Efficiency and productivity growth in Chinese universities during the post-reform period

Ng, Ying Chu; Li, Sung Ko

Published in:
China Economic Review

DOI:
10.1016/j.chieco.2009.03.004

Published: 01/06/2009

Document Version:
Early version, also known as preprint

Efficiency and Productivity Growth in Chinese Universities, 1998-2002

Ying Chu NG*
and
Sung-ko LI

Department of Economics
Hong Kong Baptist University
Kowloon Tong
Kowloon
Hong Kong, CHINA

Presented at
Asia-Pacific Productivity Conference (APPC) 2006
Seoul National University, Seoul, Korea
17-19 August, 2006

* Corresponding author, Ying Chu NG, Department of Economics, Hong Kong Baptist University, Kowloon Tong, Kowloon, Kong Kong, China, Tel: (852)3411-7555. Fax: (852)3411-5580. The authors acknowledge with gratitude the generous support of the Research Committee of Hong Kong Baptist University for the project (FRG/04-05/I-21) without which the timely production of the current publication would not have been feasible.

Abstract

While the performance of educational institutions in developed countries has been well documented, limited research is available on similar issues in the developing world. Such information is of interest, as the quality of human capital is a key factor in the development of most developing countries. Policy makers in countries undergoing transition are normally keen to train high quality manpower to facilitate economic reforms. One good example is China.

Taking advantage of panel data on social science research in more than 400 universities in China, Farrell input-oriented efficiency measures were computed and evidence was sought of the existence of congested inputs. The empirical results showed that universities in China have been relatively inefficient in producing social science research outputs. Possible savings of 37% to 50% on inputs are indicated for the 1998 to 2002 period, although congestion in input usage was rather mild.

The panel nature of the data also allowed study of the productivity changes in Chinese universities. Input-based Malmquist indices were computed which indicated a continuous decline in their productivity. The performance of universities in the coastal region was relatively better than that of their non-coastal counterparts. The observed negative productivity growth originated in a deterioration in efficiency over time, as well as in technological regression among the non-coastal universities. Among universities located in the coastal region, technological regression and worsening in over time efficiency took alternative roles in shaping the decline in year-to-year productivity.

JEL classification code: I20; L30

Keywords: technical efficiency; congestion; Malmquist productivity index; research performance of Chinese universities

1. Introduction

The remarkable economic growth in China since the 1980s has highlighted the importance of human capital investment. It is well documented that investment in human capital is one of the key factors sustaining the growth of any economy. Changes in the education sector have long term impacts on an economy, but particularly on an economy like China's undergoing economic transition.

Previous assessments of the education sector at the school district level or at the higher education level in developed countries have presented a mixed picture, but there has been only a smattering of research work in this area from the developing world. Assessing the education sector in China during its education reforms thus provides a real-world case for understanding the education sector's responses to the changing environment during economic transition.

Interpreting the effects of the recent education reforms in China is complicated by the economic reforms (enterprise and industrial reforms) in progress at the same time. It is well documented that the economic reforms of the past two decades have resulted in growth imbalances among China's regions. The coastal region has consistently been the fastest growing region, with annual growth averaging 10%, compared to the non-coastal (central and west) region with annual growth of 7.4%-8.4% during the course of reform (Bao, Chang, Sachs and Woo 2002). This coastal-led development effect has been especially strong since 1990 (Jian, Sachs and Warner 1996). Not until the late 1990s did the growth disparities narrow as the government directed more support towards the inland provinces.

The regional disparities have had implications for the self-funding of higher education institutions granted by the education reforms. The shrinking of the central education fund over time has meant that Chinese higher education institutions have had to rely on fund raising for both current expenses and development. Although institutions in the coastal region should be in a better position to raise funds, only if they can manage their resources effectively would they outperform institutions in the other region. Accordingly, an analysis of the productive efficiency of Chinese institutions of higher education by region is warranted.

Before the education reforms, the management and the operation of higher education institutions in China was strictly regulated through communist-style central planning. Since the mid-1980s, the reforms have granted management autonomy and freedom in raising funds to the institutions. These changes in practice raise the issue of mis-utilizing resources. Typically, the concern is about over-utilizing resources in the sense that the existing outputs can be produced by fewer inputs. This phenomenon is referred as congestion in productive efficiency analysis. Together with standard efficiency measures, this study examined the extent of congestion in Chinese higher education institutions by region.

An assessment at a given point in time only reveals part of the picture for economies in transition. Taking advantage of the availability of five-year panel data, this study sought to document productivity growth or regression at higher education institutions in China during the post-reform period. Malmquist productivity indices were calculated on a year-to-year basis to provide a more thorough understanding of the performance of the higher education institutions. Decomposition of the Malmquist indices analyzed the sources of productivity change into changes in efficiency and technological change. Such information should be of great value to both policy makers and researchers involved with the education reforms implemented since the mid-1980s.

The rest of the paper is organized as follows. Section 2 highlights the situation of the higher education sector in China since the reform, followed by the methodology section. Findings of the analyses are presented in Section 4. Section 5 concludes.

2. The Chinese Higher Education Sector During the Reform Period

A series of education documents were published in the early 1990s granting more autonomy to China's universities (Cai 1997). A fixed amount of money was granted by the central government, and each institution was allowed to carry forward any surplus. At the same time, the government's expenditure on higher education as a percentage of total government education spending had been declining since the mid-1980s, from 27.1% in 1985 to 19% in 1994 (The World Bank 1997). Since the education reform, the Communist Party of China has begun to encourage universities to search for additional funding (Mok 2000). The key non-government sources of funds have been from self-raised funds and from tuition fees. According to Lang (2002), self-raised funds came to 21.6 million yuans by 1992 as compared to 0.6 million yuans in 1978. The fall in the proportion of government funds mirrored the changes. Government funds fell from 95.9% of higher education revenue in 1978 to 81.8% in 1992 (The World Bank 1997). In 1994, this figure was down to 77.2% (Cai 1997). By the early 2000s, the percentage was less than 65% (Heckman 2005, Table 3). For the nation as a whole, the public budget for higher education amounted to 70.12% of tertiary institutions' current expenditure in 1995 (Qi and Chen 2000).

In addition to the shrinking of central funds, total education funds allocated by the government were greatly differentiated among universities across the regions (Cai 1997). In 1992, Beijing and Shanghai spent 2.9% and 2.4% of their city GDPs on higher education (The World Bank 1997). Sichuan and Anhui, on the other hand, spent 1.6% and 1.8%, respectively. Bray and Borevskaya (2001) have pointed out that earmarked educational subventions slowly shifted from the coastal region to the non-coastal region in the 1980s and 1990s. By the late 1990s, the inland had the most emphasis. In 2001, provinces in the east spent about 59-70% of their GDP on education. These shares in the provinces of the central region and the west region were 56-78% and 62-93%, respectively (Heckman 2005). Gong (1988) has commented that the disparity in regional development resulting from economic reforms made self-raised funds relatively more important to the non-coastal universities during the early phase of education reform. By the late 1990s, the situation may have been reversed.

The Higher Education Law of 1998 made the provincial government responsible for adopting a preferential policy with regard to the import of books and materials, equipment for teaching and scientific research, and with regard to industries run by institutions of higher learning. Returns from industries run by such institutions or from the transfer of intellectual property rights or other scientific and technological achievements were to be used for running the institution. Institutions of higher learning were enjoined to rationally use and strictly control education funds, and to improve the performance of education investments.

In 1985, new research initiation was called for in institutions of higher education in China (Hayhoe 1989, 1991). In 1986, the Chinese government established a national natural science research fund and a high-tech fund (called the 863 fund) for funding basic and technological research. The allocation of these funds entirely depends on the academic quality of the proposals submitted by the universities. A national social science research fund was founded in 1987 (Hayhoe 1993, 1999). Hayhoe and Zhong (1995) have documented that in 1986-1990 only about 860 social science papers and 300 arts and humanities papers from China were published in major international journals. In 1994, the majority of humanities and social science personnel devoted 10 percent of their work time to R&D (The World Bank 1997). Nevertheless, as pointed out by that World Bank report, output per researcher was low by international standards, and the quality of research also varied considerably across institutions. This may be attributable to the research spending differential across institutions.

3. Measures of Productive Efficiency and Productivity Growth

A. Efficiency Measures and a Measure of Congestion

Let $U_j = (u_{1j}, u_{2j}, \ldots, u_{Mj})$ and $X_j = (x_{1j}, x_{2j}, \ldots, x_{Nj})$ be the observed output and input vectors of the jth university in a sample of J universities. Assuming strong disposability of inputs and outputs, the overall Farrell input-oriented technical measure (ote) can be computed using a typical nonparametric frontier,

$$ote_j = \min \lambda$$

$$\text{subject to } \sum_i z_i u_{mi} \geq u_{mj} \qquad (m = 1, \ldots, M)$$

$$\sum_i z_i x_{ni} \leq \lambda_j x_{nj} \qquad (n = 1, \ldots, N)$$

$$\sum_i z_i = 1. \tag{1}$$

The technology behind this problem exhibits variable returns to scale and strongly disposable inputs. The main assumption is that the technology set is convex.

Following the approach of Färe, Grosskopf and Lovell (1985), the ote can be decomposed into a congestion measure and a pure technical efficiency measure. The pure technical efficiency (pte) can be computed by solving the following linear programming problem:

$$pte_j = \min \lambda$$

$$\text{subject to } \sum_i z_i u_{mi} \geq u_{mj} \qquad (m = 1, \ldots, M)$$

$$\sum_i z_i x_{ni} = \lambda_j x_{nj} \qquad (n = 1, \ldots, N)$$

$$\sum_i z_i = 1. \tag{2}$$

The congestion measure is defined as congestion = ote / pte. It follows that ote = congestion $\times$ pte.

A change in the input mix may give rise to diminishing returns. Universities may not be able to make the best use of their available resources, and thus may see no increase in outputs even with extra inputs. To address the existence of congested inputs (congestion), two isoquants can be constructed for the same level of output. As indicated in Figure 1, isoquant abcd is backward bending while abcd′ is not. The shape of the isoquant constructed depends on the behavior of the data. If a negative marginal product is indicated by the data, the isoquant constructed should resemble abcd; if there are no congested inputs, the isoquant should be similar to abcd′. Consider the input mix combination x^* in which input x_1 is congested, reflecting negative marginal product. As discussed by Färe, Grosskopf and Lovell (1985), the level of congestion is measured by oe/oe′.

These measures were applied to the sample of universities in the coastal and non-coastal regions of China.

B. The Productivity Index

To begin with, the university's production technology at each period t, t=1, …, T, is defined as S^t, where $S^t = \{(X^t, U^t) : X^t \text{ can produce } U^t\}$ (for ease of presentation, the subscript j has been dropped as was done for the efficiency measure). The technology is modeled by the input requirement set

$$L^t(U^t) = \{X^t : (X^t, U^t) \in S^t\} \qquad (t = 1, \ldots, T) \qquad (3)$$

The input requirement set, $L^t(U^t)$, denotes all input vectors X^t that are capable of producing outputs U^t during period t. For each period t, there are $j = 1, \ldots J^t$

observations and same number of observations are assumed in each period (that is, $J^t = J$).

As with Färe, Grosskopf, and Lovell (1985), the input requirement set is formed as follows:

$$\begin{aligned} L^t(U^t) = \{X^t : u_m^t &\le \sum_{j=1}^{J} z_j^t u_{mj}^t && (m = 1, \ldots, M) \\ x_n^t &\ge \sum_{j=1}^{J} z_j^t x_{nj}^t && (n = 1, \ldots, N) \\ z_j^t &\ge 0\} && (j = 1, \ldots, J) \qquad (4) \end{aligned}$$

where z_j^t is an intensity variable familiar from activity analysis. Further, constant returns to scale are imposed on the reference technology.

The Malmquist input-based productivity index is expressed in terms of four input distance functions (Caves, Christensen and Diewert 1982). First are the evaluation observations at t relative to the technology at t.

$$D_i^t(U^t, X^t) = \sup\{\lambda > 0 : X^t/\lambda \in L^t(U^t)\}. \qquad (5)$$

Secondly is the evaluation of observations at t+1 relative to the technology at t+1.

$$D_i^{t+1}(U^{t+1}, X^{t+1}) = \sup\{\lambda > 0 : X^{t+1}/\lambda \in L^{t+1}(U^{t+1})\}. \qquad (6)$$

The next two distance functions evaluate observations at t relative to the technology at t+1 and at t+1 relative to the technology at t.

$$D_i^{t+1}(U^t, X^t) = \sup\{\lambda > 0 : X^t/\lambda \in L^{t+1}(U^t)\}. \qquad (7)$$

$$D_i^t(U^{t+1}, X^{t+1}) = \sup\{\lambda > 0 : (X^{t+1}/\lambda \in L^t(U^{t+1})\}. \qquad (8)$$

For observation j^*, $j^*=1, \ldots, J$, the value of the distance function $D_i^t(U_{j^*}^t, X_{j^*}^t)$ can be obtained by solving the following linear programming problem:

$$\left[D_i^t(U_{j^*}^t, X_{j^*}^t)\right]^{-1} = \min \lambda ,$$

$$\text{subject to } U_{mj^*}^t \le \sum_{j=1}^{J} z_j^t u_{mj}^t \qquad (m = 1, \ldots, M)$$

$$\lambda X_{nj^*}^t \ge \sum_{j=1}^{J} z_j^t x_{nj}^t \qquad (n = 1, \ldots, N)$$

$$z_j^t \ge 0 \qquad (j = 1, \ldots, J). \qquad (9)$$

If $X_{j^*}^t$ is an element of the input set, the distance function takes values larger than or equal to one. The computation of the distance function outlined by equation (6) is identical to that of equation (9) with t+1 substituting for t.

Evaluating the distance function $D_i^{t+1}(U^t, X^t)$ of equation (7) requires the solution to the following linear programming problem:

$$\left[D_i^{t+1}(U_{j^*}^t, X_{j^*}^t)\right]^{-1} = \min \lambda \ ,$$

$$\text{subject to } U_{mj^*}^t \le \sum_{j=1}^{J} z_j^{t+1} u_{mj}^{t+1} \qquad (m = 1, \ldots, M)$$

$$\lambda X_{nj^*}^t \ge \sum_{j=1}^{J} z_j^{t+1} x_{nj}^{t+1} \qquad (n = 1, \ldots, N)$$

$$z_j^{t+1} \ge 0 \qquad (j = 1, \ldots, J). \qquad (10)$$

Note that $X_{j^*}^t$ need not be a member of the input requirement set $L^{t+1}(U_{j^*}^t)$. The value of this distance function may be strictly less than one. The computation of equation (8) is the same as that of equation (10) replacing t+1 by t. Again, (X^{t+1}, U^{t+1}) need not be feasible under technology L^t, and thus the distance function $D_i^t(U^{t+1}, X^{t+1})$ may be strictly less than one.

In Caves, Christensen and Diewert (1982), the productivity of an observation relative to the technology in time t is

$$\frac{D_i^t(U^{t+1},X^{t+1})}{D_i^t(U^t,X^t)}. \tag{11}$$

Similarly, the productivity relative to the technology in time t+1 is

$$\frac{D_i^{t+1}(U^{t+1},X^{t+1})}{D_i^{t+1}(U^t,X^t)}. \tag{12}$$

To avoid arbitrariness in the choice of base period, Färe Grosskopf, Norris and Zhang (1994) defined the the input-based Malmquist productivity index as the geometric mean of two Malmquist indices defined by Caves, Christensen and Diewert (1982).

That is,

$$M_i^{t+1}(U^{t+1},X^{t+1},U^t,X^t)$$

$$=\left[\frac{D_i^t\left(U^{t+1},X^{t+1}\right)}{D_i^t\left(U^t,X^t\right)}\cdot\frac{D_i^{t+1}\left(U^{t+1},X^{t+1}\right)}{D_i^{t+1}\left(U^t,X^t\right)}\right]^{\frac{1}{2}}. \tag{13}$$

Allowing for inefficiencies, the productivity index can be decomposed into two components. Equation (13) becomes

$$M_i^{t+1}(U^{t+1},X^{t+1},U^t,X^t)$$

$$=\frac{D_i^{t+1}\left(U^{t+1},X^{t+1}\right)}{D_i^t\left(U^t,X^t\right)}\left[\frac{D_i^t\left(U^{t+1},X^{t+1}\right)}{D_i^{t+1}\left(U^{t+1},X^{t+1}\right)}\cdot\frac{D_i^t\left(U^t,X^t\right)}{D_i^{t+1}\left(U^t,X^t\right)}\right]^{\frac{1}{2}}. \tag{14}$$

The term in front of the bracket measures the change in technical efficiency and is known as the "catching-up index". The terms in the bracket measure the shift in the frontier between periods t and t+1, the "frontier productivity index". If the estimated value of M_i^{t+1} or its components is larger than unity, it indicates a deterioration in productivity. Values less than unity mean an improvement in productivity.

4. Empirical Findings

A. The Productive Efficiency of Chinese Universities

In the literature on the evaluation of the education sector or of higher education institutions, the choices of inputs and outputs have been debated. This analysis included all variables for which data were available. It focused on the social science research performance of Chinese universities between 1998 and 2002. Research performance was chosen for analysis for two reasons: (1) the availability of data; and (2) that it is relatively easy to evaluate the quantity and quality of the outputs of such work. The period was chosen to allow capture of any effects of education reforms. It was anticipated that the most recent 5-year data would clearly reveal the productivity changes in Chinese universities.

The data came from *Summary Statistics on the Social Sciences Areas of Higher Education Institutions*, an annual official publication of the China Statistical Publishing House. The 5 years of data covered 422 universities, including 242 in the coastal region and 180 located in the non-coastal region. Three inputs (the number of teaching staff, the number of research staff, and the amount of research funding), and six outputs (the number of books published, the number of manuscripts published overseas, the number of manuscripts published domestically, the number of overseas awards received, the number of domestic awards received, and a miscellaneous category for other recognized outputs) were used in the analysis.

As shown in Table 1, universities in the coastal region, on average, received larger amounts of all inputs than the non-coastal institutions. In particular, the average amount of research funding for universities in the coastal region was nearly double that of the others in the late 1990s and early 2000s. In terms of growth rate, the universities in the coastal region increased their research staff by 40%, versus 23% for the non-coastal universities between 1998 and 2003. While there was no difference in the percentage growth in teaching staff between regions, the amount of research funds increased nearly five times in the non-coastal universities but only about four times in their coastal counterparts during the study period.

As with the inputs, universities in the coastal region produced more of all six types of outputs during 1998-2002, with only two exceptions in early 2000 (Table 2). Regardless of region, all universities exhibited an increasing trend in book publications and in manuscripts published overseas. By 2002, the number of these two outputs at coastal universities had increased about 1.6 to 1.7 times compared to 1998, while the comparable figure was only 1.5 to 1.6 times for non-coastal universities. In terms of manuscripts published domestically, universities in the non-coastal region produced more year after year, while there was no particular pattern for universities located in the coastal region. The other three types of outputs varied little over the period except for the number of "other recognized outputs" from the non-coastal universities.

According to Farrell's input-base technical efficiency measures, universities in China were found to be relatively inefficient in producing social science research outputs regardless their location. The figures in Table 3 show that the average overall technical efficiency ranged between 0.5198 and 0.6261 for universities in the coastal region, and between 0.4979 and 0.6010 for non-coastal universities for the period 1998-2002. That is, on average the universities were able to produce the same output with 50% to 63% of the observed inputs. In general, both types of university showed improvements in efficiency before 2000, but deteriorations in efficiency since 2000. With the exception of 1999 and 2002, the overall performance of the universities showed no notable regional differences. Most of the universities' inefficiency was pure technical inefficiency. As a result, congestion (waste of resources) was not an issue for these universities between 1998 and 2002. Nevertheless, the deterioration in their overall efficiency was a result of both a worsening in pure technical efficiency and continuous mild congestion problems.

Regionally, the estimated pure technical efficiency scores exhibit a trend similar to those for overall technical efficiency. The only exception is that universities in the coastal region outperformed those in the non-coastal region by a small margin throughout the period. On the other hand, universities in the non-coastal region seem to have become more efficient in using their inputs since the late 1990s. Their congestion scores have been consistently higher than those of universities in the coastal region except in 1998, although both types of universities showed an increasing tendency to waste inputs from 2000 on.

B. Productivity Change in Chinese Universities

Mirroring the efficiency performance, the Chinese universities did not do well in terms of year-to-year productivity change. The computed Malmquist index is presented in Table 4, and all figures are greater than unity. For the universities in the coastal region, substantial declines in productivity were found just before and just after 2000. Universities in the non-coastal region showed similar performance in 1998-1999 and 2000-2001. Within the five years, the universities in the coastal region were in a relatively better position than those elsewhere with respect to productivity change, except in 1999-2000. Nevertheless, a continuous decline in average productivity was found for all universities.

Decomposing these changes into changes in efficiency and technological change reveals some similar regional phenomena as well as some regional differences. Universities, regardless of region, experienced technological improvement in 1999-2000 and 2001-2002, but technological regression in the other two periods (Table 4). Nevertheless, regardless of their technological improvement or regression, universities in the coastal region still performed better than those elsewhere. On a year-to-year basis, universities in both regions showed an overall declining trend in efficiency. It was particularly the case for universities in the coastal region. In other words, a continuous deterioration in average efficiency was found between 1998 and 2002 for Chinese universities as a whole. Another observation is that the source of productivity change was quite different by region. As shown in Table 4, it was either change in efficiency alone or change in technology alone which played a dominant role in shaping the productivity change each year in the coastal region. On the contrary, the continuous decline in productivity of inland universities was attributable to both deterioration in efficiency over time and technological regression (although there was an improvement in technology in 1999-2000 and 2001-2002).

5. Conclusions

The estimated efficiency measures indicate that universities in China remained quite inefficient in their social science research even after a decade of reform. There was no notable regional difference in overall efficiency for the study period 1998-2002. Universities in both regions experienced only mild congestion. In other words, over-utilization of resources was not a concern. It seems that even though universities in the coastal region consistently had access to much more resources than those in the non-coastal region, they were able to manage their inputs in a reasonable manner so that negative marginal product of inputs was never found. However, universities in the coastal region were less efficient than their non-coastal counterparts. Indeed, poor average technical efficiency characterized all universities, and there is definitely room for improvement.

In parallel with the efficiency performance, universities in China exhibited continuous declines in productivity between 1998 and 2002. The year-to-year productivity decline was much more serious for universities located away from the coast. This was attributable to deterioration in efficiency over time as well as to technological regression. In other words, not only was less research output produced by the best universities, but also the discrepancy between the poor universities and the best performers widened (there was no catching-up effect). For universities in the coastal region, the sources of their productivity decline changed annually, with technology regression dominating in one year while worsening efficiency became the key factor in another year. This may indicate that the performance of the best practice universities varied substantially from year to year while the inefficient universities did not make much progress over time.

In sum, universities in the coastal region performed slightly better. The autonomy brought by the education reforms definitely provided room for universities to manage their allocated resources as well as to increase their ability of raising resources for the development of the institutions. However, the present study has shown that universities have not taken the advantage of opportunities to optimize their use of resources. This is particularly the case for non-coastal universities, which are less exposed to market forces and may find it harder to access to external sources of funds or other resources. The only encouraging fact is that the universities in general did not have serious congestion problems. In other words, regardless of region, most universities were able to managing their resources (inputs) in a reasonable manner. In order to enhance the performance of Chinese universities, further improvements in technical efficiency are called for, perhaps by restructuring the sector by region or locality.

As with most empirical work, a few limitations are worthy mentioning. First, the results rely heavily on the available data on inputs and outputs, so the empirical analyses can only serve as an example in understanding the performance of Chinese universities. Second, this evaluation of university performance has been rather selective: only technical efficiency, congestion and productivity change were addressed. Third, only the social science research of the universities was considered. Taking no account of the teaching component, caution is called for when interpreting the results.

References

Bao, S., Chang, G.H., Sachs, J.D., Woo, W.T., 2002. Geographic factors and China's regional development under market reforms, 1978-1998. China Economic Review 13 (1), 89-111.

Bray, M., Borevskaya, N., 2001. Financing education in transitional societies: lessons from Russia and China. Comparative Education 37(3), 345-365.

Cai, K.Y., 1997. Woguo Gaodeng Jiaoyu Tizhi Gaige Ji Qi Zonghe Xiaoyi Fenxi (My country's Higher Education System Reform and Its Overall Effectiveness Analysis). Renmen Jiaoyu Publisher, Beijing, China.

Caves, D., Christensen, L., Diewert, E., 1982. The economic theory of index numbers and the measurement of input, output, and productivity. Econometrica 50, 1393-1414.

Färe, R., Grosskopf, S., Lovell, C.A.K., 1985. The Measurement of Efficiency of Production. Kluwer-Nijhoff Publishing, Boston, USA.

Färe, R., Grosskopf, S., Norris, M., Zhang, Z. 1994. Productivity growth, technical progress, and efficiency change in industrialized countries. American Economic Review 84, 66-83.

Gong, F.,1988. Zhongguo jingji fazhan de quyuhau ji qi dui gaodeng jianyu de yingxiang (The regionalization of China's economic development and its effects on higher education). Jiaoyu Yanzhou (Education Research) 9, 8-13 & 78.

Hayhoe, R., 1989. China's Universities and the Open Door. M. E. Sharpe, New York and OISE Press, Toronto.

Hayhoe, R., 1991. The tapestry of Chinese higher education, in: Epstein, I. (Ed.), Chinese Education: Problems, Policies and Prospects. Garland Publishing Inc., New York, Ch. 4.

Hayhoe, R., 1993. Chinese universities since Tiananmen: a critical assessment. China Quarterly 134(June), 81-98.

Hayhoe, R., 1999. China's Universities 1895-1995: A Century of Cultural Conflict.

Comparative Education Research Centre, The University of Hong Kong, Hong Kong.

Hayhoe, R., Zhong, W.H., 1995. Universities and science in China: new visibility in the world community, in: Yee, A.H. (Ed.), East Asian Higher Education: Transitions and Transformations. IAU Press, UK.

Heckman, J.J., 2005. China's human capital investment. China Economic Review 16(1), 50-70.

Jian, T., Sachs, J.D., Warner, A.M., 1996. Trends in regional inequality in China. China Economic Review 7(1), 1-21.

Lang, Y.F., 2002. Zhongguo Gaodeng Jiaoyu Touzi Moshi Yanjiu (Research in China's Higher Education Investment Model). Haerbin Engineering University Press, Haerbin, China.

Mok, K.H., 2000. Marketizing higher education in post-Mao China. International Journal of Educational Development 20(2), 109-126.

Qi, Y.G., Chen, Y.K., 2000. Diversification of sources of funding and innovation in management methods in Chinese universities, in: Current Issues in Chinese Higher Education, Institutional Management in Higher Education, OECD.

The World Bank, 1997. China: Higher Education Reform. The World Bank, Washington, D.C., USA.

Figure 1. Congestion in input usage

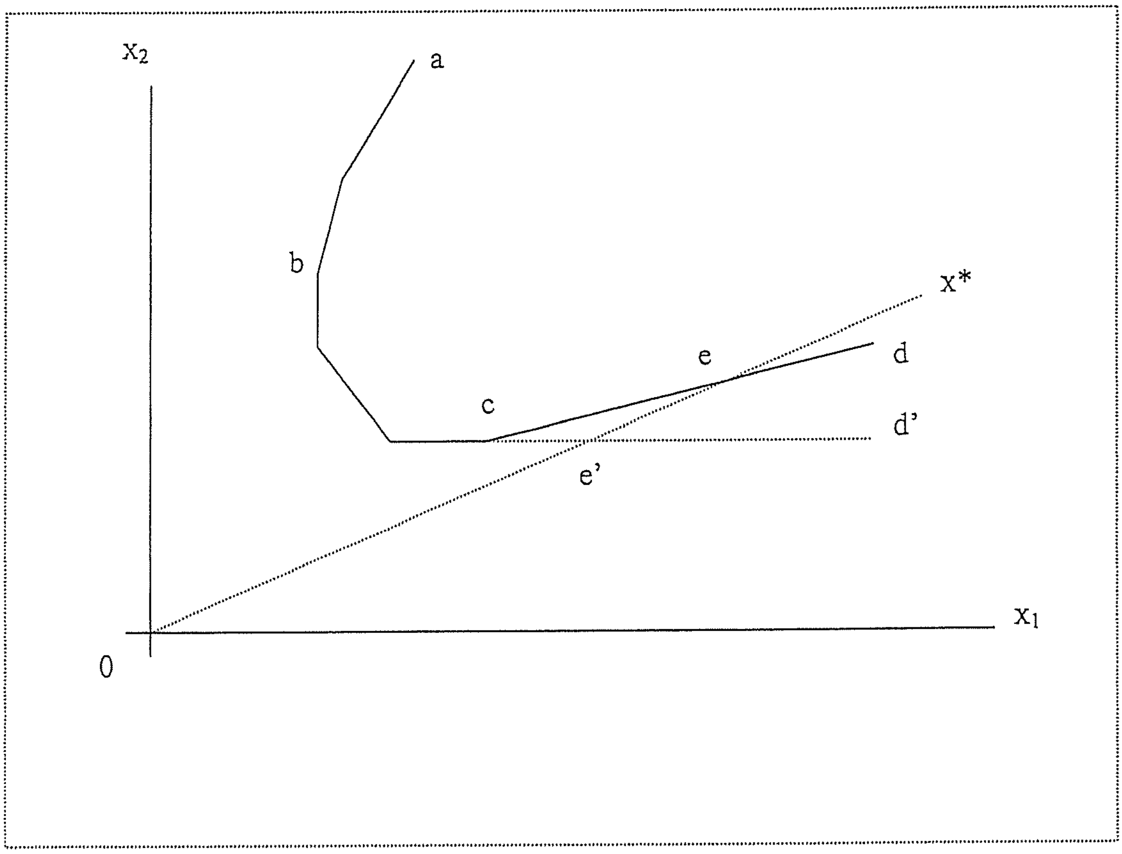

Table 1 Sample Statistics for Inputs by Type of University, 1998-2002

	1998	1999	2000	2001	2002
Coastal Universities					
The number of teaching staff	369.42 (307.66)	379.05 (312.02)	401.02 (312.12)	423.52 (317.19)	448.26 (333.58)
The number of research staff	117.35 (151.14)	126.52 (154.73)	142.66 (161.49)	157.32 (167.13)	163.57 (173.57)
The amount of research funding (in 100 yuans)	7421.19 (17077.51)	8139.35 (18783.27)	14894.26 (31805.75)	26229.62 (59559.36)	36688.35 (68713.77)
N	242	242	242	242	242
Non-coastal Universities					
The number of teaching staff	347.04 (256.49)	350.43 (252.26)	374.36 (277.54)	391.88 (289.92)	417.77 (297.28)
The number of research staff	104.29 (132.85)	103.78 (126.65)	112.24 (124.51)	118.21 (137.06)	128.70 (146.80)
The amount of research funding (in 100 yuans)	3532.51 (7739.67)	4332.83 (9833.88)	8220.71 (19137.79)	14274.94 (33645.13)	21068.51 (41437.31)
N	180	180	180	180	180

Standard deviations are in parentheses.

Table 2 Sample Statistics for Outputs by Type of University, 1998-2002

	1998	1999	2000	2001	2002
Coastal Universities					
The number of books published	28.95 (52.31)	32.15 (62.96)	38.24 (70.65)	47.06 (79.63)	50.52 (82.22)
The number of manuscripts published overseas	214.12 (256.10)	240.96 (289.19)	269.80 (325.08)	316.98 (392.83)	351.29 (415.34)
The number of manuscripts published domestically	3.83 (11.13)	4.52 (13.32)	5.57 (19.11)	3.92 (9.06)	5.74 (17.11)
The number of other recognized outputs	4.68 (19.87)	5.72 (32.09)	8.10 (44.87)	5.07 (18.38)	6.00 (20.04)
The number of overseas awards	4.30 (12.50)	4.14 (10.43)	3.38 (9.38)	3.79 (10.21)	4.45 (12.61)
The number of national awards	3.59 (10.75)	3.58 (9.17)	3.91 (11.30)	2.14 (6.38)	4.84 (13.19)
N	242	242	242	242	242

Table 2 (continued)

	1998	1999	2000	2001	2002
Non-coastal Universities					
The number of books published	19.13 (28.23)	19.94 (28.95)	19.93 (29.57)	25.75 (41.00)	29.11 (42.19)
The number of manuscripts published overseas	181.46 (207.27)	205.13 (235.30)	228.45 (256.94)	254.27 (297.37)	284.49 (309.36)
The number of manuscripts published domestically	1.74 (4.31)	1.92 (4.77)	2.59 (9.80)	2.21 (6.77)	2.64 (7.40)
The number of other recognized outputs	1.68 (4.37)	2.34 (6.04)	1.96 (5.44)	1.99 (6.36)	9.73 (110.50)
The number of overseas awards	2.71 (7.88)	2.82 (9.24)	2.37 (7.49)	1.92 (6.85)	3.72 (17.53)
The number of national awards	2.88 (7.54)	2.16 (7.55)	3.58 (8.68)	5.01 (16.27)	3.45 (8.48)
N	180	180	180	180	180

Standard deviations are in parentheses.

Table 3 Efficiency Measures by Type of University, 1998-2002

	1998	1999	2000	2001	2002
Coastal Universities					
Overall technical efficiency	0.5237	0.6261	0.5505	0.5827	0.5198
Congestion	0.9300	0.9619	0.9379	0.9348	0.9078
Pure technical efficiency	0.5738	0.6554	0.5919	0.6319	0.5883
N	242	242	242	242	242
Non-coastal Universities					
Overall technical efficiency	0.5213	0.6010	0.5565	0.5814	0.4979
Congestion	0.9309	0.9767	0.9545	0.9480	0.9420
Pure technical efficiency	0.5671	0.6151	0.5871	0.6172	0.5371
N	180	180	180	180	180

Table 4 Year-to-year Productivity Change by Type of University, 1998-2002

	1998-1999	1999-2000	2000-2001	2001-2002
Coastal Universities				
Malmquist index	1.0391	1.3183	1.4058	1.1186
Change in efficiency	0.9513	1.5358	1.2853	1.4042
Technological change	1.1028	0.8837	1.0507	0.8365
N	242	242	242	242
Non-coastal Universities				
Malmquist index	1.7067	1.1098	1.4855	1.2343
Change in efficiency	1.3881	1.3393	1.3176	1.4686
Technological change	1.1682	0.8522	1.1467	0.8538
N	180	180	180	180