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The Impact of Reform on Economic Growth in China

A Principal Component Analysis

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Abstract

The study decomposes the sources of Chinese growth by first making a distinction between technological progress and technical efficiency in the growth accounting framework, and then identifying a series of reform programmes, such as urbanization, structural change, privatization, liberalization, banking and fiscal system reforms as the key components in institutional innovation which facilitate the improvement of technical efficiency and through which economic growth. These components are then incorporated into the model specification, which is estimated based on a panel dataset by applying the principal component analysis (PCA) to eliminate the multicollinearity problem. The results show that urbanization, liberalization and structural change in the form of industrialization are the most important components in contributing to the improvement of technical efficiency and hence growth, highlighting the importance of government policies aimed at enhancing further urbanization, openness to trade and industrial structural adjustments to sustain the growth momentum in China. The study also found that the potential for further enhancing growth through technical efficiency in China is considerable, which can be realized by deepening state-owned enterprises (SOEs) restructuring, and banking and fiscal system reform.

Keywords: institutional reform, growth, technical efficiency, principal component analysis, stochastic frontier analysis

JEL classification: O11, O23, O47, E61

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1 Introduction

It is generally accepted that institutional reform plays an important role in enhancing economic growth in China.[1] However, the ways in which various reform programmes impact on growth are complex. To shed light on how reform enhances growth, the paper decomposes the sources of Chinese growth by making a distinction between technological progress and technical efficiency (and the latter is assumed to be influenced by various kinds of institutional innovation) in the growth accounting framework. It then identifies a series of reform programmes, such as urbanization, industrial structural change, ownership reform, trade liberalization, and banking and fiscal system reforms as the key components in institutional innovation which facilitate the improvement of technical efficiency and through which economic growth. These components are then incorporated into the model specification, which is estimated based on a panel dataset by applying the principal component analysis (PCA) to eliminate the multicollinearity problem which is commonly associated with studies using multivariate approaches in examining the impact of reform on growth.

The paper is structured as follows. The following section surveys the literature, which is relevant to the current study. The third section applies a technical efficiency model to decompose output growth and to derive the relationship between institutional reform and economic growth. The fourth section specifies the empirical form of the technical efficiency model with some instrumental variables generated from applying the PCA method. It discusses the panel data of 26 provinces in China from 1979 to 2003 on which the empirical modelling was based. The fifth section presents the estimation results with respect to the impact of eight institutional reform measures on technical efficiency and through which economic growth in China. The final section concludes.

2 Literature survey

How institutional reform underlies China's rapid and sustained economic growth is an ongoing debate. Krugman (1994), Woo (1997) and Young (2000) argue that China's economic growth, similar to other newly industrialized economies (NIEs) in East Asia, had been driven mainly by massive injection of factor inputs due to the transfer of labour out of agriculture and the high saving rate. For example, Woo (1997) notes that the contribution of capital accumulation and labour force growth to GDP growth during the period 1979-93 was 6.2 percentage points accounting for 67 per cent of total GDP growth. Moreover, Young (2000) observes that the rising labour market participation rates, improvements in educational attainment and the rural-urban migration account for most of China's GDP growth after controlling the understating inflation rate per annum (say, 2.5 per cent). Thus, they conclude that institutional reform affects China's economic growth through enlarging the stocks of capital and labour.

Other studies, such as Chow (1993), Borensztein and Ostry (1996), Fleisher and Chen (1997), Hu and Khan (1997) and Wang and Yao (2001), argue that China's economic growth came mainly from technological progress rather than factor accumulation. For example, Borensztein and Ostry (1996) and Hu and Khan (1997) show, by employing a

1 The annual GDP growth rate was around 9.6 per cent during 1979-2003 (the State Statistical Bureau 2005).

growth accounting method, that productivity had become the primary driving force of China's rapid economic growth since 1978. Moreover, Fleisher and Chen (1997) and Wang and Yao (2001) investigate the impact of human capital and foreign investment on regional variations in productivity, and find that technological progress and innovation accounted for more than one-third of the total increase in output in the post-reform period. As such, they conclude that institutional reform affects China's economic growth through promoting technological progress.

Kalirajan, Obwona and Zhao (1996), Wu (2003) and Cheng (2006) turn to use a more flexible form of production function to estimate productivity growth over time and across different regions. For example, Wu (2003) applies an extended Solow model to examine the role of productivity in China's economic growth and found that efficiency changes (as an important component of TFP) played an important role in promoting economic growth especially during the period 1982-97. More recently, Cheng (2006) uses the stochastic frontier method with industrial data over time and across regions to decompose China's output growth into factor contribution, technological progress and efficiency change, and observes that the significant efficiency change in regional production during the period 1993-2002. This study highlights, for the first time, a new way of capturing how institutional reform affects economic growth through its impact on changes in efficiency in addition to those contributions made through promoting technological progress and factor accumulation.

Although previous studies have made progress in exploring the impact of institutional reform on China's economic growth, none of them had attempted to decompose the contribution made by various institutional reforms to economic growth. The practical difficulty of doing so especially in applying multivariate methods is that different policy measures are usually highly correlated with each other and the problem of multicollinearity emerges in conducting empirical regressions.[2] To deal with this problem, this paper applies the principal component analysis into a technical efficiency model to decompose contribution of eight reform measures to efficiency changes in China with the panel data of 26 provinces and metropolitan cities from 1979 to 2003. In doing so, this paper makes two contributions. First, it uses the stochastic frontier method to decompose the productivity growth into efficiency change and technological progress, and attributes the impact institutional reform on China's economic growth to efficiency change. Second, it applies the principle component analysis to eliminate the multicollinearity of various policy measures in maximum likelihood regression, and distinguishes the contributions of various policy measures to efficiency changes so that the role of different institutional reform in promoting economic growth in China can be examined independently.

3 The analytical framework

The technical efficiency model, developed and applied by Coelli (1992), Coelli and Battese (1996), Kong, Mark and Wan (1999) and Coelli, Sanzidur and Colin (2003), is devised to analyse the production function for measuring the technology efficiency of

2 In reality, various institutional reform measures interact with each other in impacting on efficiency and growth. However, methodologically, we need to separate them out in order to examine how each measure impacts on economic activities and performance.

production. The core of the approach is to utilize 'the specification in the production function which allows for a non-negative random component in the error term' (Kompas 2004: 1633) to generate a measurement of technical efficiency or the ratio of actual to expected maximum output, given inputs and the existing technology. Applying this approach to analysing economic growth and its determinants, one can conveniently specify the relationship between institutional reform and efficiency change.

Specifically, index country or region by i and time period by t, the mathematical specification of the stochastic production function for examining the technical efficiency with the panel data can be written as

$$Y_{it} = f(K_{it}, L_{it}) e^{v_{it} - u_{it}} \tag{1}$$

where Y_{it} represents total output, and K_{it} and L_{it} represent the capital and labour stocks respectively. The error term v_{it} is assumed to be independently and identically distributed, $N(0, \sigma_v^2)$ which captures the random variation in output due to factors beyond the control of a country's or region's production. The error term u_{it} is non-negative and captures technical inefficiency in the production function.

Equation (1) enriches Solow's dichotomy by attributing growth in observed output to movement along a path on or beneath the production frontier (input growth), that is movement towards or away from the production frontier, namely efficiency change, and shifts in the production frontier, namely technological progress (Wu 2003). If we define a frontier production level or the so-called 'best practice' output $Y_{it}^F = f(K_{it}, L_{it})$ for ith country or region at time t given technology $f(.)$, then any observed output with inputs (K_{it}, L_{it}) may be expressed as $Y_{it} = Y_{it}^F TE_{it}$ where TE_{it} represents technical efficiency. Thus, Solow's economic growth can be decomposed into factor accumulation, technological progress and efficiency change.

Since our purpose is to assess the impact of institutional reform on technical efficiency in China since 1978, we can assume that technological progress is made smoothly over time. It is also assumed that technical efficiency is changing following the progress of institutional reform. Thus, the technical efficiency distribution parameter can be specified as:

$$u_{it} = \delta_0 + z_{it}\delta + \varpi_{it} \tag{2}$$

where ϖ_{it} is the residual with the distribution of $N(0, \sigma_{\varpi}^2)$, z_{it} is a vector of specific institutional factors which influence technical efficiency of production, including in this study urbanization, structural change, ownership reform, openness to trade, inflation, financial market reform, government purchase and tax/revenue system reform. Given that these institutional reform measures are highly correlated in practice, we will use the principal component analysis (PCA) to generate eight uncorrelated instrumental variables to be used in regression.[3]

[3] The PCA method was originally used in the field of face recognition and image compression, which is essentially a mathematical technique devised to find the underlying patterns or structure in data of

The PCA is to use a score matrix, derived from the eigenvalues and eigenvectors of the covariance matrix of the given data, to transform the *n*-dimension (usually correlated) data into *n* orthogonal one-dimension vectors so as to eliminate their correlation in regression. In our case, we use the method to transfer vector $Z = [z_{it}]$ into an instrumental vector.

The Eckart-Young theorem assumes that there exists the following condition $V'ZU = \Lambda$ for Z, where V is a nxr orthonormal column-wise matrix, containing the *n* eigenvectors of *Q*, U is a mxr orthonormal column-wise matrix, containing the *m* eigenvectors of *R*, and Λ is a real, positive, diagonal matrix (rxr) which is the singular value of *X*. Now we can define matrix *R*, called the minor product, as $R = Z'Z$. This matrix has r non-zero eigenvalues which, if Z is properly standardized, will be identical to the covariance matrix of *Z*. From this, we can further demonstrate that $\Lambda^2 = I\lambda'$, where λ represents a vector containing the r non-zero eigenvalues of *Z*. In addition, the columns of U contain the r eigenvectors of *Z*. Because this analysis is closely related to the duality between R and the covariance matrix of *Z*, we call this R-mode analysis. It turns out that the columns of V contain the eigenvectors of Q, also known as the major product (ZZ').

Eigenvectors are all of unit length and the magnitude of them is given by the square root of the eigenvalues. If we multiply the eigenvectors times their singular values (i.e. the square roots of the eigenvalues), we obtain the factor loadings for each variable on each component. This is given by: $A^R = U\Lambda = UI\sqrt{\lambda'}$. The eigenvectors are a new set of axes (*U*) or basis functions. The projection of each data vector (matrix column) onto these new component axes is called its principal component score. Let matrix S^R, which is a vector with the same number of column with Z and we then have

$$S^R = ZA^R = ZU\Lambda \tag{3}$$

Equation (3) shows that matrix S^R is essentially the same thing as Z except that the factor scores have been scaled by the magnitude of the singular values. Thus, S^R can be used to substitute *Z* in the technical efficiency model to eliminate the multicollinearity problem.

Substituting equation (3) into (2), the empirical function for assessing the impact of institutional reform on technical efficiency and then through which economic growth with the panel data can be written as:

$$u_{it} = \delta_0 + A_{it}^R\varphi + \varpi_{it} \tag{4}$$

And the marginal effects of Z can be retrieved with the inverse of the score matrix.

high dimension. Due to its advantage of reducing the number of dimension without much loss of information, the method has been widely applied into econometric regressions to eliminate the multicollinearity between independent variables (Stromberg 1997).

Finally, the assumption of $u_{it} > 0$ in equation (1) guarantees that all observations either lie on, or are beneath, the stochastic matching frontier. Following Battese and Coelli (1995), variance terms are parameterized by replacing σ_v^2 and σ_u^2 with

$$\sigma^2 = \sigma_v^2 + \sigma_u^2 \text{ and } \gamma = \frac{\sigma_u^2}{\sigma_v^2 + \sigma_u^2} \tag{5}$$

The technical efficiency of production in the i th country or region at the t th period can be defined as:

$$TE_{it} = \frac{E(M_{it} | \mu, V_{it}, U_{it})}{E(M_{it} | \mu = 0, V_{it}, U_{it})} = e^{-u_{it}} \tag{6}$$

where E is the expectations operator. Equation (6) provides the basis for measuring the technical efficiency with the conditional expectation. The values of $v_{it} - u_{it}$, evaluated at the maximum likelihood estimates of the parameters for the function, can be specified, where the expected maximum value of Y_{it} is conditional on $u_{it} = 0$ (Battese and Coelli 1995). The measure TE_{it} has a value between zero and one, and the overall mean technical efficiency is:

$$TE = \left\{ \frac{1 - \phi[\sigma_u - (\mu / \sigma_u)]}{1 - \phi(\mu / \sigma_u)} \right\} e^{-\mu + (1/2)\sigma_u^2} \tag{7}$$

where $\phi(.)$ represents the density function for the standard normal variable.

The above discussion has specified the theoretical basis for using the technical efficiency model with PCA method to examine the impact of institutional reform on economic growth through changing technical efficiency of production. Different from traditional growth accounting method, the technical efficiency model with PCA method not only allows for production below the best practice output but also eliminates the multicollinearity of various institutional reform measures.

4 Model specification and data

The paper chooses the model of Battese and Coelli (1995) to estimate the Cobb-Douglas stochastic production function for China's economic growth. The model has the merit that determinants of the technical efficiency can be estimated together with the frontier production function by maximum likelihood method. Two empirical functions of the model are specified.

First, if we assume that the production function takes the Cobb-Douglas form, its empirical specification can be written as:

$$\ln Y_{it} = \beta_0 + \beta_1 t + \beta_2 \ln K_{it} + \beta_3 \ln L_{it} + v_{it} - u_{it} \tag{8}$$

where Y_{it} denotes the total output in region i at time t, t denotes time trend, and K_{it} and L_{it} denote the stocks of capital and labour in region i at time t respectively.

Second, the technical efficiency function can be written as the linear form of Equation (4).

$$u_{it} = \delta_0 + \gamma_1 f_1 + \gamma_2 f_2 + \gamma_3 f_3 + \gamma_4 f_4 + \gamma_5 f_5 + \gamma_6 f_6 + \gamma_7 f_7 + \gamma_8 f_8 + \varpi_{it} \tag{9}$$

where ϖ_{it} is an error term to account for random differences in the technical efficiency across different regions. f_1 - f_8 denote the instrumental variable generated from eight institutional reform measures (or Z_1 - Z_8) as specified in last section using the PCA method. The coefficient of each reform measure can be retrieved from those in Equation (9) with the score matrix.

The data used for the panel data regression cover 26 provinces and metropolitan cities in China during the period 1979-2003. The provinces and metropolitan cities include Beijing, Tianjin, Hebei, Shanxi, Inner Mongolia, Liaoning, Jilin, Heilongjiang, Shanghai, Jiangsu, Zhejiang, Anhui, Jiangxi, Shandong, Henan, Hubei, Hunan, Guangdong, Guangxi, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia and Xinjiang. The data for the period 1978-98 come from *The Comparison of Data in China: 1949-1998*, and the data for the period 1999-2003 come from *China Statistical Yearbooks*.

The total output is defined as regional GDP data, which are calculated from the official statistics with the 1990 constant price.[4] The stock of labour is defined as the total number of people employed instead of manhours due to lack of data on the part-time and casual work.[5] The stock of capital is defined as the total fixed assets used in production, which is calculated by using perpetual inventory method with the data of fixed asset investment adjusted with the price deflator. That is, given a rate of depreciation, δ and the initial capital stock, $K_{i,1978}$, the value of capital stock for the i th region in the t th year can be expressed as $K_{it} = K_{i,t-1}(1-\delta) + \Delta K_{it}$. The initial capital stock $K_{i,1978}$ and the depreciation rate are taken from Chow (1993) and Wu (2003), taking 1990 as 100 in determining the price deflator for fixed asset investment.

The urbanization index is defined as the share of urban population over the total population. The industrialization index is defined as the share of the output value of secondary and tertiary industries over that of total output value. The ownership reform index is defined as the share of the industrial output value of non-state owned and non-collective enterprises over that of all enterprises. The openness to trade index is defined as the share of total value of international trade, adjusted with the current exchange rate, to the GDP for each metropolitan and provinces each year. The inflation index is

4 For recalculating GDP figures for all Chinese regions, this paper uses official statistics with the adjustment of inflation as other studies did. For detailed discussions on measurement issues with respect to the Chinese official statistics, please refer to Ren (1997) and Maddison (1998).

5 Since 1998, statistics exclude the laid-off workers, who were made redundant in the process of enterprise restructuring (Garnaut et al. 2005).

defined as the change of consumer price index (CPI) for each province and each year. The tax/revenue reform index is defined as the share of total tax over the total government revenues. The financial market reform index is defined as the proportion of the commercial loan over the total investment used for fixed assets investments. The government purchase index is defined as the share of government consumption over the total final consumption.

There are two shortcomings with respect to the data collection method. First, there might be some inconsistencies between the data for 1978-98 and that for 1999-2003, since they come from different sources. For example, the statistical definition for the state owned and collective enterprises has been changed to be those enterprises in which state and collective have dominant shares since 1999. This will affect the magnitude of the ownership reform index. Second, not all metropolitan and provinces are considered due to data availability. The missing data for some indexes in some metropolitan and provinces for certain periods make the data an incomplete panel.

5 The PCA method and empirical results

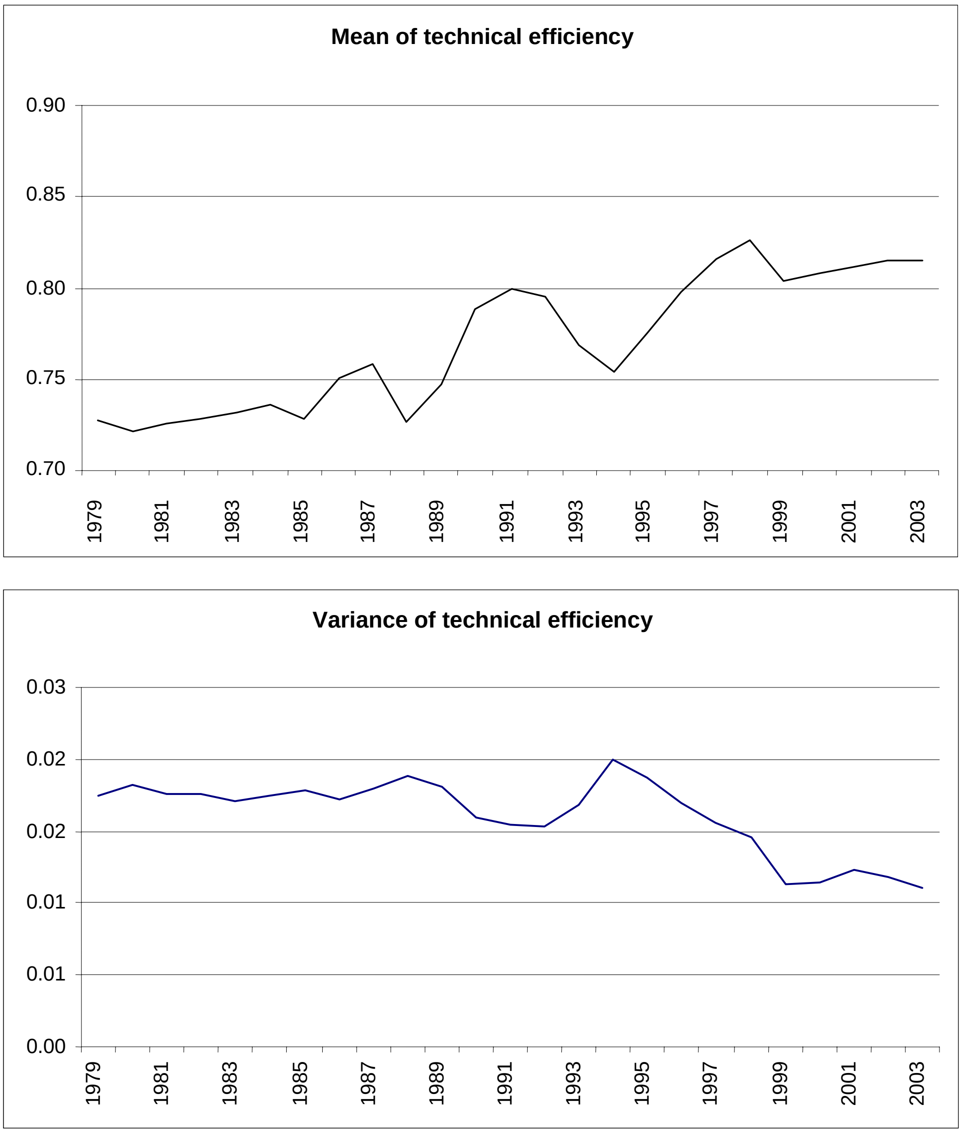
The mean changes in technical efficiency of production in China during the period 1979-2003 could be obtained by applying the stochastic frontier modelling approach (Equation 7) based on the panel dataset. Both the mean and variance of technical efficiency are shown in Figure 1.

Figure 1 shows clearly that although there are fluctuations, the average technical efficiency of production increases over time in China. This finding confirms that the improvement in technical efficiency as an important component of TFP (together with the advancement in technological progress) contributed positively to economic growth in China. The finding is significant in that the improvement in technical efficiency is linked to the institutional changes and reform undertaken since the late 1970s in China. Such finding provides some empirical support to the view that reform has contributed to economic growth not only through enlarging the stocks of capital and labour (as reviewed), but also by improving the technical efficiency of the economy. The latter helps move the economy from some interior point marked by inefficiency and wastes due to market distortion towards the production possibility frontier.

Figure 1 also shows that the variances of technical efficiency of production decrease over time, implying that there is a trend of convergence with respect to across regional impact of institutional reform on economic growth in China. The falling trend of the variances of technical efficiency accelerates from the mid 1990s, reflecting the fact that reform has been deepened since then.

The task now is to connect the improvement in technical efficiency with those institutional factors by adding PCA adjusted instrumental variables into the panel data regression. We ran a PCA on the original explanatory variable of macroeconomic indexes using the correlation matrix because of the large order of scale between some of the variables. The eigenvalues from the PCA are listed in Table 1 from which a score matrix could be derived to transform the data into eight orthogonal one-dimension vectors so as to eliminate the correlation between the instrumental variables in regression.

Figure 1
Changes in mean and variance of technical efficiency in China, 1979-2003



Source: Authors' own calculations

Table 1
The eigenvector for the PCA analysis on the macroeconomic reform indexes

Component	Eigen value	Difference	Proportion	Cumulative
f_1	2.50	0.97	0.31	0.31
f_2	1.52	0.40	0.19	0.50
f_3	1.13	0.26	0.14	0.64
f_4	0.86	0.12	0.11	0.75
f_5	0.74	0.15	0.09	0.84
f_6	0.59	0.12	0.07	0.92
f_7	0.47	0.28	0.06	0.98
f_8	0.19	-	0.02	1.00

Note: It is shown that f_2, f_4 and f_7 are not significant in technical efficiency model.

Source: Authors' own calculation.

The correlation between the PC scores and the original explanatory institutional variables are given in Table 2. These correlations are also referred to as the PC loading. Table 2 shows that the variables *UR* load heavily on f_1, f_5 and f_8, *IN* on f_1 and f_8, *PR* on f_3 and f_7, *OP* on f_1 and f_7, *IF* on f_2 and f_6, *FI* on f_2 and f_6, *GP* on f_1 and f_5, and *TR* on f_2 and f_4. Using the PC weights and the original standardized variables, we can produce the PC scores. Using the PC scores as the explanatory variables, we ran a panel data regression with the new instrumental variables and the results are reported in Table 3.

Since that PCA selects the principal components as instrumental variables that are un-correlated with each other, we have eliminated all the multicollinearity problems in the regression between technical efficiency of production and institutional reform in China. The estimation results show that the model demonstrated a slight diminishing return with respect to inputs as the sum of the coefficients for both capital and labour was smaller than unity. This result holds for both Model I estimation in which all eight components were included in the estimation and Model II in which the three insignificant ones (f_2, f_4 and f_7) were excluded from the estimation. The estimation results of the technical inefficiency model passed the general and specific tests for its statistical significance and this is especially true for both capital and labour and most of the instrumental variables.

Consistent with the findings of other studies, the coefficient estimations for both capital and labour show that capital takes more weight in production function than labour. It is also shown that technological progress plays a significant role throughout the period under study though it is not the focus of this study. Excluding the three insignificant components in Model II only slightly changed the magnitude of the estimated technical efficiency, suggesting partly that the estimated extent of the technical inefficiency is fairly stable (the bottom line in Table 3).

Based on the coefficient estimations for the instrumental variables as reported in Table 3, the coefficients of each institutional variables can be retrieved (Equation 9). Since some of the variables are statistically insignificant in the regression, we excluded them when retrieving the real coefficients of institutional variables. The retrieved coefficients from the model estimation are reported in Table 4.[6]

The figures show that urbanization, industrialization, openness to trade, and financial market reform, tended to increase the technical efficiency of production. Among them, urbanization exerted the largest impact on technical efficiency, suggesting that the so-called 'resource shift' effect of urbanization not only transfers surplus labour from rural to urban areas thereby adding more labour to the total labour force, but also helps improve the overall technical efficiency of production. Given the current level of urbanization rate and the rapid pace at which it rises, China will continue to enjoy the

6 As it is a model for technical inefficiency which has been estimated, the variables with negative signs are those which contributed positively to the improvement of technical efficiency. Please refer to Tables A1 and A2 in Appendix for the detailed results of such impact on technical efficiency over time and across different regions covered in the study.

benefit of improved technical efficiency brought about by the massive transfer of labour from rural to urban areas.[7]

Table 2
The score matrix generated for the PCA analysis

	f_1	f_2	f_3	f_4	f_5	f_6	f_7	f_8
Urbanization	0.44	0.03	-0.46	0.09	-0.53	0.01	-0.18	0.52
Industrialization	0.57	-0.05	-0.17	-0.01	-0.05	0.08	-0.24	-0.76
Ownership reform	0.33	0.10	0.67	-0.21	0.10	-0.07	-0.55	0.25
Openness to trade	0.44	-0.04	0.41	0.02	-0.23	-0.18	0.74	0.01
Inflation	0.01	0.65	0.04	-0.24	-0.10	0.70	0.16	-0.01
Financial market reform	0.08	0.58	-0.29	-0.35	0.25	-0.62	0.07	-0.01
Government consumption	0.41	-0.13	-0.20	0.15	0.76	0.26	0.15	0.29
Tax/revenue reform	0.00	0.46	0.14	0.86	0.03	-0.12	-0.09	-0.06

Source: Authors' own calculation.

Table 3
Estimation results of the inefficiency model, 1979-2003

	Model I			Model II		
Independent variables	Coeff	Std error	t-ratio	Coeff	Std error	t-ratio
C	-117.29	1.76	-66.74	-117.30	0.86	-135.78
T	15.72	0.23	67.02	15.70	0.11	138.74
K	0.71	0.01	80.60	0.72	0.00	229.60
L	0.18	0.01	13.26	0.20	0.01	20.72
f_0	0.23	0.02	12.34	0.25	0.01	16.90
f_1	-0.10	0.01	-14.25	-0.10	0.01	-13.00
f_2	0.01	0.01	1.28	–	–	–
f_3	0.07	0.01	9.10	0.09	0.01	12.00
f_4	0.01	0.01	1.10	–	–	–
f_5	0.08	0.01	12.52	0.09	0.01	17.64
f_6	0.05	0.01	5.15	0.06	0.01	9.10
f_7	0.00	0.01	0.35	–	–	–
f_8	-0.08	0.02	-4.38	-0.05	0.02	-2.06
sigma	0.04	0.00	18.78	0.04	0.00	26.22
gamma	0.03	0.01	4.33	0.03	0.00	8.59
Log likelihood		129.86			130.00	
LR		208.40			208.67	
Tech. efficiency		78.00			77.00	

Source: Authors' own calculation.

Table 4
Retrieved coefficients of institutional reform

	URBN	INDU	OWNE	OPEN	INFL	FINA	GOVE	TAXR
Coefficients	-0.16	-0.03	0.02	-0.04	0.04	-0.05	0.02	0.01

Source: Authors' own calculation.

7 The urbanization rate defined as the ratio of urban population to total population is about 43 per cent in 2005. It is expected that the rate will continue to rise in the next ten years or so reaching about 50 per cent by 2010 and 60 per cent by 2020.

Financial market reform, openness to trade and industrial structural changes all had a similar level of impact on technical efficiency as far as their magnitudes are concerned. However, what matter here are the signs rather than the magnitudes of these variables. It is significant to observe that China's continuous policy towards open trade, rapid movement towards an industrial structure where the primary industry share falls rapidly while the secondary and tertiary industries' shares in the total economy continue to rise contributed positively to the improvement in technical efficiency.

It may be surprising to see that financial market reform has already exerted some positive influence on technical efficiency, given that the task of reforming China's banking sector is far from over. In fact, despite the existing problems such as high levels of non-performing loans associated with the banking sector, there is evidence that investment efficiency measured by the incremental capital output ratio (ICOR) has been improving since the mid 1990s.[8] The better utilization of capital may partly explain why there are some improvements in technical efficiency even though the analytical approach adopted in this study does not allow us to sort it out whether the observed technical change is labour or capital augmenting. At the same time, it can be inferred that more changes to China's financial market by deepening reform in both its banking sector and equity markets could further improve the overall technical efficiency of the economy.

The remaining instrumental variables including inflation, ownership reform, government purchase and tax system reform, tended to decrease technical efficiency of production. In terms of their magnitude, the impact of inflation was larger than that of others. Inflation could negatively impact on technical efficiency because the price distortion it generated does not convey the right signals to both producers and consumers for allocating their resources in most efficiency manner. The negative impact of both government purchase and tax system on technical efficiency illustrated the same point of the way in which resources are not being allocated efficiently, highlighting the importance of deepening reform in these areas.

However, the question one should ask is why ownership reform, regarded as the core part of economic transformation, has some negative impact on technical efficiency of production. Possible explanations could be two. First, from the macroeconomic point of view, reform measures such as the state-owned enterprise restructuring, clarification of property rights, and national treatment of incentives, may 'take longer to bear fruit in the aggregate and may generate a negative impact on growth as resources are reallocated across sectors' (Borensztein and Ostry 1996: 227). From the microeconomic perspective, ownership reform has produced gains in terms of profitability but not in terms of productivity (Garnaut, Song and Yao 2006). Since the PCA regression has eliminated the effects of factor accumulation and technological progress which largely contributed to the rapid growth of the economy, this implies that ownership reform itself is yet to bear fruit in terms of generating the aggregate effect on efficiency.

We now turn our attention to the impact of institutional reform on technical efficiency over time during the period under study and across different provinces in China. Figures 2-9 depict the impacts of the eight institutional variables on technical efficiency,

8 See *Asia-Pacific Economics Analyst* (2006).

Figure 2
Impact of urbanization on technical efficiency

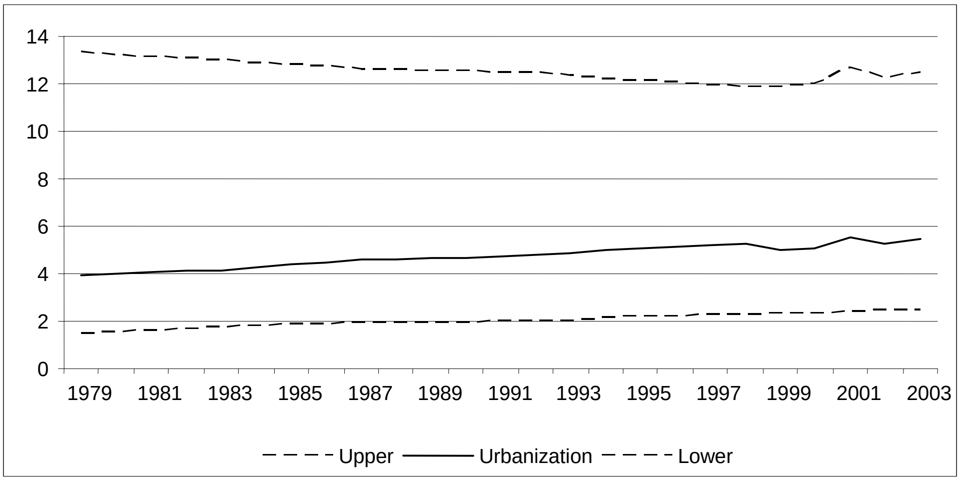


Figure 3
Impact of industrial structural change on technical efficiency

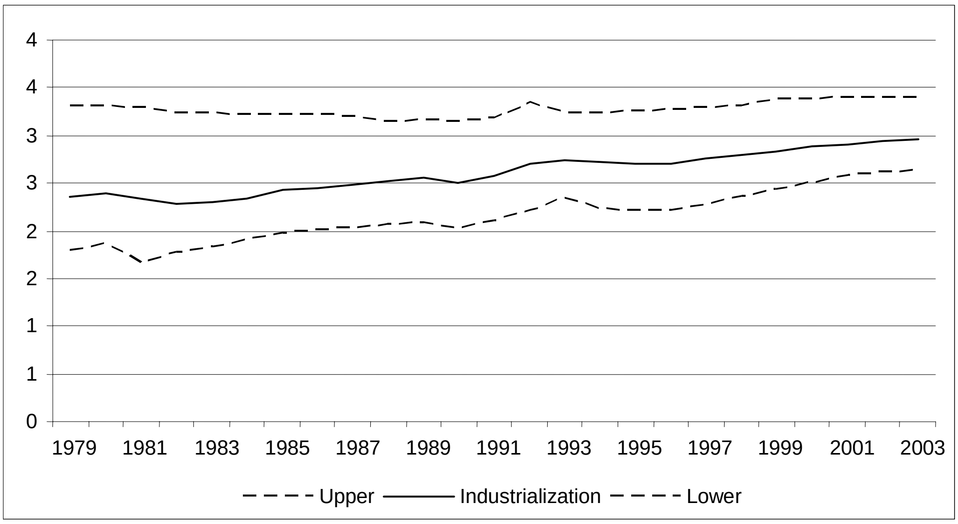
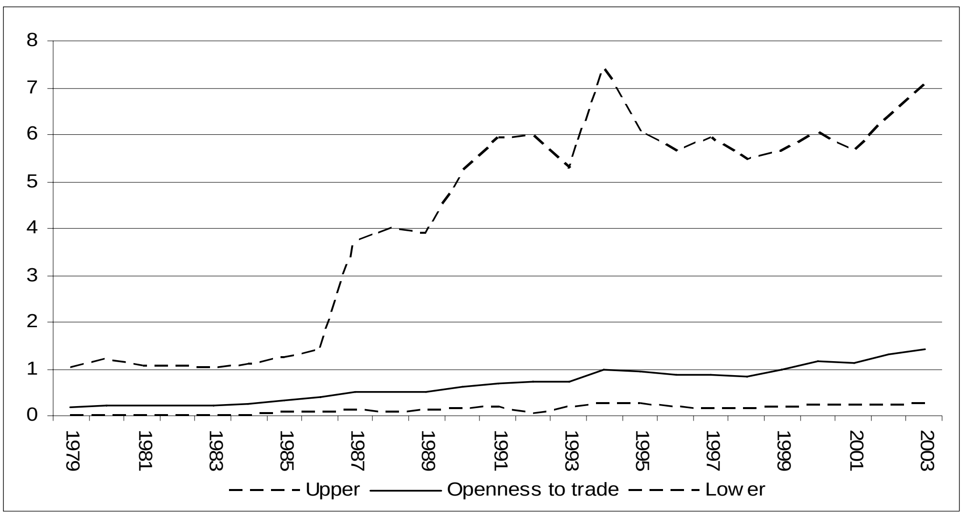


Figure 4
Impact of openness to trade on technical efficiency



Source: Authors' own calculations for Figures 2, 3 and 4.

respectively with those impacts being marked by the solid lines. The two dotted lines above and below the solid lines are upper and lower bounds, respectively reflecting the variations of these effects across different regions. Smaller variances mean that such effects tend to converge while larger variances mean that they tend to diverge among different regions over time. Positive numbers mean that they are contributing to the improvement of technical efficiency and negative numbers mean that they are negatively impacting on technical efficiency.

Figure 2 shows that the contribution of urbanization to technical efficiency is steadily increasing within a range of 4-6 per cent. However, there have been considerable variations across different regions with respect to the impact of urbanization on technical efficiency. For example, major cities such as Beijing, Tianjin and Shanghai witnessed the largest impact resulting from urbanization while those relatively poor provinces such Guizhou, Gansu and Guangxi received relatively small impact on technical efficiency. There are some encouraging signs as the variances of urbanization effects across regions show a tendency of decreasing over time.

Government regional policies in favour of those less developed regions and wide spread institutional reform to facilitate freer flows of labour across provincial borders help narrow the regional gap of development. However, the wide gap between the upper bound and the solid line suggests that China needs to accelerate the pace of urbanization, especially in those inland regions in order to have a more balanced pattern of growth.

Figure 3 shows that the contribution of industrial structural change to technical efficiency has been steadily increasing over the period under study and the magnitude of such change was within the range of 2-4 per cent. There have been less regional variations as shown by the relatively narrow gap between the upper and lower bounds and there has been a trend that the variances of industrial structural-change effects across regions decrease over time. It is encouraging that those inland provinces have been characterized with relatively higher shares of primary industry as compared with those in the coastal regions. Narrowing the gap suggests that those inland provinces have moved gradually towards an industrial structure which allows them to enjoy more the benefit of improved technical efficiency.

Figure 4 shows that China’s openness to trade has had positive effects on technical efficiency. A key feature of this figure is that significant differences existed with respect to the impact of openness to trade on technical efficiency across different regions. The figure also shows that the divergence has been enlarged especially since the mid 1980s as shown by the changing shape of the upper bound line as against the mean. The result is expected, as the coastal regions have benefited more from foreign trade than those in inland regions because of geographical, historical, and policy reasons. It remains a challenge for the governments at both central and local levels to deepen the reform in order for the gains from trade to spread across different regions. China’s accession to and conformity to the requirements of the World Trade Organization (WTO) help achieve this objective.

Figure 5 shows that financial market reform has had some positive effects on technical efficiency throughout the period of reform, and such effects became considerable since the late 1980s. The variance of the impact is large, and different regions seemed to benefit from the reform differently especially since the beginning of the 1990s as shown by the changing shape of the upper bound. However, as the variable for financial market reform was rather narrowly defined and no attempts have been made to trace the relationship between the size of bank loans and changing management through banking restructuring, some caution is needed to interpret this result.

The remaining four institutional variables have had some negative impact on technical efficiency. The negative impact could mean that institutional changes and innovation in these areas have not achieved the goal of improving technical efficiency, but at the same time it also suggests that the potential progress and gains in improving technical efficiency by deepening reform in these areas could be considerable.

Figure 6 shows the trend for ownership reform in influencing technical efficiency of production. There have been negative effects on technical efficiency throughout the period under study even though the negative impact has been relatively small. The trend had been persistent until the end of 1990s when it has been reversed. This is when China began to carry out wide spread privatization programme targeting the large number of medium- and small-sized state-owned enterprises (SOEs) with noticeable improvement in firms' profitability and sales (Garnaut et al. 2005).

Figure 5
Impact of financial market reform on technical efficiency

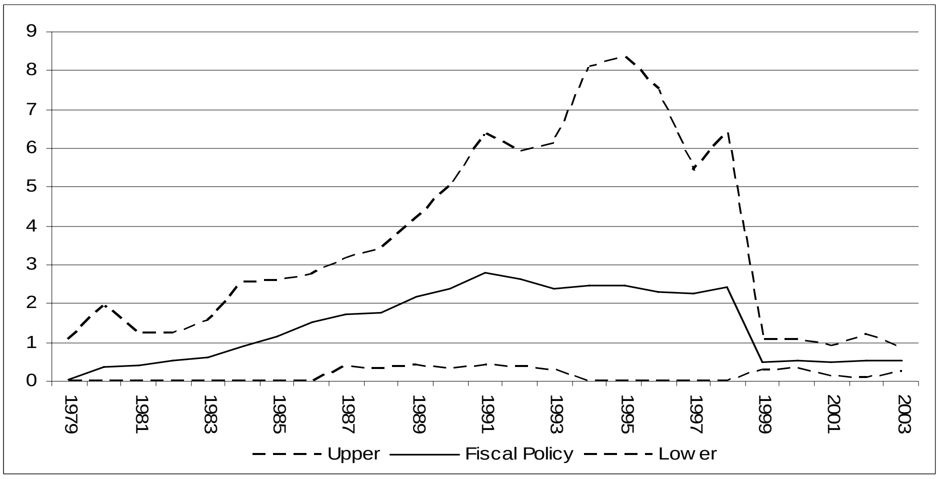
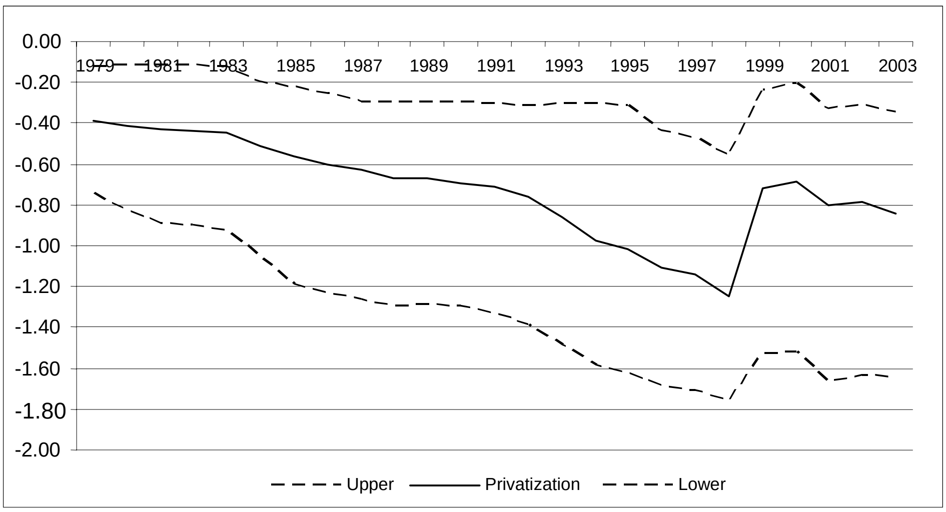
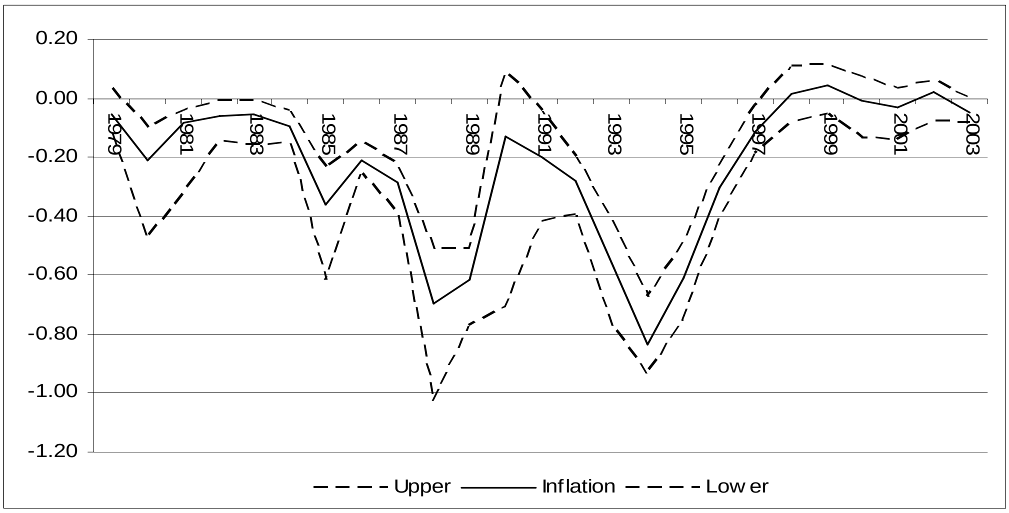


Figure 6
Impact of ownership reform on technical efficiency



Source: Authors' own calculations for Figures 5 and 6.

Figure 7
Impact of price change on technical efficiency



Source: Authors' own calculations.

It can also be seen that there have been large variances of such impact across different regions reflecting the fact that the progress in reforming SOEs has been uneven in different parts of China (Song 2007). However, since the variable for ownership change is too broadly defined, it may not accurately capture its actual impact of privatization on technical efficiency.

Figure 7 shows that inflation has had some negative impact on technical efficiency and there have been no significant differences across different regions with respect to such impact. There have been cyclical changes over the sub-periods, 1979-83, 1985-86, 1987-91, 1992-97, and the last subperiods saw the large fluctuations of technical efficiency in response to changes in prices. This synchronization of movements between price and technical efficiency highlights the importance of maintaining macroeconomic stability in the process of economic transformation to sustain a constant improvement in technical efficiency.

The figure also shows that the pattern of change in technical efficiency has tended to stabilize since the end of 1990s and the impact has become positive over the latest period. This may suggest that China has entered a new phase of macroeconomic development since the end of 1990s in which changes in prices have become less volatile as compared with what had happened in the previous cycles. The macroeconomic stability could lead to an improved technical efficiency as prices reflect more closely the true scarcity of goods and factors of production in the process of marketization.

Figure 8 shows that government purchase has some negative effects on technical efficiency, though the magnitude of such negative impact was insignificant, and the trend of the negative effect has been worsening throughout the period under study. The variances which reflect the regional distribution of the change tended to converge towards the end of 1990s but have begun to widen since the beginning of the century.

The finding may be due to the fact that the ways in which government conducts its purchase or procurement are still not transparent and in conformity to the requirements of the WTO. China is facing increasing pressure to open up its public sector market despite the fact that China did not make a firm commitment to do so according the accession protocol. The finding may suggest that improving the ways in which governments conduct public sector transactions could contribute to the improvement in technical efficiency of production.

Figure 9 shows that the tax system reform has had some negative effects on technical efficiency, although the negative effect has been decreasing over time especially since the mid 1990s. However, it is observed from the figure that at the early phase of reform, China began with some wide regional distributions with respect to the impact of taxes on technical efficiency. In fact, some provinces were especially negatively affected as marked by the changing shape of the lower bounds by the two taxation system reforms

Figure 8
Impact of government consumption on technical efficiency

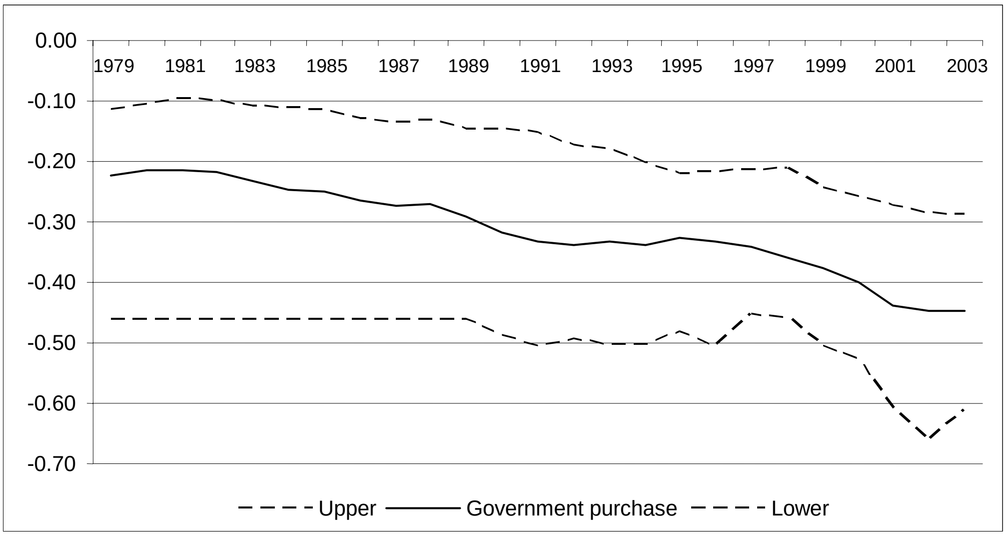
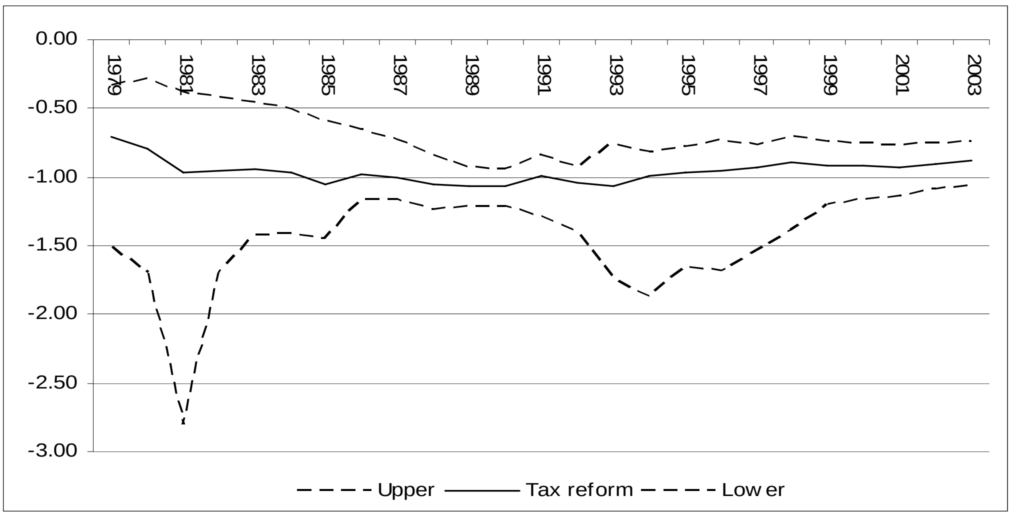


Figure 9
Impact of tax/revenue system reform on technical efficiency



Source: Authors' own calculations for Figures 8 and 9.

which took place first in 1980 under the programme of ‘fiscal decentralization, and then in 1994 with a new revenue-sharing system. It is also observed from the figure that some kind of convergence has been taking place in recent years as shown from the falling gap between the upper and lower bounds from the mean.

This finding raises the issue of how the taxation system reform impacts on technical efficiency of production, that is whether the two waves of taxation system reforms contributed to the two subsequent trends of convergences with some lagged periods (towards the end of 1980s and since the end of 1990s, respectively). However, this study does not provide a conclusive answer to this question. There is a general consensus that the current taxation system in China needs further reform and thus a more interesting question is how the future reform programme will ensure that not only the trend of convergence continues to take place, but also produces positive impact on technical efficiency of production across different regions.

6 Conclusions

The paper attempted to capture the impact of reform on economic growth through improved technical efficiency in China using the principal component approach. The main contribution of the paper is to have established the relationship between institutional change and technical efficiency of production. The results show that among these reform measures, urbanization, trade liberalization and structural change in the form of industrialization are the most important components in contributing to the improvement of technical efficiency of production and hence economic growth. Such findings highlight the importance of government policies aimed at enhancing further urbanization, openness to trade and industrial structural adjustments to sustain the growth momentum in China. The study also found that the potential for further enhancing growth through technical efficiency is considerable, which can be materialized by deepening state-owned enterprises (SOEs) restructuring, banking and fiscal system reform, and government system reform.

Appendix: explanation to acronyms used in this paper

CPI consumer price index, which is widely used as an indicator for measuring inflation. The CPI data used in this paper are derived from the *China Statistical Yearbooks*.

NIEs newly industrialized economies, a term that refers to those Asian countries and regions with rapid economic growth during the past two decades including South Korea, Hong Kong, Taiwan, some ASEAN countries, etc.

PCA principal component analysis, which is a widely used method in the graphing topology to eliminate the multicolinearity between independent variables.

SOEs state-owned enterprises, a term that refers to those enterprises with more than 50 per cent of shares being controlled by central or local governments or collective legal persons.

TFP total factor productivity, which is defined as the total value of output minus the value of various inputs (i.e., capital, labour and intermediate inputs) in the growth accounting framework and widely used to measure technology progress and technology efficiency with the Hick neutral assumption.

WTO World Trade Organization, which initiated from GATT since 1948 and is currently the largest multilateral free trade agreement in the world.

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Appendix

Appendix Table A1
Impact of institutional reform on technical efficiency over time, 1979-2003

	URBN	INDR	PRIV	OPEN	INFL	FINR	GOVP	TAXR
1979	3.94	2.36	-0.39	0.18	-0.06	0.05	-0.22	-0.71
1980	4.02	2.40	-0.42	0.22	-0.21	0.39	-0.22	-0.79
1981	4.07	2.33	-0.43	0.23	-0.08	0.42	-0.21	-0.97
1982	4.11	2.29	-0.43	0.23	-0.06	0.55	-0.22	-0.95
1983	4.16	2.30	-0.45	0.23	-0.05	0.61	-0.23	-0.94
1984	4.28	2.33	-0.51	0.26	-0.09	0.92	-0.25	-0.96
1985	4.41	2.43	-0.56	0.34	-0.36	1.16	-0.25	-1.06
1986	4.46	2.45	-0.60	0.39	-0.21	1.50	-0.26	-0.98
1987	4.57	2.48	-0.63	0.52	-0.28	1.74	-0.27	-1.00
1988	4.62	2.52	-0.67	0.51	-0.70	1.77	-0.27	-1.05
1989	4.68	2.55	-0.67	0.49	-0.62	2.17	-0.29	-1.06
1990	4.69	2.50	-0.69	0.61	-0.13	2.36	-0.32	-1.06
1991	4.72	2.58	-0.71	0.69	-0.20	2.81	-0.33	-0.99
1992	4.79	2.69	-0.76	0.74	-0.28	2.65	-0.34	-1.04
1993	4.89	2.74	-0.86	0.72	-0.56	2.39	-0.33	-1.07
1994	5.01	2.71	-0.98	0.99	-0.84	2.46	-0.34	-1.00
1995	5.09	2.71	-1.01	0.94	-0.61	2.46	-0.33	-0.97
1996	5.16	2.71	-1.11	0.87	-0.30	2.32	-0.33	-0.95
1997	5.22	2.76	-1.14	0.87	-0.11	2.27	-0.34	-0.92
1998	5.26	2.79	-1.24	0.83	0.02	2.42	-0.36	-0.89
1999	4.99	2.84	-0.72	0.98	0.05	0.50	-0.38	-0.92
2000	5.07	2.88	-0.68	1.16	-0.01	0.53	-0.40	-0.92
2001	5.52	2.91	-0.80	1.13	-0.03	0.49	-0.44	-0.92
2002	5.28	2.93	-0.78	1.32	0.02	0.52	-0.45	-0.90
2003	5.48	2.97	-0.85	1.42	-0.05	0.54	-0.45	-0.88
Average	4.74	2.61	-0.72	0.67	-0.23	1.44	-0.31	-0.96

Source: Authors' own calculation.

Appendix Table A2
Impact of institutional reform on technical efficiency across regions

Prov\item	URBN	INDR	PRIV	OPEN	INFL	FINR	GOVP	TAXR
Beijing	10.15	3.25	-0.56	1.20	-0.28	0.32	-0.45	-1.04
Tianjin	8.97	3.22	-0.90	1.88	-0.23	1.73	-0.33	-0.88
Hebei	2.57	2.63	-0.96	0.36	-0.20	0.94	-0.26	-0.95
Shanxi	10.96	2.89	-0.79	0.29	-0.22	0.65	-0.33	-0.92
Inner Mongolia	4.99	2.42	-0.53	0.30	-0.24	1.79	-0.30	-1.25
Liaoning	6.70	2.95	-0.80	1.12	-0.22	1.53	-0.34	-0.88
Jilin	6.30	2.54	-0.54	0.45	-0.22	1.57	-0.26	-0.97
Heilongjiang	6.87	2.79	-0.46	0.47	-0.23	3.08	-0.26	-1.08
Shanghai	10.95	3.07	-0.71	1.49	-0.26	3.10	-0.30	-0.83
Jiangsu	3.64	2.69	-1.24	0.91	-0.22	0.76	-0.28	-0.92
Zhejiang	2.82	2.68	-1.34	0.80	-0.24	0.76	-0.25	-1.01
Anhui	2.55	2.31	-0.83	0.24	-0.22	1.24	-0.22	-0.97
Jiangxi	3.09	2.26	-0.66	0.27	-0.22	1.76	-0.30	-0.89
Shandong	3.10	2.54	-1.04	0.68	-0.21	0.46	-0.36	-0.93
Henan	3.19	2.49	-0.98	0.16	-0.21	1.21	-0.35	-0.93
Hubei	3.70	2.44	-0.76	0.28	-0.20	1.56	-0.26	-0.87
Hunan	2.59	2.27	-0.74	0.27	-0.26	1.13	-0.25	-0.86
Guangdong	4.18	2.71	-1.19	4.08	-0.25	1.16	-0.30	-0.94
Guangxi	2.32	2.21	-0.68	0.40	-0.24	1.37	-0.35	-0.89
Guizhou	2.08	2.20	-0.48	0.18	-0.23	0.33	-0.27	-0.96
Yunnan	2.08	2.36	-0.47	0.29	-0.22	1.41	-0.22	-0.96
Shaanxi	3.11	2.59	-0.55	0.31	-0.23	1.24	-0.30	-0.92
Gansu	2.71	2.63	-0.42	0.19	-0.22	1.98	-0.37	-0.94
Qinghai	4.39	2.67	-0.35	0.20	-0.25	2.96	-0.38	-1.05
Ningxia	3.88	2.62	-0.48	0.37	-0.23	1.88	-0.47	-0.99
Xinjiang	5.32	2.36	-0.34	0.38	-0.22	1.51	-0.38	-1.02
Average	4.74	2.61	-0.72	0.67	-0.23	1.44	-0.31	-0.96

Source: Authors' own calculation.