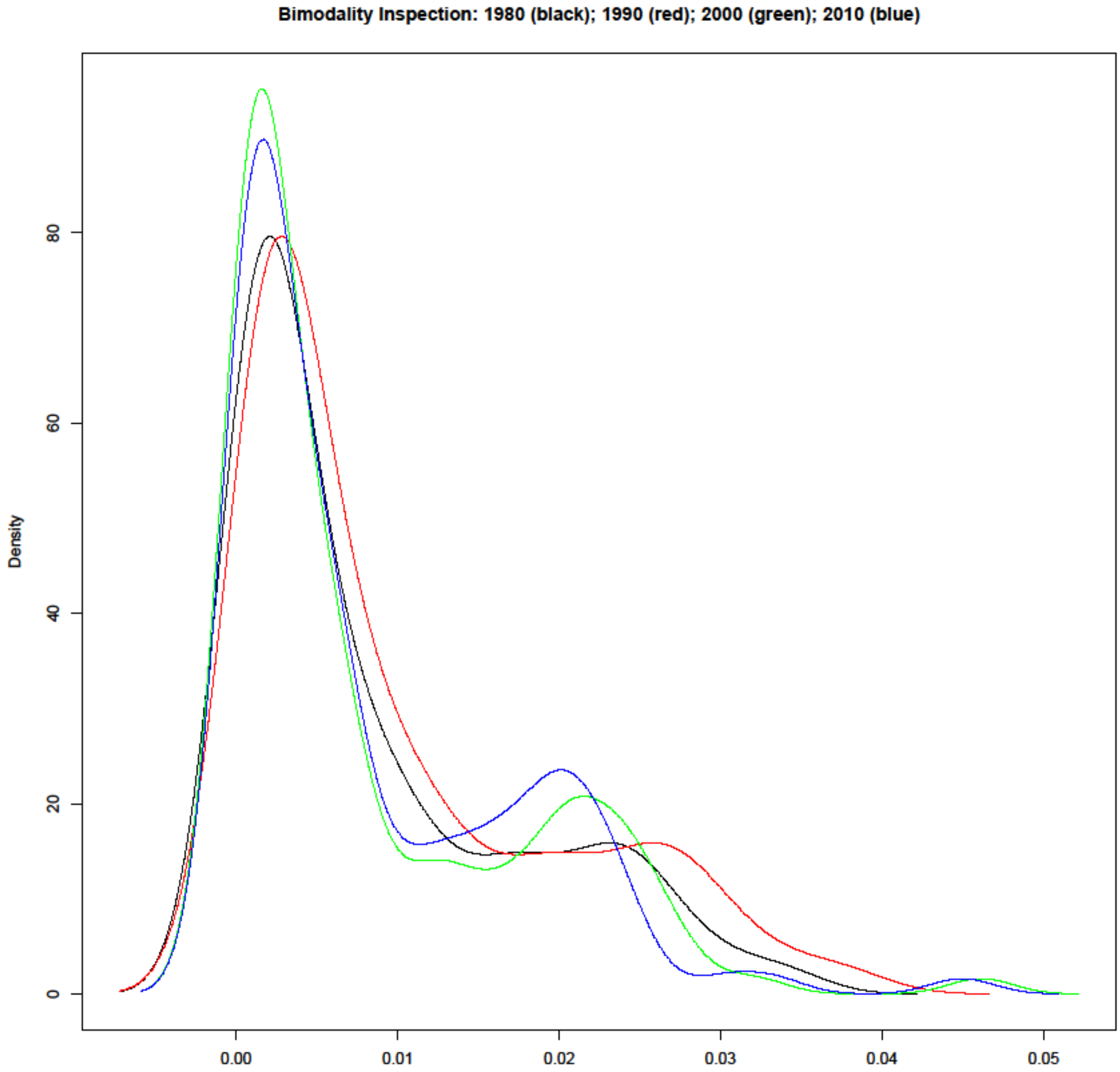
Appendix I

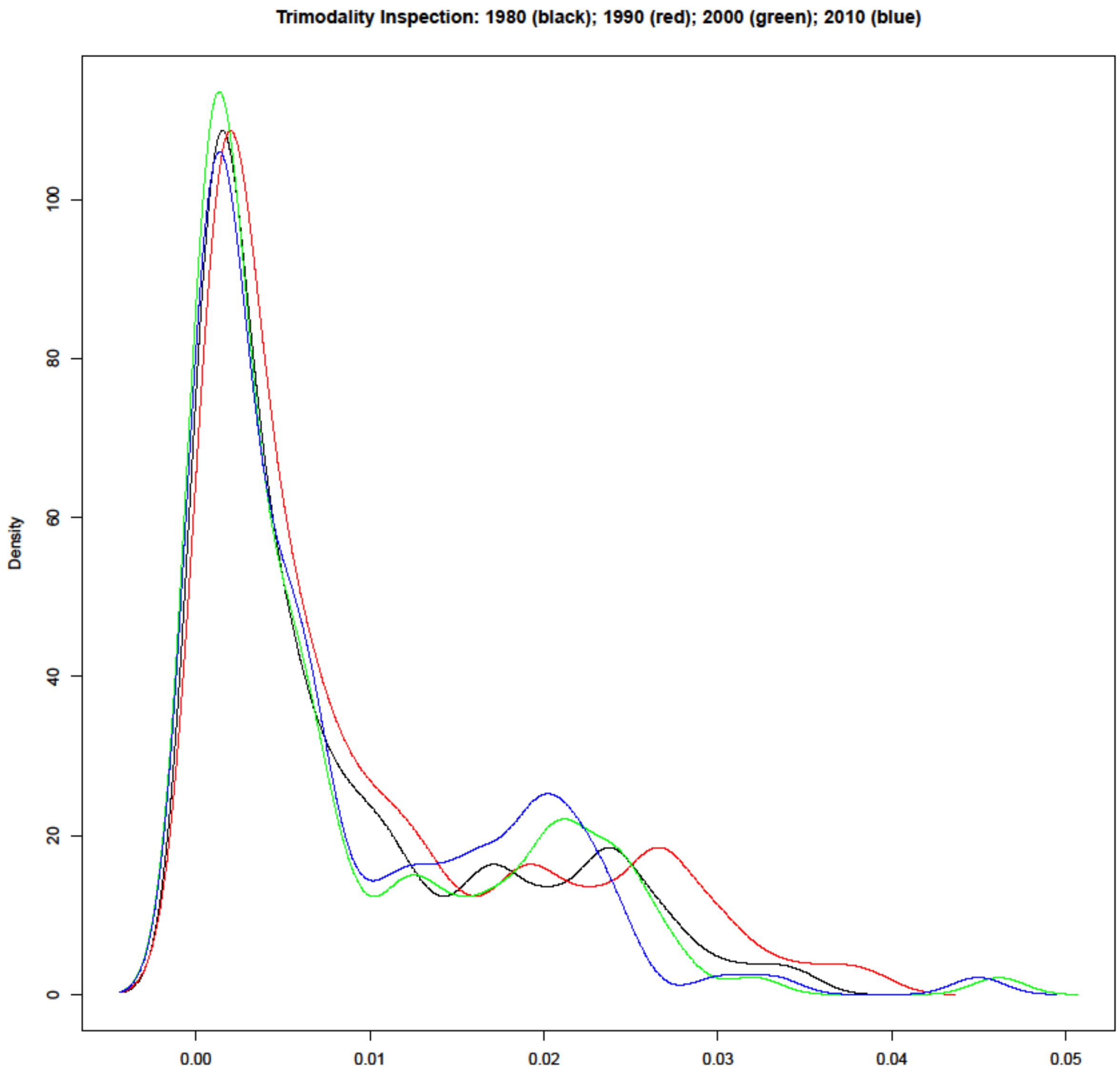
World: One mode



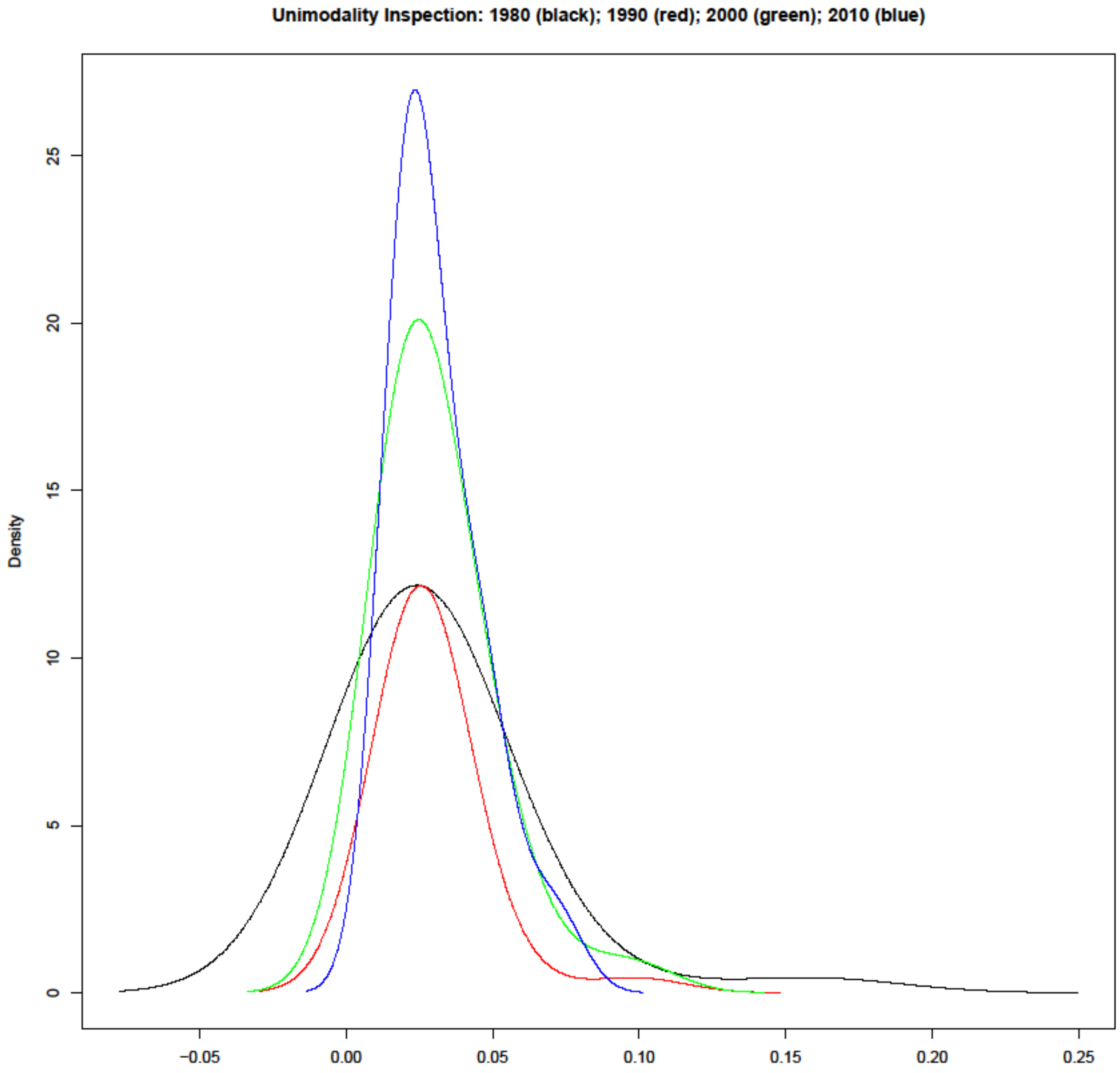
World: Two modes



World: Three modes



China: One mode



Appendix II

Ranking of provinces

1980		1990		2000		2010	
Shanghai	0.15940	Shanghai	0.10325	Shanghai	0.09752	Tianjin	0.07437
Beijing	0.09032	Beijing	0.07686	Beijing	0.06945	Shanghai	0.06546
Tianjin	0.07938	Tianjin	0.06696	Tianjin	0.06834	Beijing	0.05830
Liaoning	0.04744	Liaoning	0.04745	Zheijiang	0.04976	Jiangsu	0.05380
Heilongjiang	0.04060	Guangdong	0.03762	Jiangsu	0.04753	Zheijiang	0.04994
Jiangsu	0.03165	Jiangsu	0.03761	Guangdong	0.04605	*Shandong*	0.04496
Guangdong	0.02814	Zheijiang	0.03640	Liaoning	0.04497	Liaoning	0.04401
Qinghai	0.02767	**Heillongjiang**	0.03462	*Fujian*	0.04408	Guangdong	0.04335
Zheijiang	0.02755	*Shandong*	0.03424	*Shandong*	0.04017	*Mongolia*	0.04315
Tibet	0.02755	Xinjiang	0.03301	Hebei	0.03631	*Fujian*	0.04162
Jilin	0.02603	*Fujian*	0.02953	**Heillongjiang**	0.03243	Hebei	0.03426
Shanxi	0.02586	Jilin	0.02920	Jilin	0.02982	Jilin	0.03174
Ningxia	0.02530	Hubei	0.02893	Xinjiang	0.02948	*Henan*	0.02985
Hubei	0.02504	Hebei	0.02826	*Henan*	0.02760	Hubei	0.02716
Hebei	0.02498	**Qinghai**	0.02823	Hubei	0.02502	Shaanxi	0.02688
Xinjiang	0.02398	Shanxi	0.02742	*Mongolia*	0.02378	**Heillongjiang**	0.02640
Shandong	0.02352	Ningxia	0.02498	Chongqing	0.02278	Ningxia	0.02571
Gansu	0.02270	*Mongolia*	0.02422	Hainan	0.02233	Shanxi	0.02567
Hunan	0.02135	Yunnan	0.02293	Shanxi	0.02226	Chongqing	0.02556
Mongolia	0.02112	Shaanxi	0.02290	Ningxia	0.02175	Xinjiang	0.02395
Chongqing	0.02088	**Tibet**	0.02279	**Qinghai**	0.01984	Jiangxi	0.02188
Hainan	0.02071	Hainan	0.02240	Shaanxi	0.01981	Anhui	0.02171
Fujian	0.02036	*Henan*	0.02204	Anhui	0.01972	**Hunan**	0.02112
Jiangxi	0.02001	Anhui	0.02201	Sichuan	0.01971	**Qinghai**	0.02025
Shaanxi	0.01954	Chongqing	0.02110	Jiangxi	0.01942	Sichuan	0.02012
Sichuan	0.01872	Sichuan	0.02086	Yunnan	0.01880	Hainan	0.01968
Henan	0.01853	**Hunan**	0.02074	**Hunan**	0.01878	Guangxi	0.01940
Anhui	0.01702	**Gansu**	0.02039	Guangxi	0.01799	**Tibet**	0.01570
Guangxi	0.01626	Jiangxi	**0.01987**	**Gansu**	0.01704	**Gansu**	0.01557
Yunnan	0.01562	Guangxi	**0.01776**	**Tibet**	0.01620	Yunnan	0.01518
Guizhou	0.01281	Guizhou	0.01541	Guizhou	0.01128	Guizhou	0.01323

Italics denote provinces that are moving upwards while bold letters indicate provinces that are moving downwards in the ranking of provinces.

Appendix III

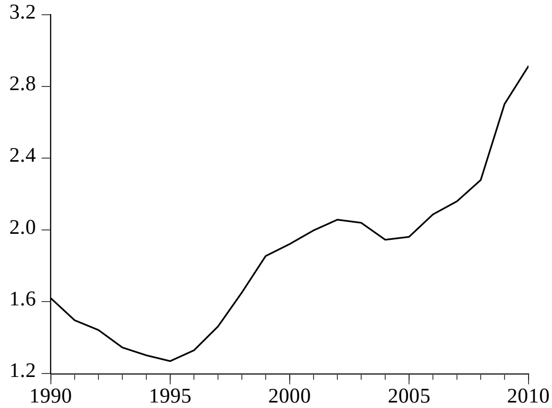
Capital-output ratio

Beijing region

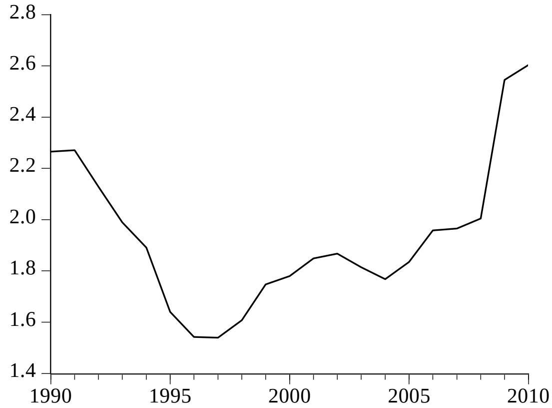
Beijing

Tianjin

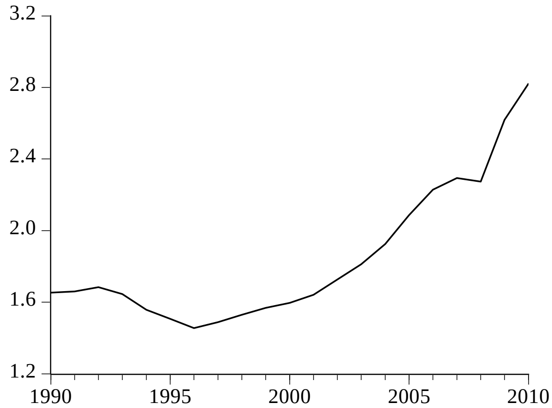
Hebei



Shanxi

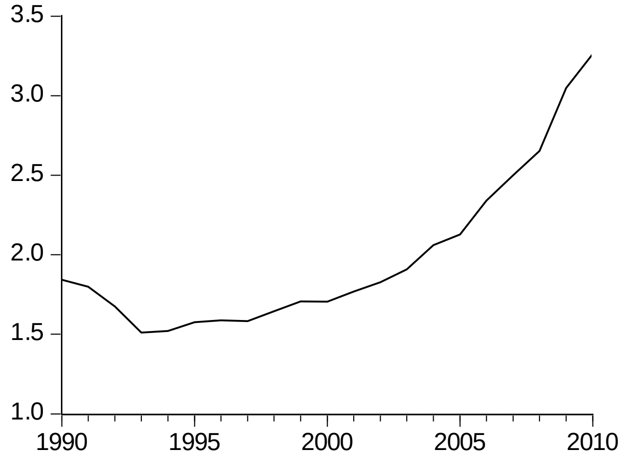


Mongolia

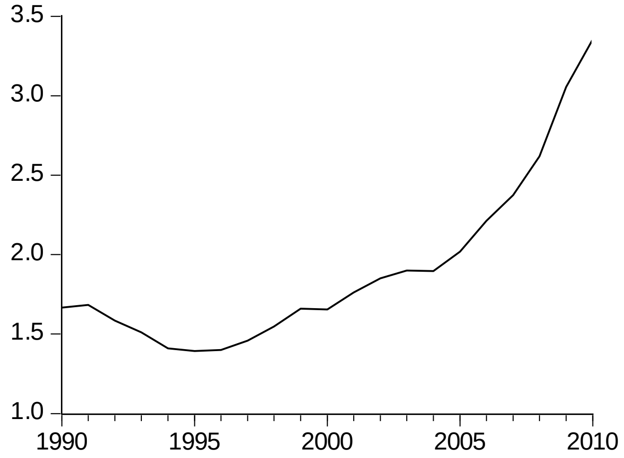


North east region

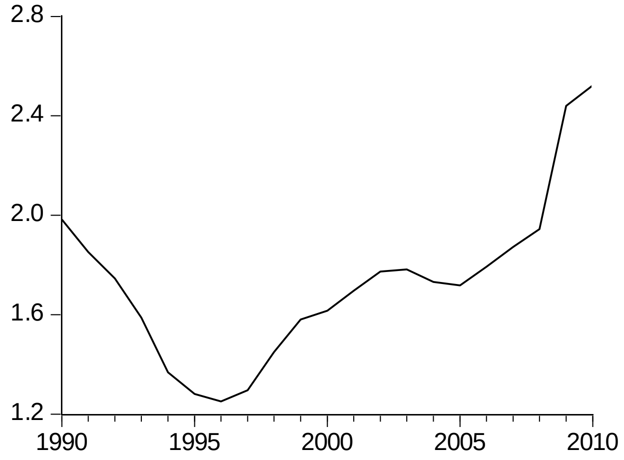
Liaoning



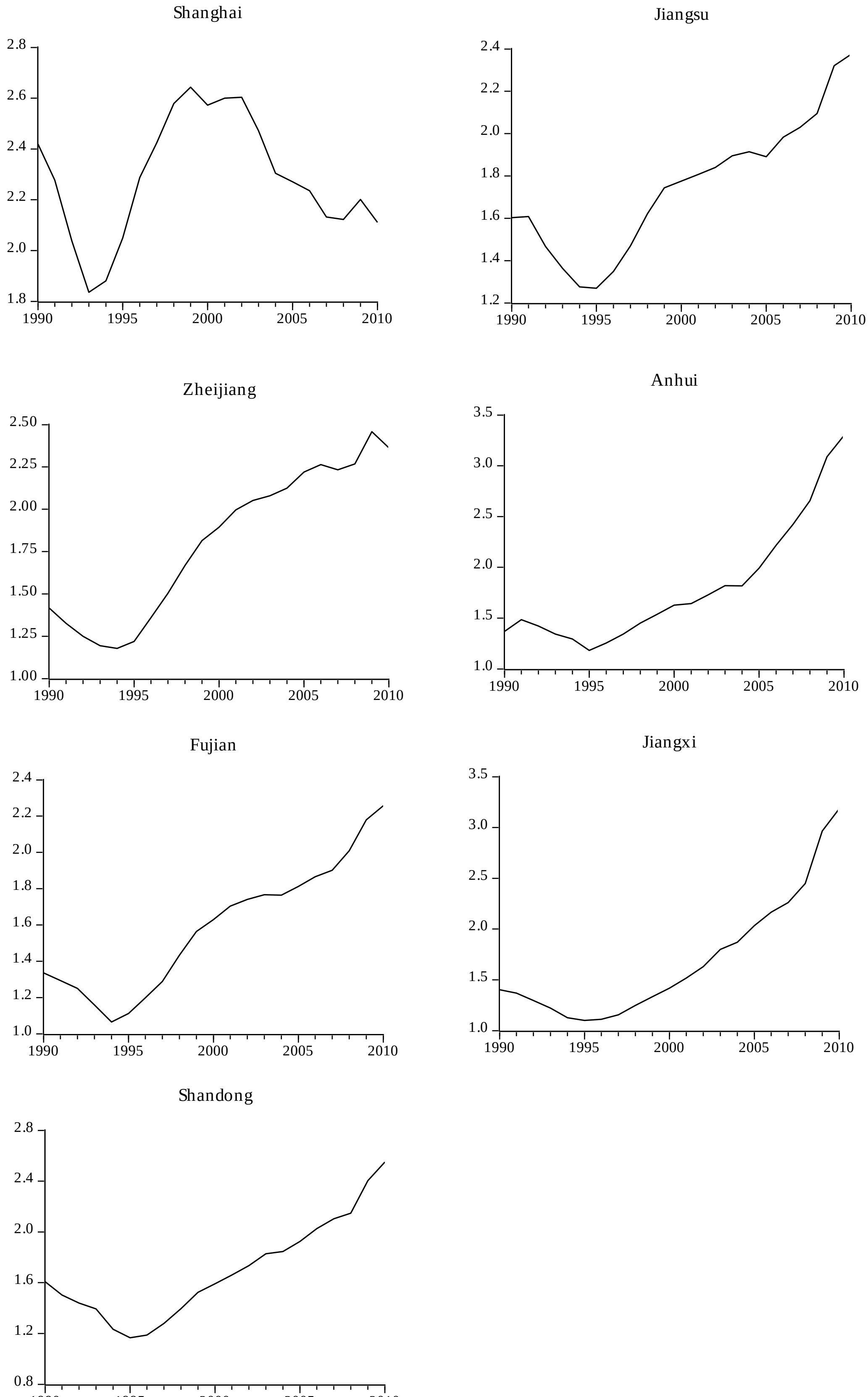
Jilin



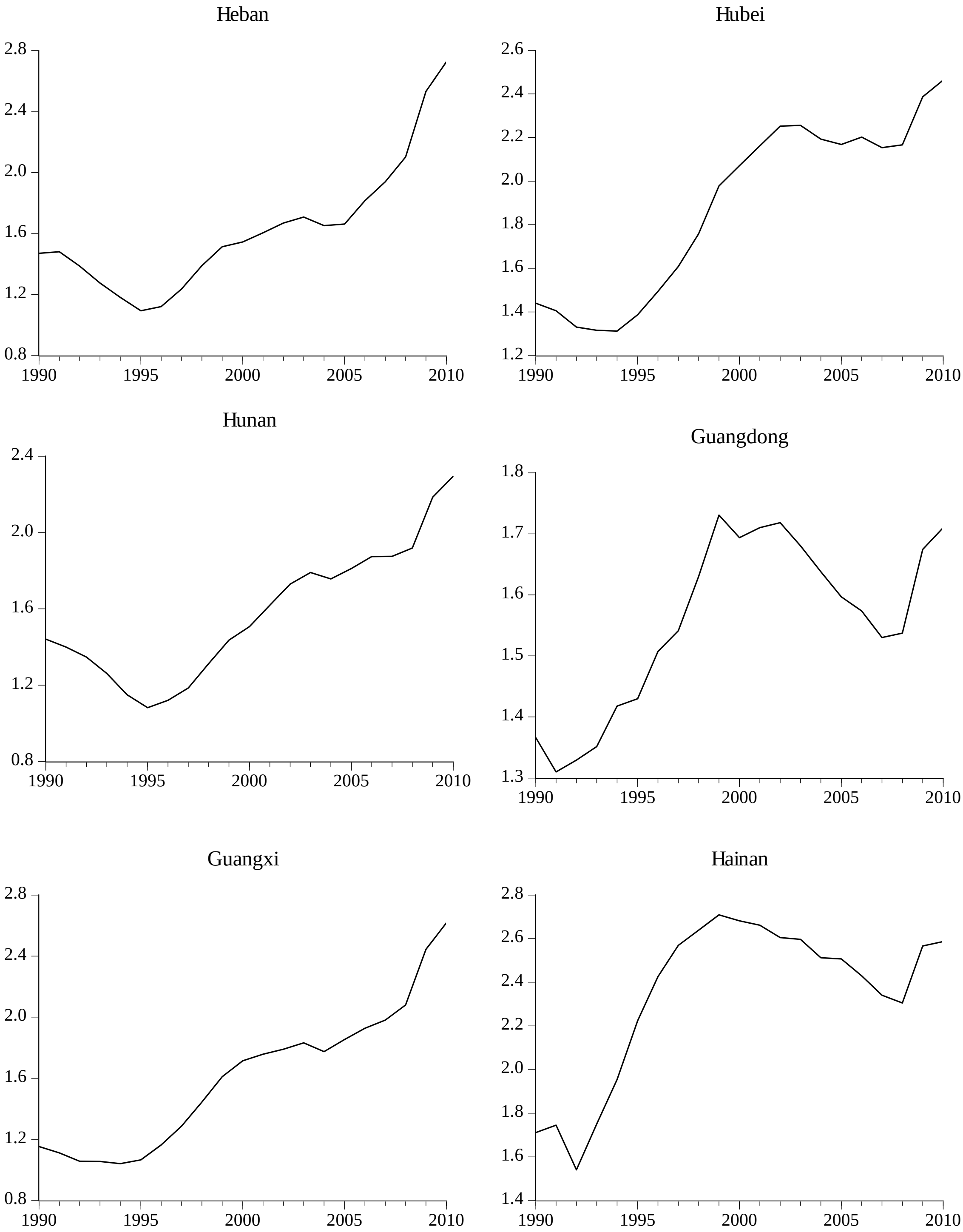
Heilongjiang



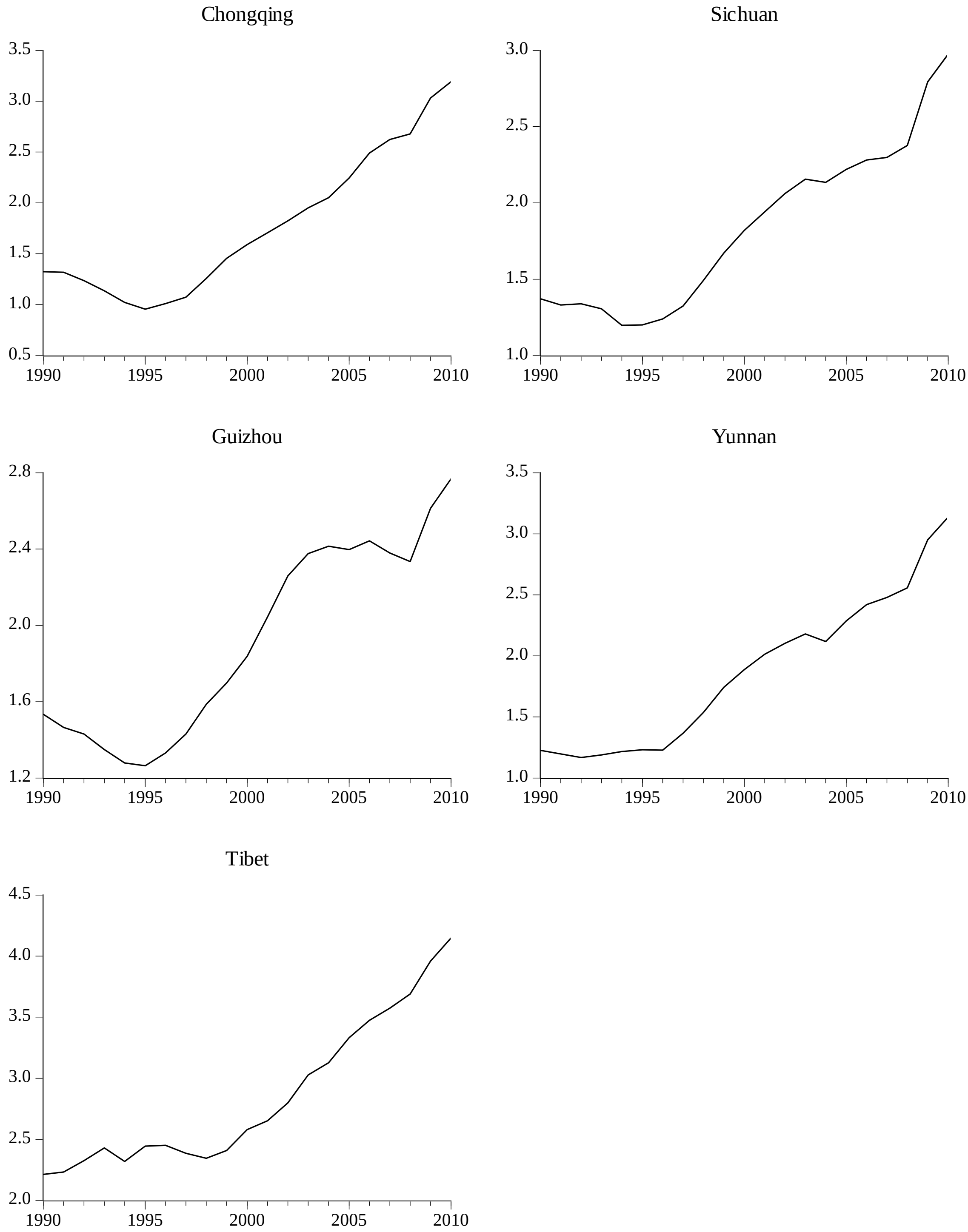
East coast


Shanghai
2.8
2.6
2.4
2.2
2.0
1.8
1990
1995
2000
2005
2010
Jiangsu
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1990
1995
2000
2005
2010
Zheijiang
2.50
2.25
2.00
1.75
1.50
1.25
1.00
1990
1995
2000
2005
2010
Anhui
3.5
3.0
2.5
2.0
1.5
1.0
1990
1995
2000
2005
2010
Fujian
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
1990
1995
2000
2005
2010
Jiangxi
3.5
3.0
2.5
2.0
1.5
1.0
1990
1995
2000
2005
2010
Shandong
2.8
2.4
2.0
1.6
1.2
0.8
1990
1995
2000
2005
2010

South coast

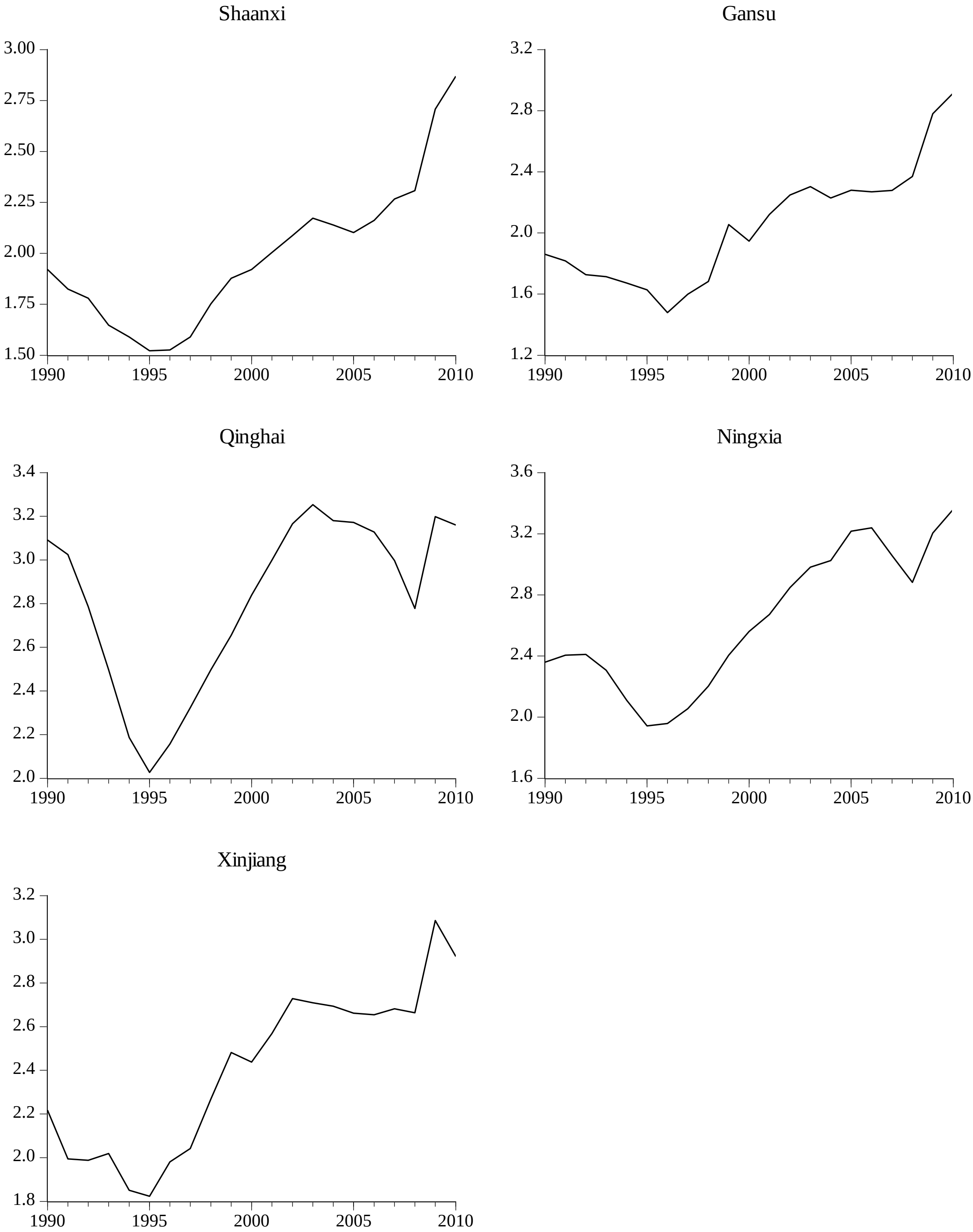

Heban
2.8
2.4
2.0
1.6
1.2
0.8
1990
1995
2000
2005
2010
Hubei
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1990
1995
2000
2005
2010
Hunan
2.4
2.0
1.6
1.2
0.8
1990
1995
2000
2005
2010
Guangdong
1.8
1.7
1.6
1.5
1.4
1.3
1990
1995
2000
2005
2010
Guangxi
2.8
2.4
2.0
1.6
1.2
0.8
1990
1995
2000
2005
2010
Hainan
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1990
1995
2000
2005
2010

Interior



Chongqing
3.5
3.0
2.5
2.0
1.5
1.0
0.5
1990
1995
2000
2005
2010
Sichuan
3.0
2.5
2.0
1.5
1.0
1990
1995
2000
2005
2010
Guizhou
2.8
2.4
2.0
1.6
1.2
1990
1995
2000
2005
2010
Yunnan
3.5
3.0
2.5
2.0
1.5
1.0
1990
1995
2000
2005
2010
Tibet
4.5
4.0
3.5
3.0
2.5
2.0
1990
1995
2000
2005
2010

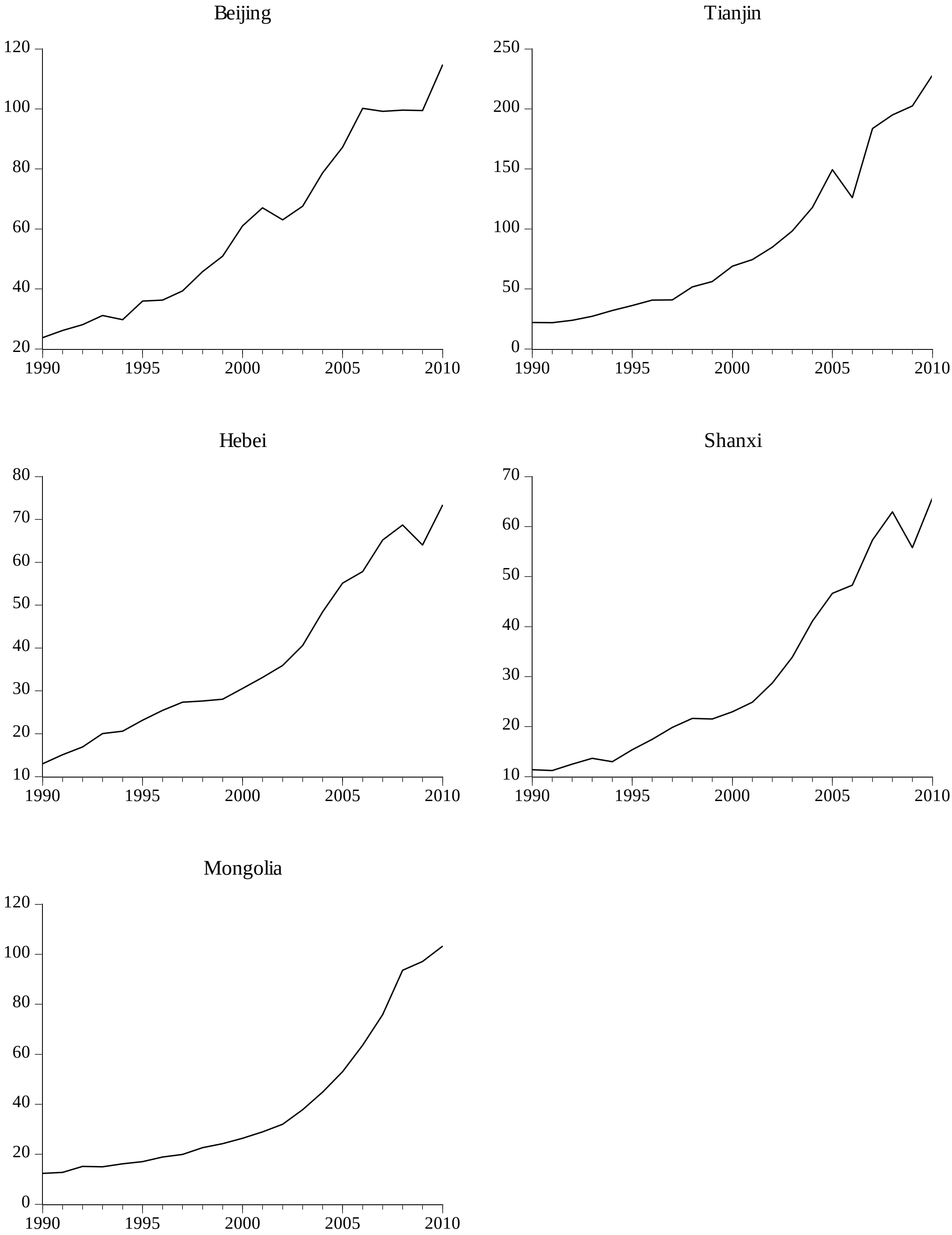
Western region



Appendix IV

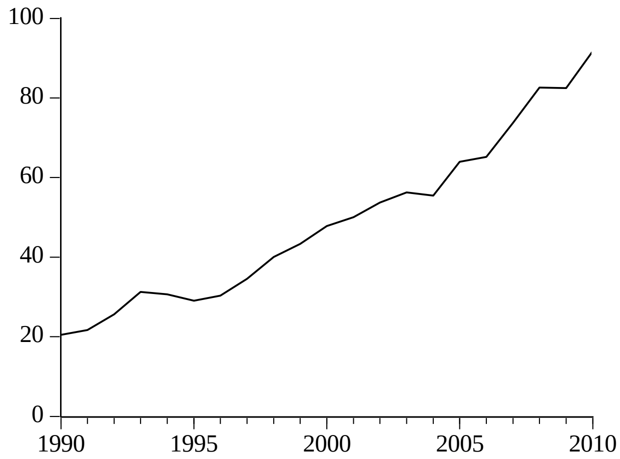
Labor productivity A for Chinese provinces estimated from equation (17)

Beijing region

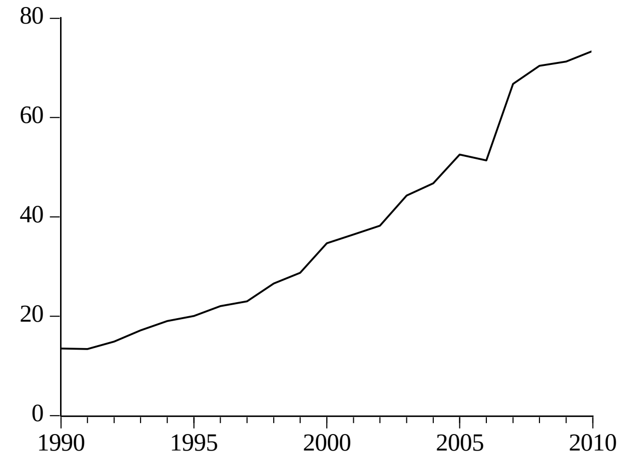


North east

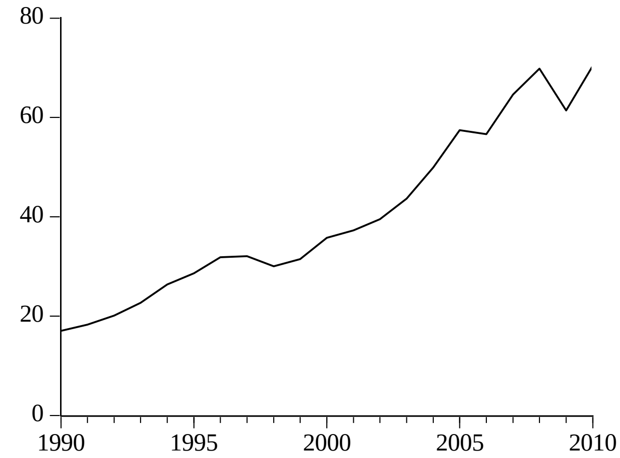
Liaoning



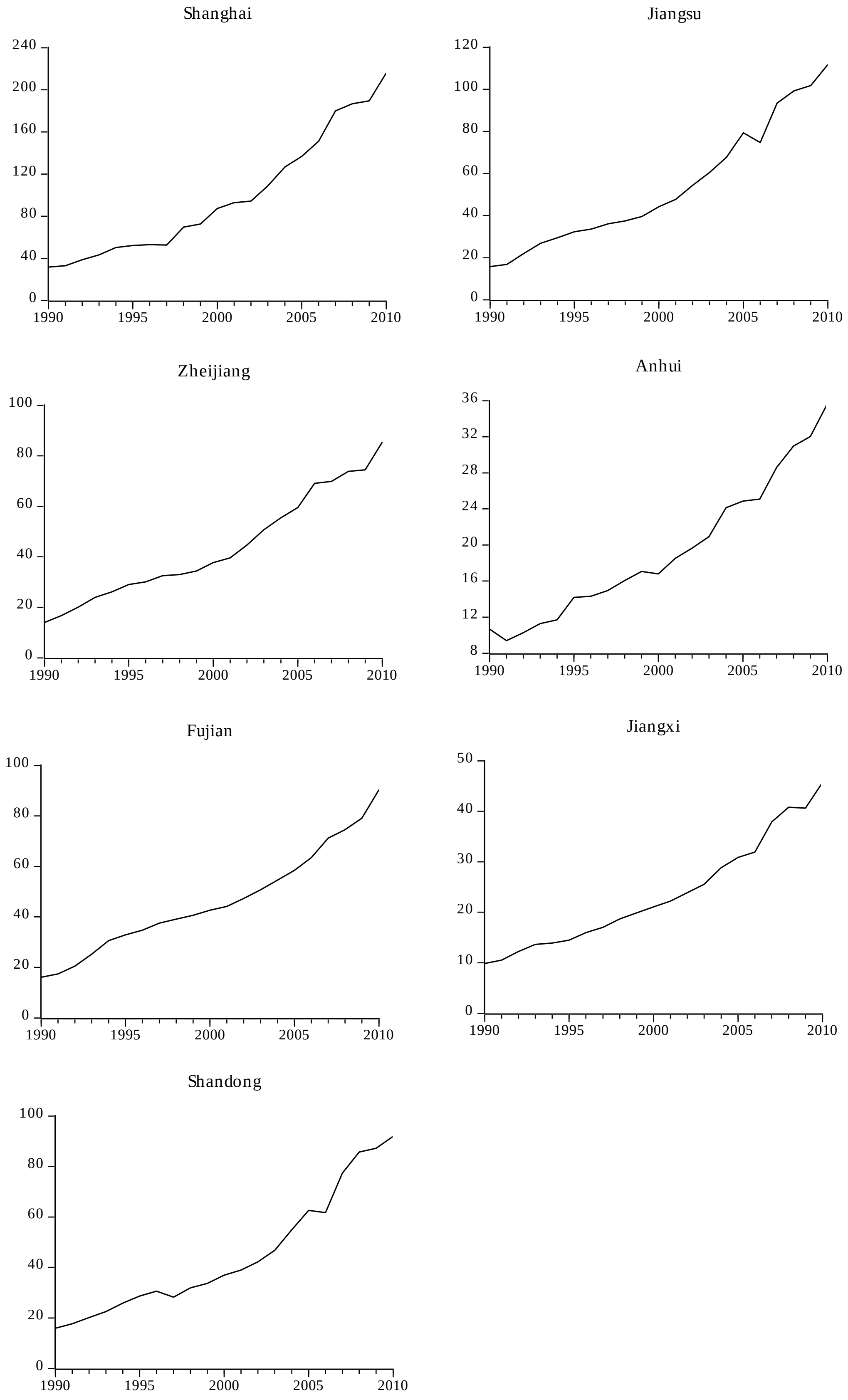
Jilin



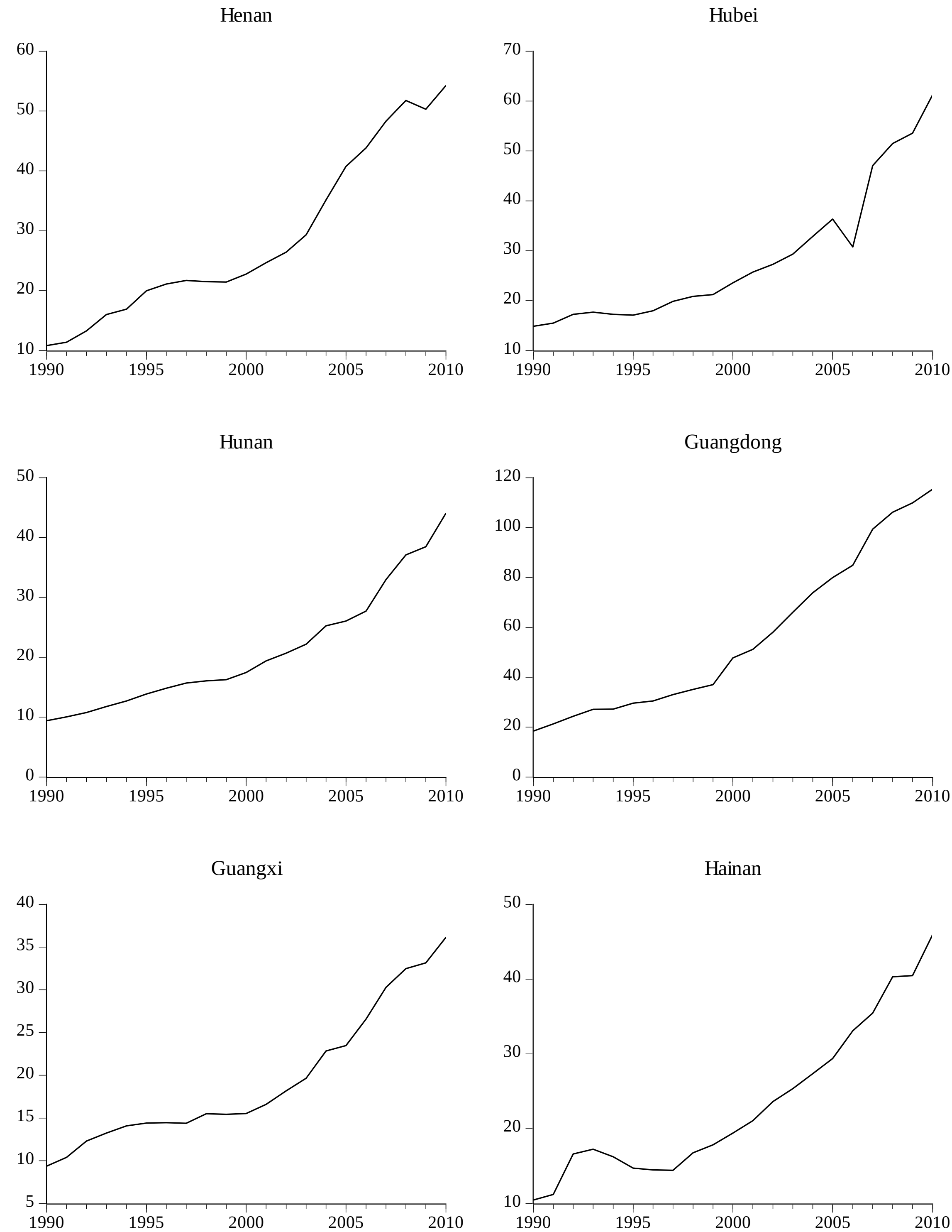
Heilongjiang



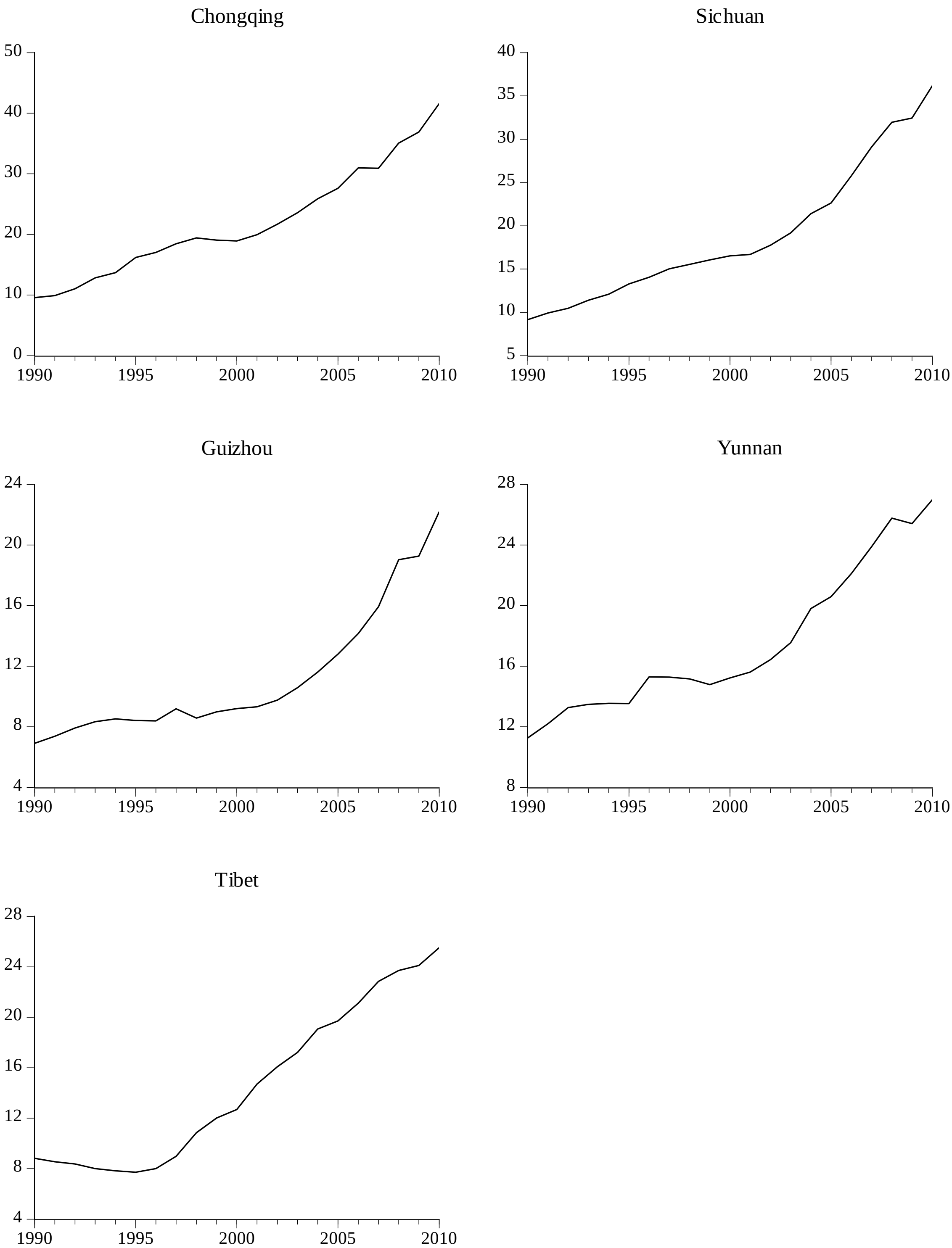
East coast


Shanghai
240
200
160
120
80
40
0
1990
1995
2000
2005
2010
Jiangsu
120
100
80
60
40
20
0
1990
1995
2000
2005
2010
Zheijiang
100
80
60
40
20
0
1990
1995
2000
2005
2010
Anhui
36
32
28
24
20
16
12
8
1990
1995
2000
2005
2010
Fujian
100
80
60
40
20
0
1990
1995
2000
2005
2010
Jiangxi
50
40
30
20
10
0
1990
1995
2000
2005
2010
Shandong
100
80
60
40
20
0
1990
1995
2000
2005
2010

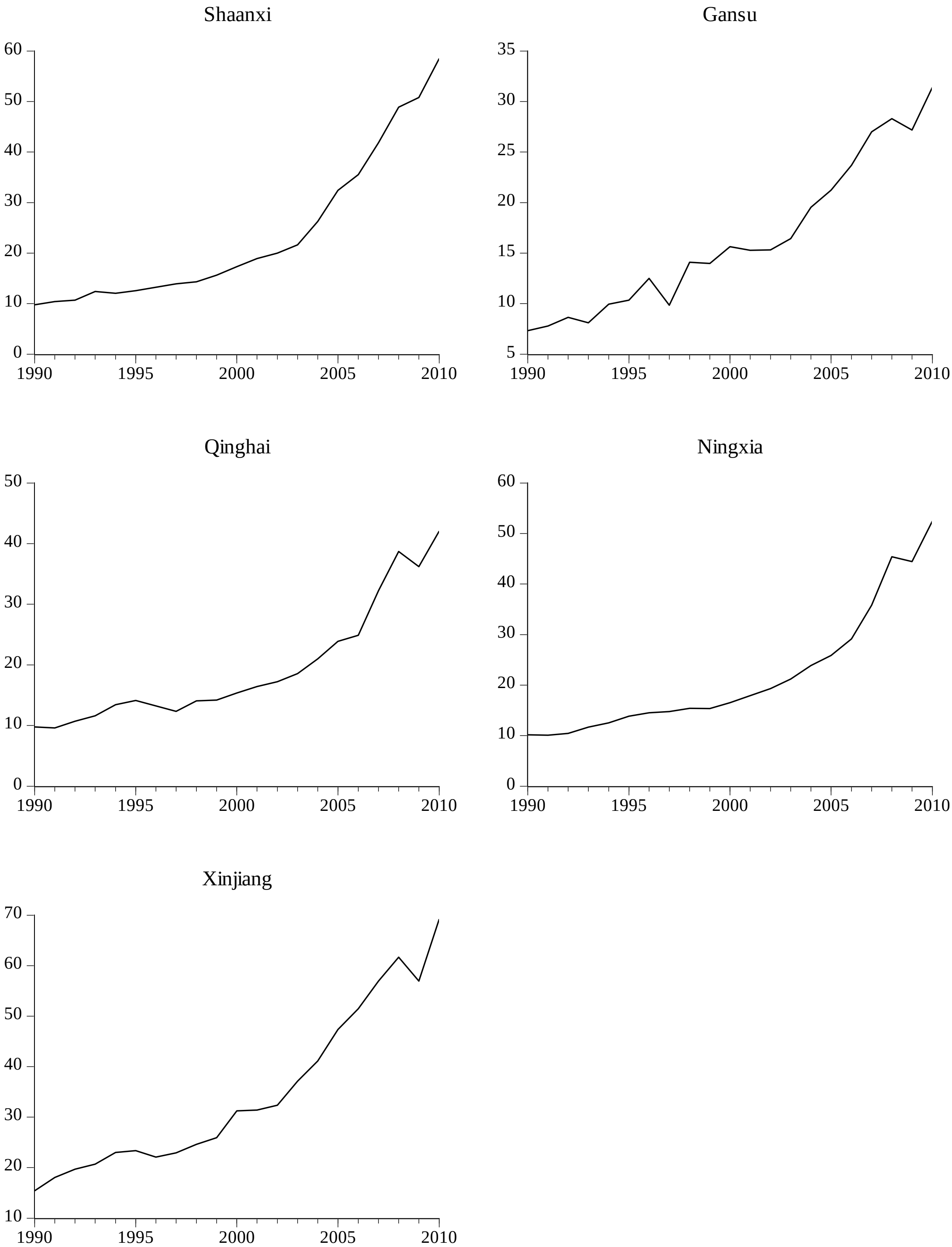
South coast


Henan
Hubei
Hunan
Guangdong
Guangxi
Hainan
1990
1995
2000
2005
2010

Interior


Chongqing
Sichuan
Guizhou
Yunnan
Tibet
1990
1995
2000
2005
2010

Western region

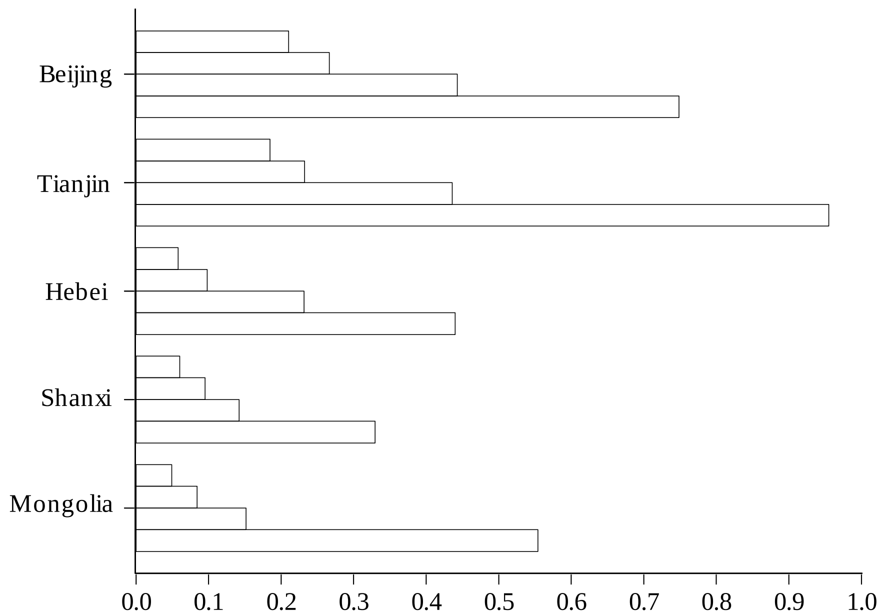


Appendix V

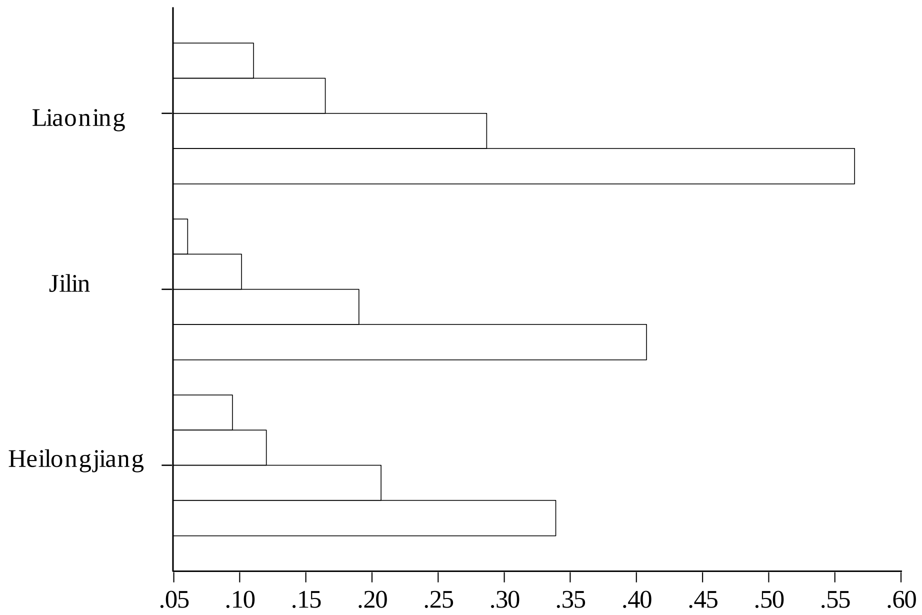
Values for $x_i = {y_i}/{\sum_{i=1}^{n} y_i} * 100$ in 1980, 1990, 2000 and 2010 by region

The midpoint between the groups of low-income and high-income countries is 1.60 for 1980, 1.75 for 1990, 1.40 for 2000 and 1.30 for 2010.

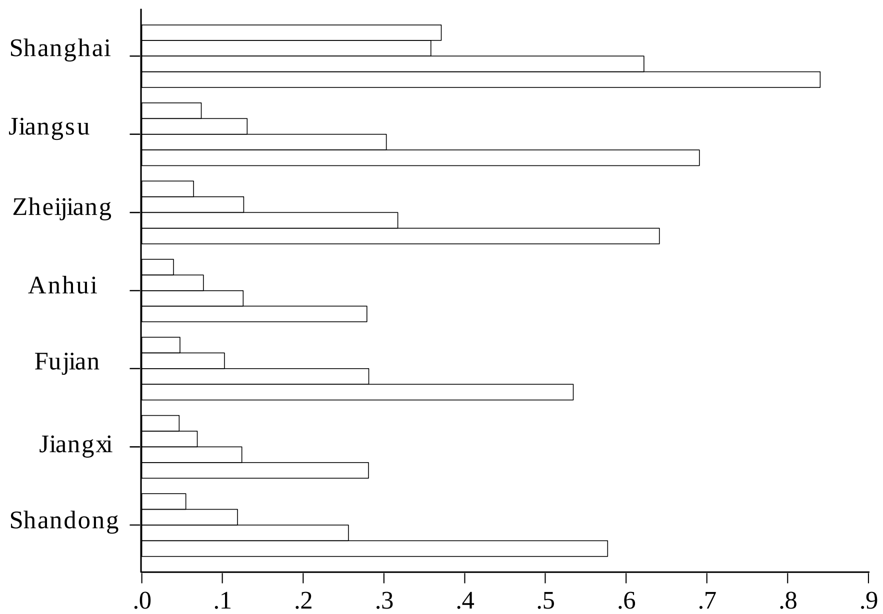
Beijing area

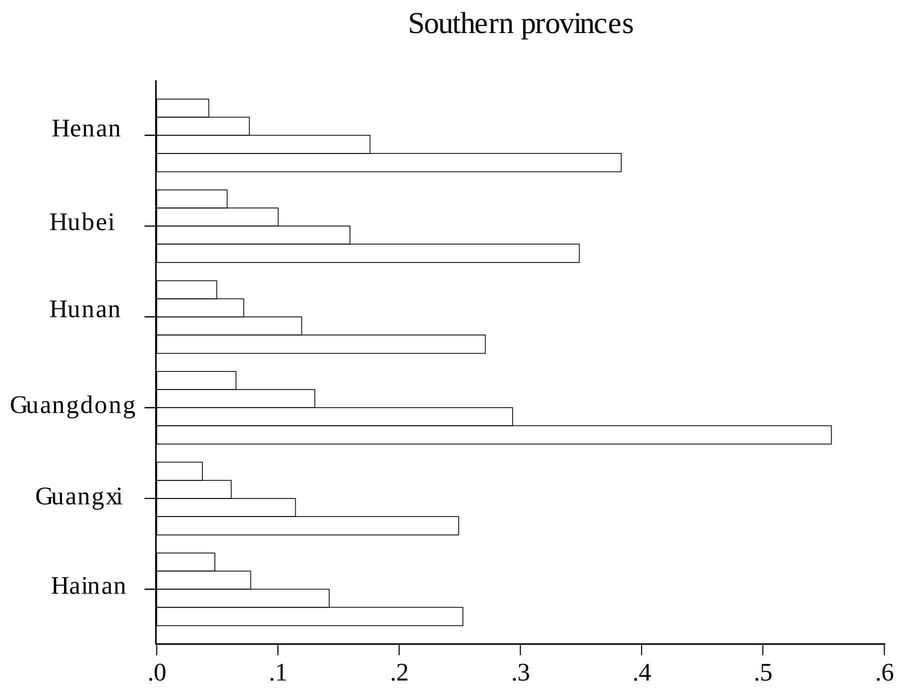


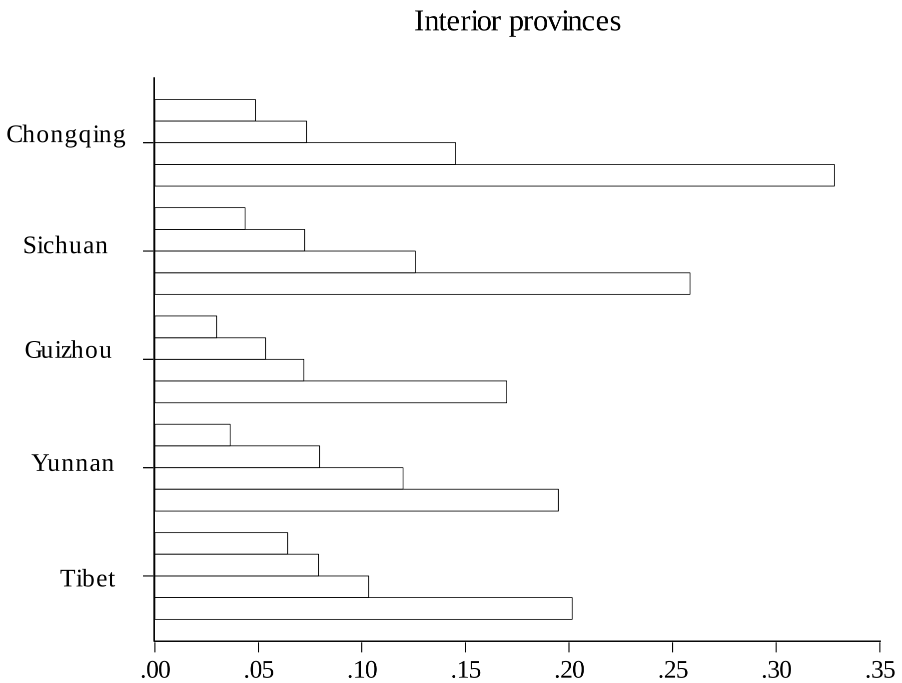
North east



Eastern provinces




Southern provinces
Henan
Hubei
Hunan
Guangdong
Guangxi
Hainan
.0
.1
.2
.3
.4
.5
.6


Interior provinces
Chongqing
Sichuan
Guizhou
Yunnan
Tibet
.00
.05
.10
.15
.20
.25
.30
.35

Western provinces