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MEASURING THE RESEARCH PERFORMANCE OF CHINESE HIGHER EDUCATION INSTITUTIONS USING DATA ENVELOPMENT ANALYSIS

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Abstract

This study uses data envelopment analysis (DEA) to examine the relative efficiency of over 100 selected Chinese regular universities. Various models are developed to measure the research efficiency of these higher education institutions (HEIs) using data for 2003 and 2004. The findings show that the *level* of efficiency depends on whether or not a subjective measure of research output (based on experts' opinions of the HEIs) is included as an output in the model. Mean efficiency is higher when the reputation variable is included (around 90%) than when it is not (mean efficiency is around 55% in this case). However, the *rankings* of the universities are remarkably insensitive to whether or not this variable is included. Bootstrapping procedures are used to find the 95% confidence intervals for the efficiencies, and indicate that the best and worst performing institutions are significantly different from each other; only the middle-performing 30% of HEIs cannot be distinguished from each other in terms of their performance. Further investigation suggests that regional location, source of funding and whether the university is comprehensive or specialist may all contribute to the observed differences in performance. The regional differences are consistent but not significant at conventional levels of significance; the efficiencies differ significantly by administrative type when the subjective measure of research output is excluded from the analysis; comprehensive universities consistently and significantly outperform specialist institutions. The possibility of regional differences in performance is particularly worrying since the already economically disadvantaged Western region may suffer a continued lag in development if its HEIs are less efficient than those in the better developed Central and coastal regions.

JEL classification: I21, I23, C14

Keywords: data envelopment analysis; efficiency measurement; Chinese higher education

Introduction

Data envelopment analysis (DEA) has become a popular tool for measuring the efficiency of non-profit institutions such as hospitals, schools and universities. Its popularity in these contexts derives from the fact that it is based on a distance function approach and hence can handle multiple outputs and multiple inputs; it does not assume any specific behavioural assumptions of the firm (eg cost minimisation or profit maximisation); it makes no assumption regarding the distribution of efficiencies; and it requires no *a priori* information regarding the prices of either the inputs or the outputs. Despite there being a plethora of studies which examine the efficiency of the higher education sectors of various countries such as the UK, the USA, Canada, Finland, Israel and Australia (Athanassopoulos & Shale 1997; Johnes 2006a; Ahn *et al* 1989; Breu & Raab 1994; Haksever & Muragishi 1998; Arecelus & Coleman 1997; El Mahgary & Lahdelma 1995; Friedman & Sinuany-Stern 1997; Coelli *et al* 1998; Avkiran 2001; Abbott & Doucouliagos 2003), little work has been done on measuring the efficiency of higher education institutions (HEIs) in China. Recent studies by Ng & Li (2000) and Liu (2001) are exceptions but are based on data for the 1990s.

This is surprising. In 2003 student numbers in China were over 11 million, and had risen by more than 168% compared to 5 years previously. Higher education funding had seen an even greater increase – 263% between 1997 and 2002 (Ji 2006). With such rapid expansion, and with the allocation of such huge sums of money to higher education, it is essential that the resources are used efficiently and that quality is maintained. Indeed, '… quantitative growth can get nowhere in the absence of guaranteed quality' (Ji 2006 p278). The purpose of this paper is therefore to examine and measure the technical efficiency of around 115 top Chinese regular[1] universities based on data for 2003 and 2004, i.e. during the period of rapid expansion.

The paper is in 5 parts. Section 1 provides some background on the Chinese higher education system and its development over the last 50 years. The methodology applied to the data is described in section 2 while the data and the models are

[1] The Chinese higher education sector includes both regular HEIs and HEIs for Adults. The latter institutions (which, in terms of total funding, represent 6% of the sector) are not included in this analysis.

presented in section 3. The results of the analysis are in section 4, while conclusions which can be drawn from the study are presented in the final section.

1. Chinese higher education

Since the People's Republic of China (PRC) was founded in 1949, China's higher education sector has experienced a number of distinct phases. The primary characteristics of these phases, and their implications for the funding, management and admissions criteria of the HEIs are summarised in table 1.

TABLE 1

From the Soviet model of higher education which was adopted at the outset, the sector continued to be centrally planned and funded (there were no tuition fees for students) throughout the subsequent three decades. A more decentralised approach to the management and funding of the sector followed the reforms of 1985. Subsequently, the process of decentralisation accelerated, and, in 1992 universities were informed that a greater proportion of their operating funds would derive from tuition fees and finance from other sectors of the economy. By 1997, Chinese HEIs had therefore attained a degree of financial and managerial freedom from government, and were opened up to market forces, since all students were (and still are) required to pay tuition fees. The effect of decentralisation on higher education funding can be seen in table 2 from which it is apparent that, while total funding for regular HEIs has been increasing in recent years, the percentage derived from government sources has been gradually decreasing from 80% in 1996 to just over 50% in 2002. Much of the reduction in the percentage of funding coming from the government has been made up by an increase over the same period in the percentage of funds deriving from tuition fees and other educational funds.

TABLE 2

The effect of these policies on student, teacher and institution numbers are fully apparent from figure 1. Student and HEI numbers noticeably increased during the brief expansion of the 1960s, but the effect was short-lived. There was a resurgence in numbers following the 1985 education reforms, and it is from this base that the sector has experienced dramatic increases in the twenty first century. It is noticeable that these recent increases have not been matched by a similar increase in full-time teacher numbers.

FIGURE 1

China's higher education sector is truly diverse. In 2003, there were 1552 regular HEIs in the sector and these can be classed into 13 different categories (China Statistical Yearbook 2004). Comprehensive universities cover all subject areas and constitute around 8% of the total HEIs (see figure 2). The remaining universities are classified on the basis of their specialist subject, the largest category being short-cycle and vocational colleges. Science and engineering and teacher training institutions are the two next largest groups, but each constitute less than one third of the number of vocational colleges.

FIGURE 2

Diversity also arises from the geographical location of the HEIs. There are 31 defined regions in China of which 4 are municipalities, 5 are autonomous regions and 22 are provinces[2]. These regions can be grouped into three broad zones of economic development: the coastal region with its highly developed provinces (compared with other regions but not by international standards, since China as a whole is developing country); the Central region with its developing provinces; and the Western area which is economically less well developed than the other two. With the steady move towards decentralisation in the Chinese higher education sector, it is likely that the economic disparities between these three broad areas will cause disparities between the HEIs located within their boundaries. Table 3 presents statistics on HEI numbers, teacher numbers[3], and population and GDP numbers by broad economic zones and by individual region. Not surprisingly, the coastal zone is the most affluent region in terms of its mean GDP, especially when this is compared with mean population levels. The Central zone, however, is almost equal to the coastal region in terms of its HEI and teacher numbers. The Western zone lags behind the other two more affluent regions having around half the number of HEIs relative to both the Central and coastal regions, whilst having more than half the mean population (but less than half the mean GDP).

TABLE 3

[2] Hong Kong, Macao and Taiwan are not included in this count.
[3] Ideally, we would like to present higher education funding by region, but these data are not available for 2003, and so number of full-time teachers is used as a proxy.

2. Methodology

DEA is a non-parametric linear programming (LP) technique which measures technical efficiency by computing the ratio of weighted outputs to weighted inputs for each decision making unit (DMU) in the data set. The resulting efficiency score has a range of 0 to 1 (or 0 to 100%) with a score of less than 1 signifying that the DMU is inefficient relative to the others in the set. The weights must be positive and are chosen such that each DMU appears to its best advantage (subject to the constraint that the weights must be universal). Consider the situation where x_{ij} represents the amount of input *i* used by DMU *j* and y_{rj} is the amount of output *r* produced by DMU *j*. An output-oriented DEA, assuming constant returns to scale (CRS), involves the solution of the following LP problem for each DMU *k* (Charnes *et al* 1978; 1979):

$$\text{Max } \phi_k + \varepsilon \sum_{r=1}^{s} s_r + \varepsilon \sum_{i=1}^{m} s_i \qquad (2)$$

Subject to

$$\phi_k y_{rk} - \sum_{j=1}^{n} \lambda_j y_{rj} + s_r = 0 \qquad r = 1,...,s$$

$$x_{ik} - \sum_{j=1}^{n} \lambda_j x_{ij} - s_i = 0 \qquad i = 1,...,m$$

$$\lambda_j, s_r, s_i \geq 0 \quad \forall j = 1,...,n; r = 1,...,s; i = 1,...,m$$

DMU *k* is efficient if $1/\phi_k = 1$ and the slacks (s_r and s_i) are zero $\forall r = 1,...,s$ and $\forall i = 1,...,m$. The CRS assumption can be relaxed by the inclusion of the additional constraint $\sum_{j=1}^{n} \lambda_j$ (Banker *et al* 1984).

The advantages and disadvantages of DEA are well-known and will be discussed here only briefly (Worthington 2001 and Johnes 2004 provide detailed overviews). Since DEA, in calculating the efficiency score, essentially computes the value of a distance function, it has all the advantages of the distance function approach: it can handle multiple outputs and multiple inputs; it does not assume any specific behavioural assumptions of the firm; it makes no assumption regarding the distribution of efficiencies; and it requires no *a priori* information regarding the prices of either the inputs or the outputs. Furthermore, technically inefficient DMUs are provided with information regarding realistic (since they are currently being observed elsewhere in the sector) input and output targets which, if achieved, would allow them to become efficient. These have to be weighed against the drawbacks: the deterministic nature of the method means that stochastic errors (caused, for example, by omitted variables, and errors of measurement in the inputs and outputs) will contaminate the efficiency scores. In addition, DEA can be sensitive to the number of inputs and outputs and the number of DMUs included in the analysis. Sensitivity checks are therefore essential.

There is a long tradition of using DEA to measure the technical efficiency of HEIs. Studies have fallen into two main groups: those which have examined the efficiency of a particular department or programme (Tomkins & Green 1988; Beasley 1990;1995; Johnes & Johnes 1992; 1993; Madden *et al* 1997; Haksever & Muragishi 1998; Coelli *et al* 1998; Korhonen *et al* 2001; Johnes 2006b), and those which have examined the performance of the entire HEI (Ahn *et al* 1989; Ahn & Seiford 1993; Breu & Raab 1994; El Mahgary & Lahdelma 1995; Athanssopoulos & Shale 1997; Ng & Li 2000; Avkiran 2001; Johnes 2006a). By definition, a set of DMUs included in a DEA should be a set of identical production units, and this therefore provides justification for performing the analysis at subject or department level. There is no doubt, however, that a clearer picture of an HEI's overall efficiency is gained from an institution level DEA than from an analysis of just one component of the institution, and this is the advantage of an institution level DEA.

Two alternative approaches have been taken in a small number of empirical studies: to evaluate the performance of all departments within one university (Arcelus & Coleman 1997; Friedman & Sinuany –Stern 1997), and to analyse the performance of higher education sectors across states or countries (Breu & Rabb 1994; Kocher *et al* 2001). The validity of these approaches seems particularly questionable on the grounds that the DMUs in each case are clearly not a homogenous set of producing units.

All these studies vary in the precise definitions of the variables used to reflect inputs and outputs. Most conclude that inputs can generally be classed as student inputs, staff inputs and capital inputs, while outputs can be divided into teaching and research output[4]. Some studies have focused on the efficiency of HEIs at producing

[4] Although it is generally agreed that HEIs produce social output (Cohn & Cooper 2004), this output is

either teaching only (Johnes 2006b) or research only (Ng & Li 2000), while others have attempted to measure efficiency in the joint production of the two outputs (Abbot & Doucouliagos 2003).

Technical efficiency scores in the department level analyses tend to be lower, on average, than those computed in HEI level studies. Mean technical efficiencies computed from department level studies vary as follows: 50 to 60% for UK economics departments (Johnes & Johnes 1992; 1993); around 70% in UK departments of chemistry and physics (Beasley 1990); 65 to 82% in Australian departments of economics (Madden *et al* 1997); 72% in economics research units in Finland (Korhonen *et al* 2001); and 82 to 87% in the administration sector of Australian universities (Coelli *et al* 1998). Evidence from HEI level studies suggests that mean technical efficiency varies from around 70 to 80% (Ahn & Seiford 1993; Ng & Li 2000) to well over 90% (Ahn *et al* 1989; Breu & Raab 1994; Athanassopoulos & Shale 1997; Avkiran 2001; Abbott & Doucouliagos 2003; Johnes 2006a; 2006b). The single cross country study (Kocher *et al* 2001) suggests, not surprisingly given the disparate nature of the DMUs, that mean technical efficiency is low (23% or 37% depending on whether CRS or VRS are assumed).

While the efficiency of China's HEIs have been the focus of a number of empirical studies, few of these use DEA as a tool of analysis, preferring instead to base their findings on single output to single input indices, such as cost per student (Ng & Li 2000; Liu 2001). Ng & Li (2000) use DEA in an attempt to examine the effectiveness of the education reforms of the mid-1980s in China by focusing on the research performance of 84 key Chinese HEIs from 1993 to 1995. Using three inputs and five outputs, the authors find mean efficiency in the Chinese higher education sector to be around 76-80% over the three year period. Variations in efficiency levels between the three geographical regions of China (coastal, Central & Western) are also found, but these results are mixed: the HEIs in the Central zone perform best, on average, in 1993 and 1995, but it is the Western zone which has the highest mean efficiency in 1994. Liu (2001), in contrast, performs a DEA of 312 Chinese universities in total (55 comprehensive and 257 engineering) using 14 inputs and 3 outputs. Efficiency is found to be very high amongst the comprehensive universities

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generally not incorporated into efficiency studies as there are no adequate measures for it.

with nearly 90% achieving an efficiency score of 1, compared to around 66% of the engineering universities.

3. Data

The data for this analysis were obtained from the netbig Chinese university rankings (www.netbig.com). The netbig ranking is an unofficial one, and is available for 6 consecutive years, the most recent one being the 2005 ranking (which is based on data for 2004). Changes in the universities which comprise the sector (the rapid growth of the sector is clear from figure 1) and variations in the way the data are reported make it difficult to obtain a series of consistent data. The present study therefore uses data from only the last two published rankings (2005 and 2004). These are based on the data for 2004 and 2003, respectively. While there are currently more than 1500 HEIs in the Chinese higher education sector, complete data are only available for a small subset of around 115 HEIs for which it is possible to derive indicators relating to inputs (labour and capital) and research outputs. All variables are indexed so that the highest possible value on a particular variable is 100. While it would be more satisfactory to have the original data (which are not reported by netbig), the indexing of the variables is not considered a problem since DEA is insensitive to the units in which inputs and outputs are measured. There are no satisfactory measures of teaching outputs and so this study focuses only on the research efficiency of the top 115 universities in China.

Six inputs are included in the analysis. Staff time is measured using a measure of the full-time staff to student ratio (STAFFT), while the quality of the staff input is reflected by the percentage of the faculty with associate professor position or higher (STAFFQ). These are similar to measures used in previous empirical studies (Breu & Raab 1994). Since research can be produced in association with postgraduate students, an index measuring the proportion of all students who are postgraduates (PG) is also included. Research funding is measured using research expenditure (FUNDS)[5] while capital inputs are measured using two variables: BOOKS is an index of library books (derived from an unweighted average of the indexes formed from total and per student numbers), and BLGD is an index of the area of the buildings. Three variables are

[5] This is constructed using both per person and total expenditure measures and is standardized across broad subject areas.

included to reflect outputs. An index of research output[6] per person (RESPP) is included to reflect research activity, while an index of volume of research output (RES), and an index of the prestige[7] of the HEI (REPUT) are included to capture the impact of research activity (These are similar to measures used by Korhonen *et al* 2001). The descriptive statistics of the various input and output indexes are presented in table 4.

The inclusion of REPUT is open to debate. Unlike the other measures of research output, it is a subjective measure based on people's opinions (Breu & Raab 1994). Moreover, it is likely to be based on impressions of past rather than current research activity and is open to inaccurate measurement of research output because of a possible halo effect. Thus, DEA models are run with and without REPUT in order to assess its impact on the results. Table 5 summarises the DEA models which are run.

TABLE 4

TABLE 5

4. Results

4.1 Technical efficiency

The results of applying an output-oriented DEA with variable returns to scale to the two years of data are summarised in table 6. It should be noted that results across the two years of the study are remarkably stable[8]. The first point to note is that the definition of the model makes a considerable difference to the mean efficiency derived. Models which include the variable REPUT as an output provide a mean efficiency of around 91% in both years of the study, with a minimum efficiency of 62% in 2004 and 70% in 2005. When REPUT is not included in the model, however, the mean efficiency varies around 55% to 65% in both years and the minimum is

[6] Research achievement is measured using data derived from the following sources: the Science Citation Index; the Engineering Index; the Index to Science and Technology Proceedings; the Social Science Citation Index; the Arts and Humanities Citation Index; the Statistics of Chinese Technical Thesis and Quotation Data Base; and the Social Science Quotation Data Base of China. Data from these sources are weighted (in the order that they appear) and standardized by broad subject area.

[7] This index measures the academic reputation of the HEI as perceived by survey respondents including academy fellows, scholars, education experts and school presidents. The experts are asked to consider the reputation of HEIs based on various aspects including academic impact and student quality and performance.

[8] For the 109 units included in both years, the rank correlation coefficients between corresponding models (for 2004 and 2005) all exceed 0.628.

below 5% in both cases. This is much lower than in an earlier study (Ng & Li 2000), but this study is not directly comparable with the present one since it is based on a smaller sample and data from a time period prior to the rapid expansion.

TABLE 6

Since the levels of efficiency are sensitive to the inclusion or otherwise of REPUT, it is particularly important to establish whether the rankings are similarly affected. Table 7 provides the rank correlation coefficients between the efficiencies of the different models, and it is clear that while efficiency levels vary, rankings remain remarkably stable in both years of the study with Spearman's correlation coefficient exceeding 0.61 for all pairs of models.

TABLE 7

4.2 Confidence intervals for the efficiencies

Having established that efficiency varies considerably (at best it varies from around 70%-100%, and at worst, it varies from less than 5% to 100%), the question remains: is the range of efficiency scores sufficient to indicate significant differences between the HEIs in terms of their performance? This can be resolved by using bootstrapping procedures (Simar & Wilson 2004), which allow us to derive the 95% confidence intervals for the efficiencies of the HEIs in the sample. The 95% confidence intervals[9] and the associated efficiency scores are plotted for model 1 in figure 3 using the 2004 data. The figure clearly indicates that there are significant differences between the best and worst performing colleges, but that the middle performing institutions (around 30%) cannot be distinguished in terms of their performance. It can therefore be concluded that the top 45% of HEIs are significantly more efficient than the lowest 25% of HEIs. These results are representative of all the models (including ones where REPUT is not an output).

This is a noteworthy result since it is derived from an analysis of efficiency in just over 100 of the top universities. Such significant differences in performance in this small subset of universities suggest that there must be huge differences in the efficiency levels of the population of over 1500 universities, and they therefore merit

[9] The procedure for estimating the confidence intervals can be found in Johnes (2006a). The programme CIDEA (Johnes 2004) has been used to derive the confidence intervals. A bandwidth of h = 0.02 is used to derive the plots but alternative values of the bandwidth do not alter the conclusions derived.

further investigation. There are clear differences between regions in their level of economic development, and this in turn may affect the efficiencies of the universities located within them. Source of funding has been shown to affect efficiency in higher education in US states (Robst 2000), and hence it is worth exploring whether source of funding is important in determining differences in performance in Chinese higher education. Finally, Chinese universities differ in the degree to which they specialise, and whether or not this affects efficiency warrants further investigation. These three factors will be examined for their possible effect on efficiency in the remainder of this section.

4.3 Differences in efficiency between universities: possible explanations

The sample universities are split into groups on the basis of three separate criteria: by the region of their location i.e. in the coastal, Central or Western region of China; by whether they are centrally funded (by the MOE) or whether funds come from the regional level; and by whether they are a comprehensive or specialist university. The results of analysing the efficiencies (of models 1 and 5 only, since these are representative of all the models) on the basis of these three criteria are displayed in tables 8, 9 and 10.

TABLE 8

With regard to region, and in contrast to the mixed results obtained in Ng & Li (2000), it is consistently the case that mean efficiency is lowest in the Western region than in the other two regions of China. This is true of both years of study. Although the difference is not significant at conventional levels of significance, it is sufficient to cause concern: The under-developed Western region may lag behind its more developed neighbours even more if its HEIs continue to perform less efficiently than those in the Central and coastal regions.

TABLE 9

Turning to the division of the universities by whether or not they receive their funds centrally, the results are mixed and depend on DEA model. When REPUT is included as an output variable, there is no significant difference between subgroups. However, when REPUT is not included as an output variable, there is a strong significant difference between subgroups, with universities which are not administered centrally having a higher mean efficiency (around 70%) than universities which receive their funds directly from the MOE (around 50-60%). This difference is significant at the 5% significance level for both years of the study.

TABLE 10

The most conclusive finding from this section can be seen in table 10 from which it is apparent that comprehensive universities achieve higher levels of efficiency than do specialist institutions. This is true of both years and both models, and the difference is significant in most cases.

5. Conclusions

There are few empirical studies of the efficiency of the Chinese higher education sector, and none of these is based on recent data covering the period of rapid expansion experienced in the twenty first century. This study therefore attempts to fill this gap and to highlight areas which should be investigated further in future empirical studies. This study applies six DEA models to a sample of around 115 top Chinese HEIs in an attempt to measure the efficiency of Chinese HEIs in producing research. The analysis shows that mean efficiency in Chinese higher education varies between 55% and 90% depending on whether or not the subjective measure of an HEI's reputation is included as an output (mean efficiency being lower when the reputation measure is not included in the analysis). Although the level of efficiency of HEIs is clearly sensitive to the inclusion of the reputation variable, the ranking of HEIs is not.

An application of bootstrapping procedures to derive the confidence intervals of the Chinese HEIs demonstrates that there are significant differences between the best and worst performing HEIs, and only 30% of the middle performing universities cannot be significantly distinguished on the basis of their performance. This is true whether or not the reputation measure is included in the model.

An analysis of whether the significant differences between HEIs is associated with either geographical location, source of funding or type of university produces some interesting results. The HEIs in the Western region consistently have lower mean efficiency than those in either the coastal or Central regions. While the difference is not significant, it is worrying that a region which is already underdeveloped may suffer further because the performance of its HEIs is not as efficient as those in the better developed Central and coastal regions. The mean efficiency of HEIs administered regionally is significantly higher than that for HEIs which are administered centrally, but only in the case when the reputation variable excluded from the analysis. This may be grounds for encouraging further decentralisation of higher education funding in China. Finally, comprehensive universities appear to outperform the specialist institutions.

The analysis has highlighted the need for reliable objective measures of both research and teaching outputs of Chinese HEIs. There is some suggestion of differences in efficiency on the basis of both regional location and level of administration. These results are not conclusive and require further investigation. There does seem to be evidence, however, that performance levels between the best and worst HEIs is highly significant, and the possible characteristics which determine performance therefore need to be investigated further.

Table 1: Phases of the development of higher education in PRC, 1949-2001

Phase	Characteristics	Admission policy and criteria	Management and funding
1951-57	Soviet model.	NCEE & political criteria.	MHE established. Central planning. No tuition fees.
1958-59	Universal access to higher education.	NCEE & social criteria	MHE abolished. Central planning. No tuition fees.
1961-65	Education for political and economic purposes.	NCEE & social criteria	MHE re-introduced. Central planning.
1966-76	Education for political purposes.	Political criteria only (NCEE discontinued).	Universities attended, managed and reformed by workers, peasants and soldiers. System of 'Gong-nong-bin Daxue' (University of Worker-Framer-Soldier).
1977-84	Education for national economic development	NCEE & political criteria (social criteria removed)	Experimentation with decentralisation of management & finance. No tuition fees.
1985-96	Education for the development of science and technology and to provide manpower for a socialist market economy	Standardised NCEE. No social criteria, but some age and marital status bars	Decentralised management & finance continued. Dual system of tuition fees (state versus non-state-plan students, the latter paying fees).
1997-present	Training for socialist market economy. Universities transferred from state owned entities to market oriented enterprise.	NCEE. No age or marital status bars since 2001. Social bars caused by charging tuition fees, but minorities get easier access.	Further decentralisation and diversification of management and finance. Tuition fees charged to all students.

Notes: NCEE = National College Entrance Examination; MHE = Ministry of Higher Education
Adapted from Huang 2005

Table 2: Educational funds in regular institutions of higher education in China, 1996-2002 (10,000 yuan)

Year	Total	Government Appropriation for Education		Funds of Social Organisations and Citizens for running Schools	Donations and Fund-Raising for Running Schools	Tuition and Miscellaneous Fee	Other Educational Funds
			Budgetary				
1996	3267929	2625524	2299718	5667	36961	446237	153539
%	100	80.34	70.37	0.17	1.13	13.66	4.7
1997	3904842	3057455	2644494	6682	58471	578857	203377
%	100	78.3	67.72	0.17	1.5	14.8	5.2
1998	5493394	3567538	3350701	15577	114640	731134	1064505
%	100	64.94	61	0.28	2.1	13.31	19.38
1999	7087280.0	4431601.2	4226112.2	32565.1	161676.6	1207835.5	1253601.6
%	100	62.53	59.63	0.46	2.28	17.04	17.69
2000	9133504	5311854	5044173	65941	151828	1926109	1677772
%	100	58.16	55.23	0.72	1.66	21.1	18.37
2001	11665761.8	6328003.5	6060683.1	181992.7	172774.7	2824417.1	2158573.8
%	100	54.24	51.95	1.56	1.48	24.2	18.5
2002	14878590	7521463	7243459	331363	278253	3906526	2840985
%	100	50.55	48.68	2.23	1.87	26.3	19.1

Data Source: China Statistical Yearbook 1997-2004.

Table 3: Regional statistics

Region	No. of HEIs	No. of FT teachers in higher education	Population in 0000s	GDP in 100 million RMB
	2003	**2003**	**2003**	**2003**
a) Central zone				
Jilin	40	21824	2704	2522.62
Shanxi	45	20224	3314	2456.59
Heilongjiang	54	28525	3815	4430.00
Jiangxi	54	20560	4254	2830.46
Henan	71	33045	9667	7048.59
Anhui	73	24744	6410	3972.38
Hunan	73	33229	6663	4638.73
Hubei	75	46947	6002	5401.71
Mean for Central zone	**60.63**	**28637.25**	**5353.63**	**33301.08**
b) Coastal zone				
Hainan	11	2699	811	670.93
Tianjin	37	15553	1011	2447.66
Fujian	39	16171	3488	5232.17
Shanghai	56	24387	1711	6250.81
Zhejiang	64	29508	4680	9395.00
Liaoning	70	38086	4210	6002.54
Beijing	73	41904	1456	3663.10
Guangdong	77	39897	7954	13625.87
Hebei	83	33617	6769	7098.56
Shandong	85	45457	9125	12435.93
Jiangsu	94	49810	7406	12460.83
Mean for Coastal zone	**62.64**	**337089**	**4420.09**	**79283.4**
c) Western zone				
Tibet	4	972	270	184.50
Ningxia	12	3415	580	385.34
Qinghai	12	2769	534	390.21
Xinjiang	26	10913	1934	1877.61
Inner Mongolia	27	12153	2380	2150.41
Gansu	31	12274	2603	1304.60
Chongqing	34	15790	3130	2250.56
Guizhou	34	11775	3870	1356.11
Yunnan	34	12236	4376	2465.29
Guangxi	45	14106	4857	2735.13
Shaanxi	57	30696	3690	2398.58
Sichuan	62	31372	8700	5456.32
Mean for Western zone	**31.50**	**158471**	**3077.00**	**22954.66**
Overall mean	**50.06**	**23376.06**	**4141.10**	**4372.23**

Notes: 1. Beijing, Tianjin, Shanghai and Chongqing are four municipalities in China reporting directly to the central government. A municipality is similar to a province in China's administrative structure.

2. Inner Mongolia, Guangxi, Tibet, Ningxia and Xinjiang are five autonomous regions in China. They enjoy more autonomous power than provinces.

3. The others are 22 provinces. Hong Kong, Macao and Taiwan are not included.

Data Source: China Statistical Yearbook 2004.

Table 4: Descriptive statistics for the inputs and outputs

	Min	**Mean**	**SD**	**Min**	**Mean**	**SD**
Inputs	2003			2004		
STAFFT	27.16	61.26	14.58	20.80	44.79	12.88
STAFFQ	37.34	65.46	11.61	25.30	61.31	14.28
PG	7.21	32.81	17.21	9.50	39.54	19.33
FUNDS	0.99	24.74	18.20	1.00	25.37	19.15
BOOKS	10.43	41.76	20.27	10.40	33.40	16.33
BLDG	8.93	27.65	14.84	10.40	33.59	15.78
Outputs						
RES	0.06	9.76	14.88	0.00	10.41	15.34
RESPP	0.22	15.44	16.64	0.20	15.32	16.88
REPUT	40.00	59.76	13.82	40.00	59.88	13.85
n	**114**			**116**		

Note: The maximum is 100 except in the case of BLDG where the maximum is 92.80 for 2004 and 82.25 for 2003 (100 having been assigned to an HEI outside the sample). The number of HEIs which appear in both 2003 and 2004 is 109.
Source: www.netbig.com 2004 and 2005

Table 5: Variables included in each DEA model

	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**
Inputs						
STAFFT	X	X	X	X	X	X
STAFFQ	X	X	X	X	X	X
PG	X	X	X	X	X	X
FUNDS	X	X	X	X	X	X
BOOKS	X	X	X	X	X	X
BLDG	X	X	X	X	X	X
Outputs						
RES	X	X			X	
RESPP	X		X		X	X
REPUT	X			X		X

Table 6: Summary of DEA results

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
2003						
Mean	91.50 (91.50)	55.11 (54.37)	60.58 (59.99)	90.69 (90.66)	63.85 (63.33)	91.42 (91.41)
Min	62.08	2.47	3.50	62.08	3.50	62.08
SD	9.33	35.36	33.02	9.29	32.91	9.36
% efficient	39.7	28.1	32.2	33.9	34.7	39.7
2004						
Mean	91.50 (91.34)	55.42 (53.41)	57.57 (56.15)	90.15 (89.95)	63.58 (62.00)	91.24 (91.10)
Min	70.55	3.23	4.01	70.55	4.44	70.55
SD	9.28	35.27	32.62	9.35	32.30	9.28
% of HEIs which are 100% efficient	37.2	26.4	25.6	28.9	31.4	34.7

Note: Figures in parentheses denote values for the 109 HEIs which appear in both years of the data.

Table 7: Spearman's rank correlations between DEA models

	Model 1	Model 2	Model 3	Model 4	Model 5
Model 2	0.807				
Model 3	0.738	0.827			
Model 4	0.882	0.698	0.616		
Model 5	0.811	0.945	0.917	0.654	
Model 6	0.976	0.774	0.748	0.912	0.781

Table 8: Summary of efficiency by region

a) Model 1	**Coastal**	**Central**	**Western**	**F**	**Kruskall-Wallis**
2003					
Mean	91.86	92.38	88.47	1.01	1.66
SD	9.39	8.35	10.52	df=2,111	df=2
n	72	26	16		
% efficient	45.8	42.3	25.0		
2004					
Mean	92.42	91.06	87.57	1.77	5.07**
SD	33.11	31.65	34.00	df=1.77	df=2
n	72	26	16		
% efficient	41.7	34.6	18.8		

b) Model 5	**Coastal**	**Central**	**Western**	**F**	**Kruskall-Wallis**
2003					
Mean	65.76	65.22	53.02	1.01	2.82
SD	33.11	31.65	34.00	df=2,111	df=2
n	72	26	16		
% efficient	46.1	32.0	13.3		
2004					
Mean	66.66	64.02	47.27	2.31	4.20
SD	32.70	31.45	28.46	df=2,113	df=2
n	76	25	15		
% efficient	38.2	28.0	13.3		

* = significant at 5%; ** = significant at 10%

Table 9: Summary of efficiencies by administration type

a) Model 1	Central	Regional	F	Kruskall-Wallis
2003				
Mean	91.99	90.54	0.606	0.027
SD	7.81	11.87	df=1,112	df=1
n	76	38		
% efficient	35.5	55.3		
2004				
Mean	91.40	91.69	0.026	0.427
SD	8.85	10.20	df=1,114	df=1
n	77	39		
% efficient	27.6	55.3		

b) Model 5	Central	Regional	F	Kruskall-Wallis
2003				
Mean	59.23	73.09	4.64*	5.33*
SD	31.75	33.66	df=1,112	df=1
n	76	38		
% efficient	33.8	48.7		
2004				
Mean	58.46	73.70	6.02*	6.13*
SD	30.88	33.03	df=1,114	df=1
n	77	39		
% efficient	24.7	48.7		

* = significant at 5%; ** = significant at 10%

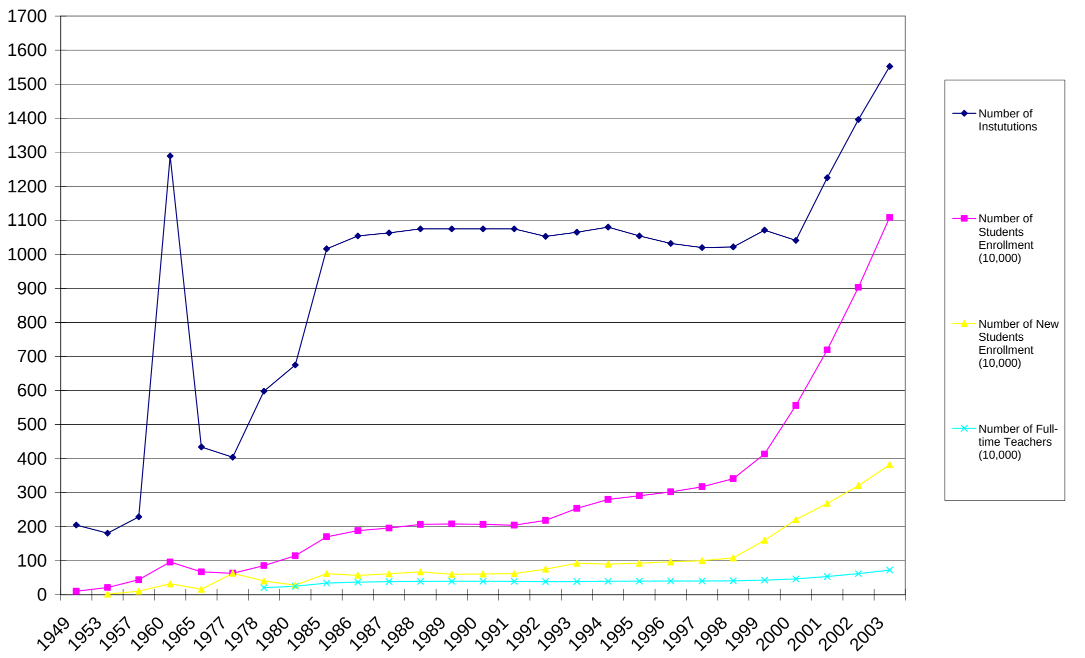
Table 10: Summary of efficiencies by university type

a) Model 1	**Comprehensive**	**Specialist**	**F**	**Kruskall-Wallis**
2003				
Mean	94.77	90.12	6.19*	4.58
SD	6.56	10.01	df=1,112	df=1
n	34	80		
% efficient				
2004				
Mean	93.17	90.72	1.77	0.82
SD	8.36	9.63	df=1,114	df=1
n	37	79		
% efficient				

b) Model 5	**Comprehensive**	**Specialist**	**F**	**Kruskall-Wallis**
2003				
Mean	73.94	59.56	4.70*	4.37*
SD	25.98	34.71	df=1,112	df=1
n	34	80		
% efficient				
2004				
Mean	72.65	59.33	4.41*	4.12*
SD	27.04	33.82	df=1,114	df=1
n	37	79		
% efficient				

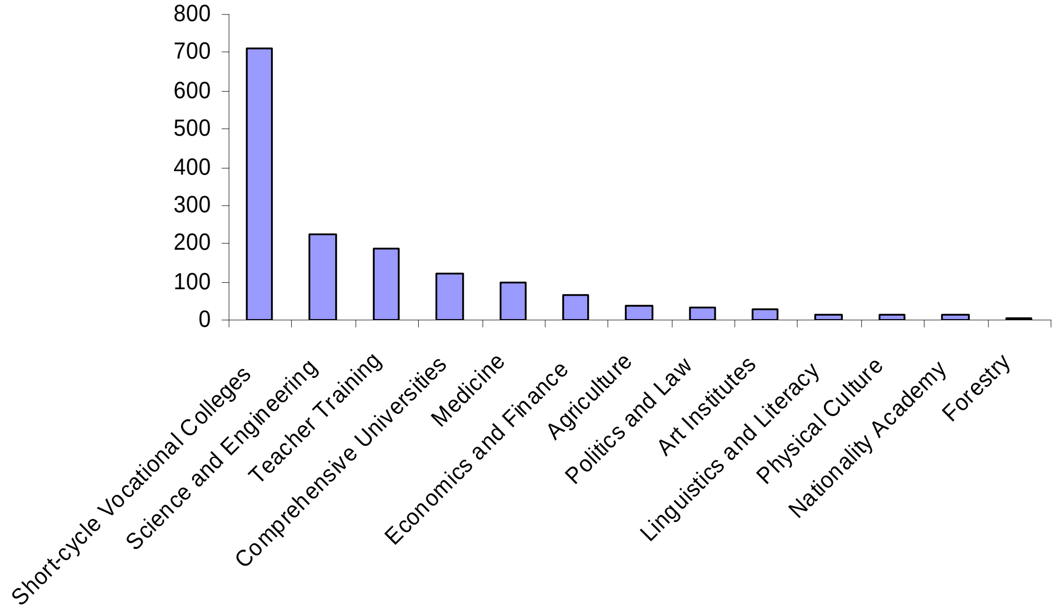
* = significant at 5%; ** = significant at 10%

Figure 1: Changes in HEI, teacher and student numbers in regular higher education in China,1949-2003



Data Source: China Statistical Yearbook 2003. China Education Yearbook 1949-1981.

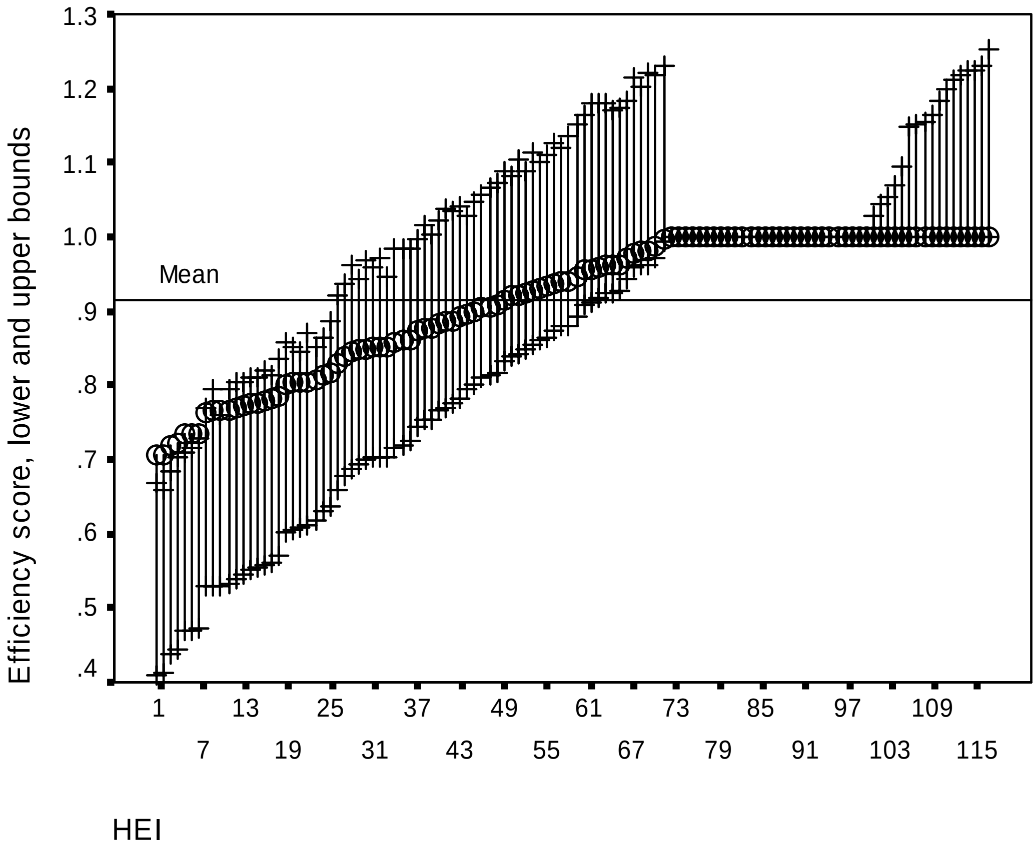
Figure 2: Number of HEIs by type



Data Source: China Statistical Yearbook 2003.

This paper does not mention the university efficiency of 13 categories in the result part.

Figure 3: Efficiency scores and confidence intervals – model 1 2004



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