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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 in the production of research of 109 Chinese regular universities in 2003 and 2004. Output variables measure the impact and productivity of research; input variables reflect staff, students, capital and resources. Mean efficiency is just over 90% when all input and output variables are included in the model, and this falls to just over 80% when student-related input variables are excluded from the model. The rankings of the universities across models and time periods are highly significantly correlated. Further investigation suggests that mean research efficiency is higher in comprehensive universities compared to specialist universities, and in universities located in the coastal region compared to those in the western region of China. The former result offers support for the recent merger activity which has taken place in Chinese higher education.

1. 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 (e.g. cost minimization or profit maximization); 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 (Abbott & Doucouliagos, 2003; Ahn, Arnold, Charnes & Cooper, 1989; Arecelus & Coleman, 1997; Athanassopoulos & Shale, 1997; Avkiran, 2001; Breu & Raab, 1994; Coelli, Rao & Battese, 1998; El Mahgary & Lahdelma, 1995; Flegg & Allen, 2007; Friedman & Sinuany-Stern, 1997; Haksever & Muragishi, 1998; Johnes, 2006a; Worthington & Lee, 2008), little work has been done on measuring the efficiency in producing any of the outputs of higher education institutions (HEIs) in China. Recent studies by Ng and Li (2000) and Liu (2001) are exceptions but are based on data for the 1990s. A more up-to-date analysis of the Chinese higher education sector is therefore overdue.

It is generally agreed that the main functions of HEIs are teaching and research. Chinese HEIs have been expanding in both these activities in recent years. The 15.5million students in enrolled in regular HEIs in China in 2005 represented an increase of 181% compared to 2000 (China Statistical Yearbook 2006). Funding for education in regular HEIs in China has risen by 133% between 2000 and 2004 (China Statistical Yearbook 2002–2006). In 2005, 978,610 postgraduates were enrolled in Chinese HEIs (of which

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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–Farmer–Soldier).
1977–84	Education for national economic development	NCEE & political criteria (social criteria removed)	Experimentation with decentralization 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 decentralization 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.

almost 20% were studying for a doctorate) and this represented an increase of 225% compared to 2000 (China Statistical Yearbook 2006). In addition, patents applied for by HEIs rose from 1942 in 2000 to 14,643 in 2005 (www.sts.org.cn/), an increase of 654%. With such rapid expansion in all aspects of activity undertaken by HEIs, and given the allocation of public resources 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 the technical efficiency in the production of research of 109 top Chinese regular[1] universities based on data for 2003 and 2004, i.e. during the period of rapid expansion.

The paper is in 6 parts of which this is the first. Section 2 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 3, while the data and the models are presented in Section 4. The results of the analysis are in Section 5, while conclusions which can be drawn from the study are presented in the final section.

2. Chinese higher education[2]

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.

In 1949, the Chinese higher education sector was very small with just 205 institutions (China Education Yearbook 1949), the majority of which were publicly owned. In addition, the geographical spread of institutions at that time was heavily biased towards the coastal areas of China. The Soviet model of higher education was adopted in order to meet the skill needs of the First Five-year Plan. Thus the higher education sector was restructured in order to fulfil these economic and political objectives. All institutions were scrutinised and many were reorganised into specialist institutions. Care was taken to ensure that any new institutions were evenly spread across the country. The comprehensive and key teachers' colleges remained under the control of the Ministry of Higher Education, but the specialist institutions were administered by central ministries corresponding to their specialization (e.g. Agricultural universities were administered by the Ministry for Agriculture). Thus, a specialist ministry set the programs of its specialist HEIs and recruited students according to the sector's needs; it also recruited its employees from the graduates of its HEIs. At the same time as the teaching function of higher education was being strengthened, however, the research function was being weakened, with research activity largely being undertaken in research institutions under the direct control of central government (Xue, 2006).

For three decades this highly centrally organised and closed system of higher education generally remained intact. But the inefficiencies of the closed system did not find favour in a climate of an increasingly market-oriented economy, and a less centralised and more competitive approach to the management and funding of the sector followed the reforms of 1985. Initially, progress was slow, but, in 1992, universities were informed that a greater proportion of their operating funds would derive from sources other than government: in the context of teaching, this meant sources such as tuition fees and finance from other sectors of the economy; in the context of research, universities would have to derive income from their research and development (R and D) activities and compete for research funding. At this time, the number of specialist ministries was reduced, and universities were removed from their control. Some of these went under local government control, others went under direct Ministry of Education

[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.
[2] Unless otherwise stated, the source of the material in this section is Xue (2006).

Table 2
Educational funds in regular HEIs 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	3,267,929	2,625,524	2,299,718	5667	36,961	446,237	153,539
%	100	80.34	70.37	0.17	1.13	13.66	4.7
1997	3,904,842	3,057,455	2,644,494	6682	58,471	578,857	203,377
%	100	78.3	67.72	0.17	1.5	14.8	5.2
1998	5,493,394	3,567,538	3,350,701	15,577	114,640	731,134	1,064,505
%	100	64.94	61	0.28	2.1	13.31	19.38
1999	7,087,280.0	4,431,601.2	4,226,112.2	32,565.1	161,676.6	1,207,835.5	1,253,601.6
%	100	62.53	59.63	0.46	2.28	17.04	17.69
2000	9,133,504	5,311,854	5,044,173	65,941	151,828	1,926,109	1,677,772
%	100	58.16	55.23	0.72	1.66	21.1	18.37
2001	11,665,761.8	6,328,003.5	6,060,683.1	181,992.7	172,774.7	2,824,417.1	2,158,573.8
%	100	54.24	51.95	1.56	1.48	24.2	18.5
2002	14,878,590	7,521,463	7,243,459	331,363	278,253	3,906,526	2,840,985
%	100	50.55	48.68	2.23	1.87	26.3	19.1
2003	17,543,468	8,405,779	8,074,148	603,015	256,375	5,057,307	3,220,992
%	100	47.91	46.02	3.44	1.46	28.83	18.36
2004	21,297,613	9,697,909	9,309,882	1,121,982	215,440	6,476,921	3,785,362
%	100	45.54	43.71	5.27	1.01	30.41	17.77

Data Source: China Statistical Yearbook 1997–2006.
Note: The following information is provided by the China Statistical Yearbook about the categories of funding. Government Appropriation for Education comprises both budgetary and non-budgetary categories. Budgetary Funds refer to education funding that is planned to be allocated to various schools and education institutions by central and local financial departments at various levels within a given year, which is within the State budgetary expenditure, including: appropriated funds for education, for science and research, for capital construction and others. Non-budgetary funds include: taxes and fees collected by governments at all levels that are used for education purposes; education fund for enterprise-run schools; income from school-run enterprises, work-study programme and social services that are used for education purpose. The remaining categories of funding are: funds of social organizations and citizens running schools; donations and fund-raising for running schools; tuition and miscellaneous fees. Funds which do not fall into these 5 categories are included in other educational funds.

(MOE) control, largely by amalgamating with existing HEIs already under the control of the MOE (indeed, the end of the twentieth century was a period of frenzied merger activity). By the end of the 1990s, Chinese HEIs had therefore attained a degree of financial and managerial freedom from central government in both teaching and research, and were opened up to market forces.

The effect of decentralization and the introduction to market forces into 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 45% in 2004 (China Statistical Yearbook 1997; 2006). 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.

Between 1985 and 1995, funds for research in Chinese universities deriving from the government fell from 75% to 43% (Xue, 2006). This has risen more recently, and in the three most recent years for which data are available (2004 to 2006), the percentage of funds derived from government has remained constant at around 55% (see Table 3).

The effect of these policies on student, teacher and institution numbers are fully apparent from Fig. 1. Student and HEI numbers noticeably increased during the brief expansion of the 1960s [3], 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. The effect of higher education policies on research activities is illustrated in Fig. 2 from which a surge in activity (measured by both postgraduate numbers, patent applications and publications of science and technology papers) can be seen particularly in the latter years (1998–2006).

It is not surprising, given its history of specialization of institutions, that China's current higher education sector is so 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 Fig. 3). The remaining universities are classified on the basis of their specialist subject, the largest category being short-cycle[4] 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.

Despite efforts in the early years of the PRC to improve the geographical spread of HEIs (Xue, 2006), there is substantial diversity in 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.[5] These regions can be grouped into three broad zones of economic development: the coastal region

[3] The increase in institution numbers was particularly sharp and this stems from the proliferation of specialist institutions during this period; some of this was contrived through the division of comprehensive institutions into smaller specialist components.
[4] Short-cycle courses are tertiary level vocational courses which last 2 to 3 years compared to a typical undergraduate course which lasts 4 years (Huang, 2005).
[5] Hong Kong, Macao and Taiwan are not included in this count.

Table 3
R & D expenditure in colleges and universities in China by source, 2004–2006 (100 million yuan)

Year	Total	Government	Business	Foreign	Other
2004	200.9	108.8	74.5	2.6	14.9
%	100	54.16	37.08	1.29	7.42
2005	242.3	133.1	88.9	4.0	16.3
%	100	54.93	36.69	1.65	6.73
2006	276.8	151.5	101.2	3.8	20.3
%	100	54.73	36.56	1.37	7.33

Source: www.sts.org.cn/.

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 decentralization 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 4 presents statistics on undergraduate enrolment numbers, teacher numbers, patent applications and R and D expenditure by broad economic zones and by individual region. Per capita GDP is also provided. Not surprisingly, the coastal zone is the most affluent region in terms of its mean per capita GDP, with the central and western regions lagging well behind. The central zone, however, is similar to the coastal region in terms of its teacher and patent applications numbers. The western zone lags

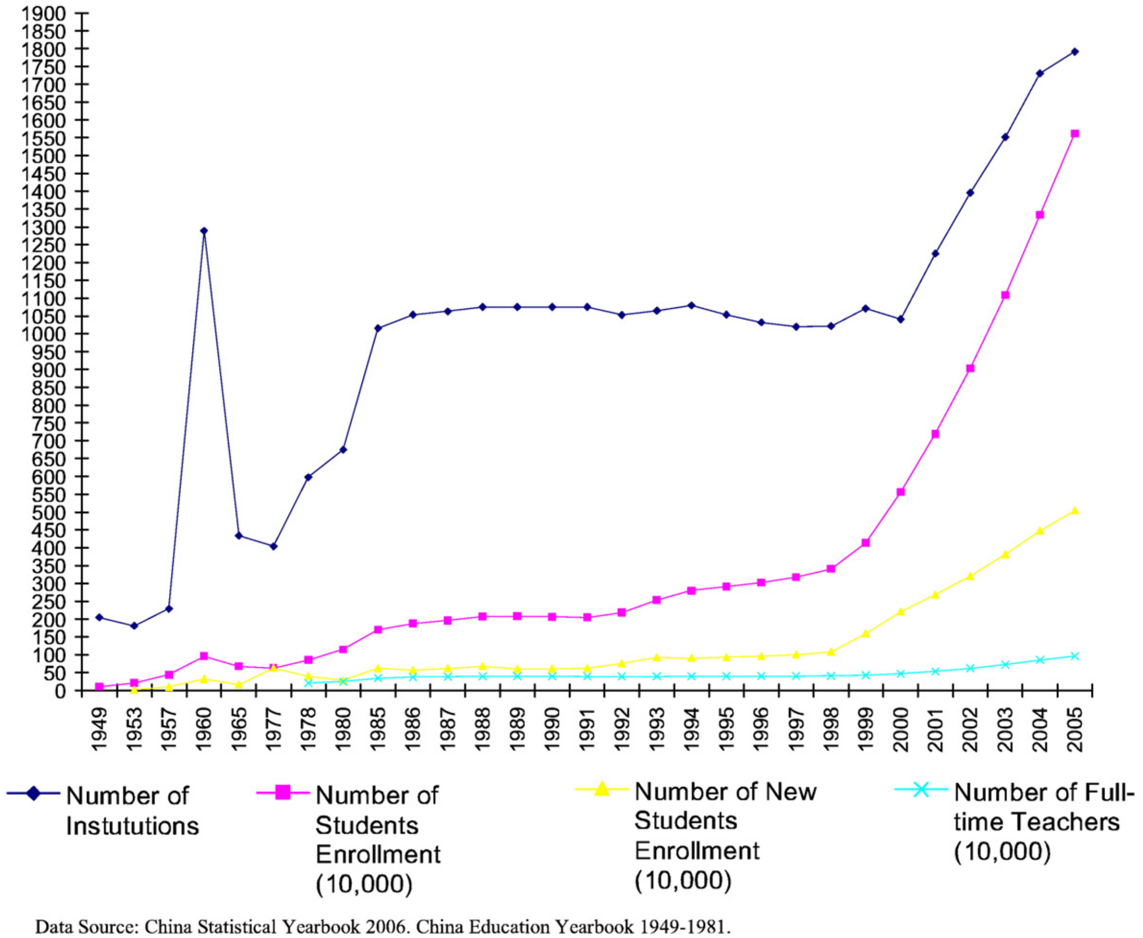

Fig. 1. Changes in HEI, teacher and student numbers in regular higher education in China, 1949–2003.

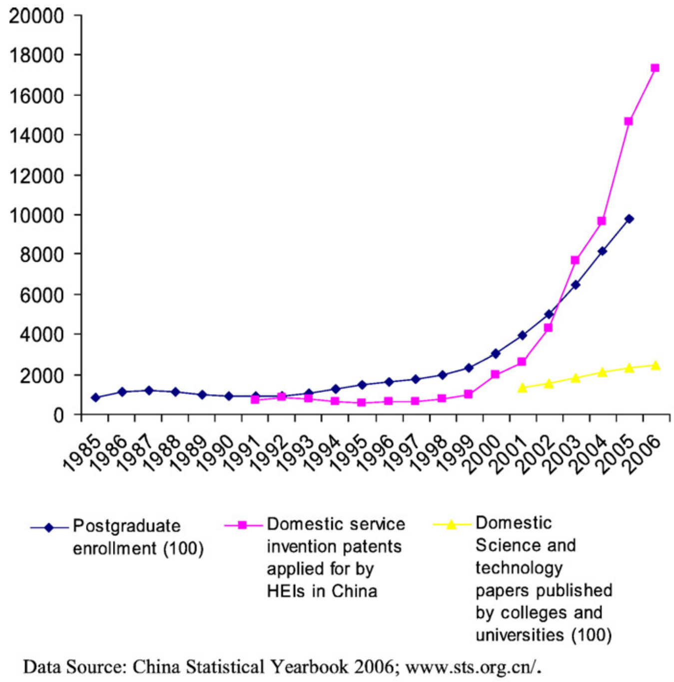

Fig. 2. Postgraduate, patent and Science and Technology publication numbers in HEIs in China, selected years 1985–2006.

behind the other two more affluent regions in terms of undergraduate enrolment, teacher and patent application numbers (China Statistical Yearbook 2006).

3. Methodology

Technical efficiency is defined using Farrell's (1957) approach: by comparing a HEI's actual production point with the point which might have been achieved had it operated on the frontier. In Fig. 4, HEIs A, B and C produce at points P^A, P^B and P^C, respectively. F^{CRS} represents the constant returns to scale (CRS) production frontier showing the efficient levels of output, y, which can be produced from a given level of input, x. Technical efficiency is measured as the ratio of $0y_A/0y_A^{CRS}$ which is in fact the CRS

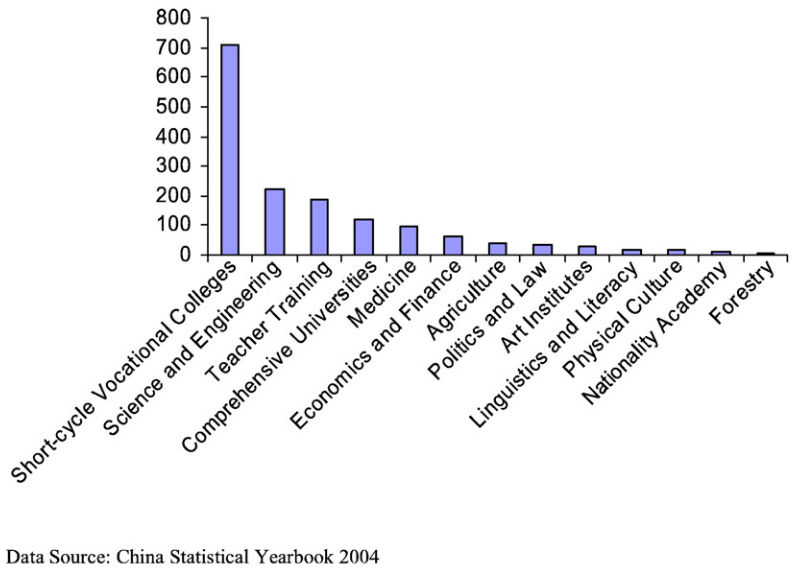

Fig. 3. Number of HEIs in China by type, 2003.

Table 4
Regional statistics 2005

Region	Ratio of total undergraduate enrolment in regular HEIs to number of regular HEIs	Ratio of number of FT teachers in higher education to number of regular HEIs	Ratio of number of patent applications in universities and colleges to number of regular HEIs	Ratio of R & D expenditure (in million yuan) to number of regular HEIs	Per capita GDP (in 100 million yuan)
a) Central zone					
Shanxi	6898.92	472.24	33.64	44.58	1245.76
Jilin	9255.95	639.30	93.20	89.32	1332.94
Heilongjiang	8723.66	566.56	97.58	78.87	1442.80
Anhui	7272.53	400.47	43.41	56.67	878.29
Jiangxi	9643.07	575.93	42.01	42.54	941.03
Henan	10,263.42	557.94	108.20	66.99	1128.72
Hubei	11,913.71	694.22	135.69	88.24	1141.88
Hunan	8116.76	486.80	94.23	47.85	1029.30
Mean for Central zone	1142.59	9011.00	549.18	81.00	64.38
b) Coastal zone					
Beijing	7120.39	633.96	293.14	496.23	1110.79
Tianjin	7894.12	515.95	277.55	172.86	3545.18
Hebei	9000.07	496.48	74.43	68.49	1473.67
Liaoning	8675.67	578.42	206.21	164.08	1897.42
Shanghai	7631.38	545.60	564.50	359.31	5148.58
Jiangsu	10,173.64	590.65	305.36	236.67	2448.92
Zhejiang	9578.04	564.74	635.60	240.15	2743.54
Fujian	7679.17	459.45	178.49	101.13	1858.25
Shandong	11,831.15	652.89	291.26	197.07	2002.26
Guangdong	8575.35	531.93	708.04	239.02	2432.73
Hainan	4665.60	308.00	33.20	10.67	1080.40
Mean for Coastal zone	2340.16	8438.60	534.37	324.34	207.79
Western zone					
Inner Mongolia	6997.03	490.58	44.09	35.45	1632.67
Guangxi	6632.57	384.51	46.65	28.63	874.62
Chongqing	9530.37	576.69	178.86	91.43	1097.39
Sichuan	11,403.47	659.62	155.40	142.06	899.31
Guizhou	6081.00	422.15	65.47	32.35	530.58
Yunnan	5788.34	382.25	58.09	48.41	780.42
Tibet	4744.75	296.75	25.50	7.50	906.90
Shaanxi	9263.10	595.33	57.86	128.33	988.08
Gansu	6953.30	448.97	53.30	59.39	745.56
Qinghai	2977.55	277.36	19.64	27.27	1000.59
Ningxia	3742.31	312.23	39.69	24.62	1016.95
Xinjiang	6060.47	424.43	61.70	21.33	1295.62
Mean for Western zone	980.72	6681.19	439.24	67.19	53.90
Overall mean	7906.03	501.37	162.00	111.21	1504.88

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 Sources: China Statistical Yearbook 2006; www.sts.org.cn/.

output distance function. The CRS assumption can be relaxed to allow for variable returns to scale (VRS). In Fig. 4, F^{VRS} represents the VRS production frontier, and technical efficiency is therefore measured as the ratio of $0y_A/0y_A^{VRS}$, which is the VRS output distance function.

The distance function approach to measuring efficiency is attractive in the context of efficiency measurement in higher education for a number of reasons: it can handle multiple outputs and multiple inputs; it does not assume any specific behavioural assumptions of the firm; and it requires no *a priori* information regarding the prices of either the inputs or the outputs.

The most common methods of estimating the distance functions required to evaluate these various measures of efficiency are data envelopment analysis (DEA) and stochastic frontier analysis (SFA). The advantages and disadvantages of these methods are well-known and will be discussed here only briefly (Johnes, 2004 provides a detailed overview). Both methods estimate a production frontier, but in the case of SFA the frontier is parametric, and hence it requires assumptions to be made regarding the distribution of efficiencies, the distribution of the stochastic errors, and the functional form of the production technology. The advantage of these assumptions is that it allows statistical inferences to be drawn from the results. But this is at the price of making what might be arbitrary assumptions about the true distributions and functional form.

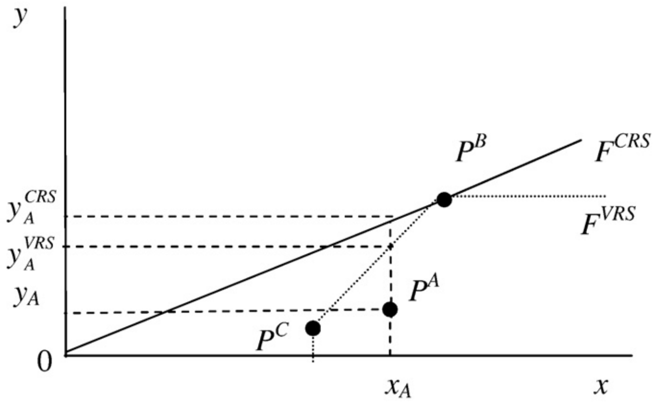

Fig. 4. An illustration of the distance function approach to measuring efficiency and productivity.

DEA is a non-parametric linear programming (LP) technique, and, as such, requires no assumptions. The estimates of technical efficiencies are therefore free of possible errors resulting from incorrect assumptions. Furthermore, technically inefficient firms or decision making units (DMU)s are provided by DEA 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. Consider, for example, 5 HEIs (A, B, C, D, E) producing 2 outputs, y_1 and y_2 from one input, x. Fig. 5 illustrates the DEA output-oriented efficiency frontier for these DMUs. University E lies inside the frontier, and the ray from the origin drawn through DMU E and extended through to the frontier which it meets at point E′ indicates that a DMU which was a combination of DMUs B and C could produce more of both outputs (given the input) than DMU E. DMUs B and C are therefore the peers which DMU E should seek to emulate in order to become efficient. Moreover, since DMU B lies closer to the hypothetical DMU E′, this DMU carries the greater weight in the combination of DMUs B and C to derive DMU E′.

The disadvantage of making no assumptions regarding the distributions is that statistical inferences cannot be drawn from the DEA results. In addition, 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 be incorporated in the efficiency scores. Finally, 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.

Perhaps the most attractive feature of DEA is that the weights assigned to each input and output are chosen to ensure that each DMU appears to its best advantage (subject to the constraint that the weights must be universal). This means that no unit can be penalised by taking an unorthodox production approach, as it might be by the imposition of a uniform set of weights across all units. Thus two efficient DMUs may look very different in terms of their input and output sets. This is important in the context of universities where freedom to set priorities is valued. SFA, in contrast, imposes the same input and output parameters on all observations (recent developments in SFA allow for a random parameters variant—see Johnes and Johnes (in press)—but this requires additional assumptions and therefore imposes considerable strain on the data). The wide diversity of units included in this

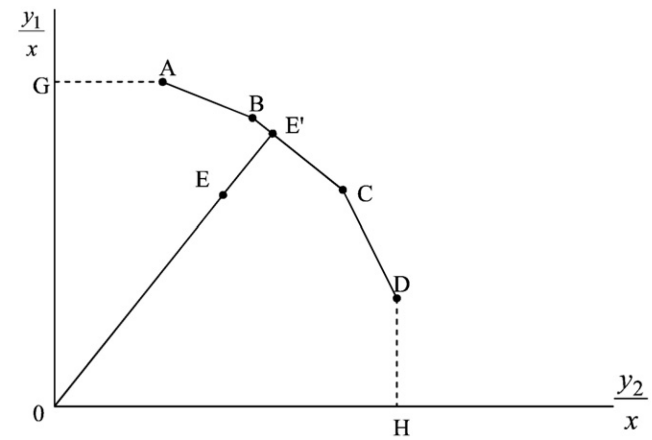

Fig. 5. Efficient peers in DEA.

analysis of Chinese higher education, and the multi-input, multi-output nature of the production specification, make DEA the technique of choice in the ensuing analysis. The LP equations required to solve both CRS and VRS DEA are standard and can be found in Coelli et al. (1998) for both the input- and output-oriented cases.

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, programme or activity (Beasley, 1990, 1995; Coelli et al., 1998; Haksever & Muragishi, 1998; Johnes, 2006b; Johnes & Johnes, 1992, 1993; Korhonen, Tainio & Wallenius, 2001; Madden, Savage & Kemp, 1997; Tomkins & Green, 1988), and those which have examined the performance of the entire HEI (Ahn et al., 1989; Ahn & Seiford, 1993; Athanassopoulos & Shale, 1997; Avkiran, 2001; Breu & Raab, 1994; El Mahgary & Lahdelma, 1995; Johnes, 2006a; Ng & Li, 2000). 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, department or activity level.

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, Luptácik & Sutter, 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.[6] Some studies have focused on the efficiency of HEIs at producing either teaching only (Johnes, 2006b) or research only (Beasley, 1990, 1995; 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% (Abbott & Doucouliagos, 2003; Ahn et al., 1989; Athanassopoulos & Shale, 1997; Avkiran, 2001; Breu & Raab, 1994; Johnes 2006a,b). The single cross country study 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 (Liu, 2001; Ng & Li, 2000). Ng and 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 research staff and funding as inputs, and publications data as outputs, the authors find mean research 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 and 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 to derive the teaching efficiency of 312 Chinese universities in total (55 comprehensive and 257 engineering). Inputs are based on staff and equipment data, while outputs are derived from data on undergraduate and postgraduate numbers. Efficiency is found to be very high amongst the comprehensive universities with nearly 90% achieving an efficiency score of 1, compared to around 66% of the engineering universities.

A study of the efficiency of Chinese HEIs in the context of expansion and marketization is clearly overdue. Like most HEIs, a typical Chinese university undertakes both teaching and research activities, and, ideally, any study of efficiency should evaluate performance in the joint production of both outputs. In reality finding appropriate data to reflect both activities is difficult, since appropriate data on both students (including their composition) and graduates (including their performance) are only published at sector level. This study, like Ng and Li (2000), but in contrast to Liu (2001), focuses on the research performance of Chinese universities. The study differs from Ng and Li (2000) by using an increased number of universities in the sample (109 compared to 84) and by updating the data (2003/04 compared to 1993–1995).

While this study only provides a partial analysis, the importance of establishing efficiency in the production of research should not be underestimated. Research has characteristics of a public good and there is therefore the potential for positive externalities from university research activity to spill over into other sectors of the economy. Indeed, recent work for the USA confirms long-standing results of a positive and significant relationship between research and innovative activity in the private sector (Anselin, Varga & Acs, 1997), and these are particularly strong in the electronics and instruments industries (Anselin, Varga & Acs, 2000). For historical reasons, there are strong linkages between universities and industrial enterprises in China (Xue, 2006)—these linkages emanate from the flow of both graduates and knowledge from HEIs to business—suggesting that spillovers from university research activity to industry in China will be particularly strong. Moreover, since the spillover effects are largest for industries located closest to the university research activity, the production of research by Chinese universities is a potentially vital tool for regional regeneration, and it is therefore crucial that research should be produced efficiently.

[6] Although it is generally agreed that HEIs produce social output (Cohn & Cooper, 2004), this output is generally not incorporated into efficiency studies as there are no adequate measures for it.

4. 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 9 consecutive years. Changes in the universities which comprise the sector (through growth of the sector and merger activity), and variations in the way the data are reported make it difficult to obtain a series of consistent data.[7] The present study therefore uses data from the rankings published in 2004 and 2005. These are based on the data for 2003 and 2004, respectively. While there are currently more than 1500 HEIs in the Chinese higher education sector, complete and consistent data over two consecutive years are only available for a small subset of 109 top HEIs for which it is possible to derive indicators relating to inputs (labour, capital and student composition) and research outputs. There are no satisfactory measures of teaching 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.

It is worth noting at this stage that the period covered by this study (2003 and 2004) not only follows a period of reform, but, as has already been illustrated in Section 2, is also part of a period of expansion in terms of student numbers (including postgraduates) and research funding. This study focuses on research. Clearly expansion of both teaching and research activity could have a strong impact on the latter. Efficiency, as estimated by DEA, is calculated relative to a frontier. During a period of expansion, it is likely that this frontier is shifting. There may, therefore, be a lag in the shifting of the frontier and the ability of the institutions to alter their performance relative to the frontier. This may be because institutions have inadequate resources initially to cope with the expansion, or it may be a consequence of slow adjustments in production methods. Thus HEIs may experience temporary falls in their technical efficiency, and this should be borne in mind when examining the results of this study of performance at a snapshot in time.

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). The variable STAFFQ requires a little more discussion. The premise underlying this variable is that the promoted faculty (associate and full professors) are more productive than their colleagues. However, it may be the case that these faculty were promoted during an era when the demands with regard to research were less than is currently the case[8]; or that, once promoted, these faculty have less motivation to continue to be productive. In light of the possible ambiguity with regard to the effect of STAFFQ on research output, and given that DEA requires that inputs should have a positive effect on output, STAFFQ was correlated with the output measures (defined below). The correlations are all significantly positive (and exceed 0.40), and hence support the original premise on which STAFFQ was included in the analysis.

Research can be produced in association with postgraduates, particularly doctoral students. An ideal measure to reflect this aspect would be based on number of doctoral students. Unfortunately, postgraduate student data are not split by level, and hence the measure of postgraduate input to research is an index measuring the proportion of all students who are postgraduates (PG). Research funding is measured using research expenditure (FUNDS)[9] 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 BLDG is an index of the area of the buildings.

The measurement of research output is known to be difficult. Research has a number of characteristics such as productivity, quality, eminence, impact and progress. Different measures capture different aspects of the activity. It might be argued that a measure based on the opinions of peers (i.e. a reputation measure) is the most appropriate as it attempts to reflect all possible characteristics of research, although, in reality, such a measure is most likely to reflect the impact of research. An index of the prestige[10] of the HEI (REPUT) is therefore included in this analysis. The disadvantages of such a reputation variable to measure research are well-known: such a measure is subjective and therefore related to the prejudices and allegiances of the panel which provided the measure; the reputation of a whole university can benefit from a strong and very public activity of just one small group within that university; and the measure may be based on past rather than current research activity and hence may not be an adequate reflection of current research activity (i.e. reputation can live on long after it is deserved). As a consequence, two additional distinctive measures of research activity are included to capture two different characteristics of research. The first is an index of the total number of research publications (RES)[11] to capture the *total volume* of research activity. An index of research publications per member of academic staff (RESPP) is also included to reflect research *productivity* across the HEI. The best performing institutions should have most of its staff actively engaged in research and so would score highly on both RES and RESPP.

[7] For example, data on publications were based on simple counts in the early publications of netbig, but in more recent years (including 2004 and 2005) publications counts are weighted by size of subject. In addition, the index based on total publications is available from netbig 2004 to 2005, but not from netbig 2003.

[8] I am grateful to a referee for pointing out this possible interpretation of STAFFQ.

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

[10] 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.

[11] Publications data are 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. Publications data from these sources are weighted by number of staff in each broad subject area.

Table 5a
Descriptive statistics for the inputs and outputs: whole sample by year

	Min	Mean	SD	Min	Mean	SD
	2003			2004		
Inputs						
STAFFT	27.16	60.85	14.77	20.80	44.81	13.02
STAFFQ	37.34	66.20	11.28	25.30	61.48	14.25
PG	7.21	33.56	17.19	10.80	41.08	18.90
FUNDS	0.99	25.47	18.26	1.50	26.43	19.17
BOOKS	10.43	42.34	20.46	10.40	34.13	16.51
BLDG	8.93	28.04	15.00	11.60	33.99	15.99
Outputs						
RES	0.07	10.17	15.10	0.00	10.99	15.55
RESPP	0.22	16.02	16.78	0.20	16.14	17.09
REPUT	40.00	60.54	13.63	40.00	60.84	13.71
n	109			109		

An institution which has only a small number of active researchers might score relatively highly on RES (and hence perform well in producing volume of research), but would inevitably have a small score on RESPP (and hence its productivity would be low). These three measures of research output are similar to measures used by Korhonen et al. (2001). The descriptive statistics of the various input and output indexes are presented in Table 5a.[12]

Ng and Li (2000) found significant differences in average efficiency between geographical regions. The descriptive statistics of the input and output variables are therefore presented by region in Table 5b. There is no consistent pattern to be observed and the only significant differences (at the 5% significance level) between means are found for the inputs PG and BLDG: in the case of PG, the mean is highest for HEIs in the coastal region of China and lowest for those in central China; in the case of BLDG, the average is highest for HEIs in central region of China and lowest in the coastal region.

Liu (2001) found comprehensive universities to have higher levels of efficiency (on average) than specialised engineering universities. Descriptive statistics for the input and output variables are presented on the basis of whether the university is comprehensive or a specialist institution (Table 5c). With the exception of the variable STAFFT, the input and output variables are all higher, on average, for the comprehensive universities than for the specialist universities.

The earlier discussion on the development of HEIs in China remarked upon the historical distinction between centrally and locally run HEIs. Thus descriptive statistics for the input and output variables are also presented split on the basis of these characteristics in Tables 5d. There is a significant difference between the means of all the variables with the exception of STAFFT. Specifically, the input and output variables are all higher, on average, for HEIs administered by the MOE than for HEIs administered locally.

5. Results

5.1. Technical efficiency

DEA can be sensitive to the specification of the inputs and outputs in the model. In addition, the RES output variable has some very low values (close to zero)[13] which can cause some instability in the efficiencies when this variable is included in the DEA. Since the correlation between REPUT and RES is high ($r = 0.896$) the two variables are likely to reflect the same aspects of research, and hence removing RES from the DEA models is not considered to be a serious problem. In addition, the full specification has a large number of inputs (6 in all). Previous studies of efficiency of research in higher education have included only labour and capital inputs (Beasley, 1990, 1995), and excluded inputs relating to students. Thus the two inputs related to students (STAFFT and PG) are removed from some models to check the relevance of these variables. Four models are estimated in all: models 1 and 3 include all three outputs, while models 2 and 4 include only REPUT and RESPP to reflect output. Models 1 and 2 include all inputs while models 3 and 4 exclude STAFFT and PG.

The results of applying an output-oriented DEA with variable returns to scale to the two years of consistent data are summarised in Table 6 (full results for models 2 and 4 can be found in the Appendix A). It should be noted that results across the two years of the study are remarkably stable.[14] In addition, whether or not the two input variables STAFFT and PG are included in the model makes some difference to the mean efficiency derived: mean efficiency with all inputs included is around 92% (regardless of definition of outputs) compared to 83% when these two inputs are removed from the DEA. The latter figure is similar

[12] The rather anomalous-seeming result that RES (based on volume of research publications) is lower, on average, than RESPP (an index based on research publications per member of staff) requires further explanation. It should be remembered that all input and output measures are indexed i.e. for a given variable, each observation is divided by the largest value observed for that variable. Since RES and RESPP are indexes rather than raw data, the fact that RES is smaller than RESPP (on average) simply suggests that there is a wider dispersion between high and low values of RES than there is between high and low values of RESPP.

[13] Note that this problem of low values affects RES but not RESPP. See footnote 12 for a discussion of the relative values of RES and RESPP.

[14] The rank correlation coefficients between the efficiencies of corresponding models (for 2003 and 2004) are all highly significant and exceed 0.614. The efficiencies of models 3 and 4 (which exclude STAFFT and PG) are remarkably stable over time with rank correlation coefficients which exceed 0.820.

Table 5b
Descriptive statistics for the inputs and outputs: by region (2003 and 2004 combined)

	Min	Mean	SD	Min	Mean	SD	Min	Mean	SD
	Coastal			Central			West		
Inputs									
STAFFT	20.80	52.39	16.55	31.70	51.99	13.73	29.20	55.95	16.99
STAFFQ	25.30	65.00	14.48	40.50	63.76	9.42	42.30	58.90	9.49
PG	7.96	39.57	19.22	7.21	31.66	17.70	15.45	35.63	13.69
FUNDS	0.99	28.10	20.58	1.50	22.99	13.46	3.54	20.81	14.84
BOOKS	10.40	36.51	19.98	16.20	42.75	17.45	16.00	39.31	15.82
BLDG	8.93	27.85	13.73	14.65	38.64	18.65	12.79	33.92	15.70
Outputs									
RES	0.00	11.51	17.64	0.30	10.29	11.12	0.30	6.93	6.67
RESPP	0.20	17.91	19.10	1.20	13.19	12.80	1.29	12.24	9.10
REPUT	40.00	61.74	14.34	44.00	59.20	12.65	41.00	58.25	11.55
n	140			46			32		

Table 5c
Descriptive statistics for the inputs and outputs: by specialist/comprehensive (2003 and 2004 combined)

	Min	Mean	SD	Min	Mean	SD
	Specialist			Comprehensive		
Inputs						
STAFFT	20.80	51.76	16.57	29.20	55.19	14.66
STAFFQ	25.30	62.12	12.93	40.50	67.64	12.57
PG	7.96	34.26	14.16	7.21	44.09	24.17
FUNDS	0.99	22.87	16.56	3.20	32.74	21.28
BOOKS	10.40	30.25	13.70	27.00	55.84	17.16
BLDG	8.93	25.29	11.11	15.32	43.65	17.15
Outputs						
RES	0.00	5.45	6.24	1.60	21.90	21.95
RESPP	0.20	11.21	10.26	3.40	26.81	22.82
REPUT	40.00	56.62	9.39	40.00	69.68	16.95
n	150			68		

to the efficiency levels found by Ng and Li (2000), a study of research efficiency whose inputs included labour and capital inputs, but not variables reflecting students.

Since the levels of efficiency are somewhat sensitive to the inclusion or otherwise of STAFFT and PG, 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 and significantly stable in both years of the study with Spearman's correlation coefficient exceeding 0.66 for all pairs of models. The inclusion or otherwise of RES, in particular, has little effect on ranking (compare model 1 to model 2; and model 3 to model 4).

5.2. Differences in efficiency between universities: Possible explanations

Efficiency varies from around 60% to 100% for the 109 HEIs in this data set across all DEA models. Estimation of the confidence intervals using bootstrapping procedures (Simar & Wilson, 2004) suggests that the differences in efficiency between the best and worst-performing colleges are significant, but that the middle performing institutions (around 35%) cannot be distinguished in terms of their performance.[15] It can therefore be concluded that the top 40% of HEIs are significantly more efficient than the lowest 25% of HEIs. This section therefore examines some possible reasons for these differences in performance.

The sample universities are split into groups on the basis of three separate criteria: the region of their location i.e. in the coastal, central or western region of China; whether they are centrally funded (by the MOE) or whether funds come from the regional level; and whether they are a comprehensive or specialist university. 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.[16] 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 research 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, particularly in light of recent merger activity. The results of analysing the efficiencies on the basis of these three criteria are displayed in Tables 8, 9 and 10.

[15] These results, which are consistent across DEA models, are not reported in detail but are available from the author on request.
[16] In fact, the relationship between economic development (reflected by geographical location) and efficiency may well be simultaneous: economic development may affect efficiency in producing research; lower efficiency in producing research may reduce economic development through smaller spillover effects to industry from the research undertaken in the universities.

Table 5d
Descriptive statistics for the inputs and outputs: by type of administration (2003 and 2004 combined)

	Min	Mean	SD	Min	Mean	SD
	MOE			Not MOE		
Inputs						
STAFFT	20.80	53.05	16.19	26.30	52.33	15.82
STAFFQ	30.30	66.83	12.58	25.30	56.96	11.45
PG	10.04	43.27	17.74	7.21	23.63	11.29
FUNDS	0.99	31.04	19.28	1.50	14.22	10.07
BOOKS	11.90	40.61	19.98	10.40	32.76	15.31
BLDG	8.93	34.21	16.44	9.33	23.65	11.04
Outputs						
RES	0.07	13.69	17.33	0.00	3.43	2.95
RESPP	0.20	19.40	18.93	0.20	8.43	5.94
REPUT	45.00	65.49	13.29	40.00	49.64	5.72
n	152			66		

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 6
Summary of DEA results

	Model 1	Model 2	Model 3	Model 4
2003				
Mean	91.68	91.56	83.21	83.15
Min	62.08	62.08	57.77	57.77
SD	9.33	9.32	13.05	12.99
% of HEIs which are 100% efficient	43.1	42.2	24.8	23.9
2004				
Mean	91.58	91.34	83.91	83.75
Min	70.55	70.55	54.86	54.86
SD	9.20	9.13	12.95	12.79
% of HEIs which are 100% efficient	39.4	36.7	23.9	20.2

Note: Figures in parentheses denote values for the 109 HEIs which appear in both years of the data.
Model 1: Outputs=RES, RESPP, REPUT; Inputs=STAFFT, STAFFQ, PG, FUNDS, BOOKS, BLDG. Model 2: Outputs=RESPP, REPUT; Inputs=STAFFT, STAFFQ, PG, FUNDS, BOOKS, BLDG. Model 3: Outputs=RES, RESPP, REPUT; Inputs=STAFFQ, FUNDS, BOOKS, BLDG. Model 4: Outputs=RESPP, REPUT; Inputs=STAFFQ, FUNDS, BOOKS, BLDG.

First, and most importantly, geographical location is significantly related to efficiency regardless of model specified to generate the efficiency scores. This is true of both years of study and the difference is significant at the 10% significance level. Universities in the west have the lowest average efficiencies; universities in the coastal zone have the highest efficiencies; performance in universities in the central region fluctuates depending on DEA specification. This last result could well be related to postgraduate numbers since universities in the central region have the lowest score on this input. Thus when it is taken into account (model 2) these universities appear to perform well; when it is not (model 4) they appear to perform relatively badly. The result regarding efficiency and geographical location of the HEI is important: the possible spillover effects of university research on the surrounding regional economy could play an important role in regional economic development. Thus the underdeveloped western region may lag behind its more developed neighbours even more if its HEIs continue to produce research less efficiently than those in the other regions. This in turn could have a negative impact on the performance of universities.

Table 7
Spearman's rank correlations between the efficiencies of various DEA models

	Model 1	Model 2	Model 3
Model 2	0.982		
Model 3	0.663	0.680	
Model 4	0.661	0.681	0.997

Note
Model 1: Outputs=RES, RESPP, REPUT; Inputs=STAFFT, STAFFQ, PG, FUNDS, BOOKS, BLDG. Model 2: Outputs=RESPP, REPUT; Inputs=STAFFT, STAFFQ, PG, FUNDS, BOOKS, BLDG. Model 3: Outputs=RES, RESPP, REPUT; Inputs=STAFFQ, FUNDS, BOOKS, BLDG. Model 4: Outputs=RESPP, REPUT; Inputs=STAFFQ, FUNDS, BOOKS, BLDG.

Table 8
Summary of efficiency by region

a) Model 2	Coastal	Central	Western	F	Kruskall–Wallis
				df = 2,106	df = 2
2003					
Mean	91.93	93.78	86.77	2.92*	4.946*
SD	9.34	7.68	10.26		
n	70	23	16		
2004					
Mean	92.43	91.13	86.87	2.494*	6.192**
SD	9.40	8.20	8.22		
n	70	23	16		
b) Model 4					
2003					
Mean	85.61	79.26	77.96	3.746**	6.832**
SD	13.15	12.50	10.49		
n	70	23	16		
2004					
Mean	86.08	79.94	79.02	3.424	6.462**
SD	12.54	13.31	11.09		
n	70	23	16		

** = significant at 5%; * = significant at 10%.
Model 2: Outputs = RESPP, REPUT; Inputs = STAFFT, STAFFQ, PG, FUNDS, BOOKS, BLDG. Model 4: Outputs = RESPP, REPUT; Inputs = STAFFQ, FUNDS, BOOKS, BLDG.

Second, a HEI's administration method (i.e. central or local) has no effect on efficiencies other than through differences in inputs. When all six input variables are included in the DEA model, there is no significant difference between subgroups. However, when student variables are removed from the DEA model, there is a strong significant difference between subgroups, with universities which are administered locally having lower mean efficiency (around 77%) than universities which receive their funds directly from the MOE (around 85%). This difference is significant at the 5% significance level for both years of the study. This result should not cause surprise as the postgraduate numbers are significantly lower in HEIs administered locally compared to those administered centrally (see Table 5c). Thus, as long as the advantageous postgraduate input to research is taken into account in the model to calculate efficiencies, the mean efficiencies for the two types of HEI are not significantly different, and there is no evidence that decentralization increases research efficiency.

Table 9
Summary of efficiencies by administration type

a) Model 2	Central	Regional	F	Kruskall–Wallis
			df = 1,107	df = 1
2003				
Mean	92.10	90.32	0.836	0.001
SD	7.85	12.10		
n	76	33		
2004				
Mean	91.34	91.33	0.000	0.278
SD	8.60	10.39		
n	76	33		
b) Model 4				
2003				
Mean	85.50	77.72	8.876**	7.853**
SD	10.68	16.07		
n	76	33		
2004				
Mean	86.01	78.54	8.377**	6.654**
SD	10.87	15.33		
n	76	33		

** = significant at 5%; * = significant at 10%.
Model 2: Outputs = RESPP, REPUT; Inputs = STAFFT, STAFFQ, PG, FUNDS, BOOKS, BLDG. Model 4: Outputs = RESPP, REPUT; Inputs = STAFFQ, FUNDS, BOOKS, BLDG.

Table 10
Summary of efficiencies by university type

a) Model 2	Comprehensive	Specialist	*F*	Kruskall–Wallis
2003				
Mean	94.74	90.12	6.006**	4.517**
SD	6.57	10.04		
n	34	75		
2004				
Mean	94.04	90.11	4.467**	3.592**
SD	7.92	9.42		
n	34	75		
b) Model 4				
2003				
Mean	85.24	82.20	1.288	1.015
SD	13.20	12.87		
n	34	75		
2004				
Mean	86.65	82.44	2.577	2.433
SD	13.36	12.39		
n	34	75		

**=significant at 5%; *=significant at 10%.
Model 2: Outputs=RESPP, REPUT; Inputs=STAFFT, STAFFQ, PG, FUNDS, BOOKS, BLDG. Model 4: Outputs=RESPP, REPUT; Inputs=STAFFQ, FUNDS, BOOKS, BLDG.

Third, comprehensive universities consistently have higher average efficiency than specialist institutions: when all inputs are included, specialist HEIs have, on average, significantly lower efficiency than comprehensive HEIs (90% compared to 94%). When PG and STAFFT are excluded, the difference is in the same direction, but it is no longer significant. This result therefore offers some support for the recent policy of mergers in China's higher education sector.

Table 11
Peers and weightings for two universities

a) Southwestern University of Finance and Economics

			Peer			
			Fudan University	Beijing University of Posts and Tele-communications	Capital Medical University	University of international Business and Economics
Weight			0.0278	0.3208	0.4517	0.1997
Variable	Actual value	Target value				
REPUT	51	62.6	92	63	62	59
RESPP	5.3	8.9	63.4	12.0	6.5	1.9
PG	36.6	36.6	71.5	52.2	28.5	25.0
FUNDS	20.3	16.3	48.4	31.4	4.2	14.9
BOOKS	27.4	17.5	62.8	16.5	16.7	14.5
BLDG	22.6	16.1	43.2	17.0	14.0	15.8
STAFFQ	52.3	52.3	67.9	72.6	25.3	78.6
STAFFT	30.5	30.5	45.3	20.8	40.1	22.3

b) Dongbei University of Finance and Economics

			Peer				
			Shandong University	Lanzhou University	Fudan University	Capital Medical University	Nanjing University
Weight			0.0121	0.0160	0.1308	0.7295	0.1115
Variable	Actual value	Target value					
REPUT	49	69.4	72	69	92	62	91
RESPP	6.8	21.5	20.9	20.9	63.4	6.5	70.3
PG	39.8	39.8	36.6	36.6	71.5	28.5	77.0
FUNDS	13.7	13.8	15.4	15.4	48.4	4.2	35.7
BOOKS	29.0	29.3	54.3	54.3	62.8	16.7	65.9
BLDG	35.1	21.9	56.0	56.0	43.2	14.0	40.3
STAFFQ	53.2	38.3	73.9	73.9	67.9	25.3	79.7
STAFFT	40.9	40.9	40.9	40.9	45.3	40.1	40.9

Studies have shown that university research can have positive spillover effects on the firms in the surrounding areas (Anselin et al., 1997; Fischer & Varga, 2003). Indeed there is evidence that new firms, particularly in high-technology industries, choose to locate in a region where there is a university in order to take advantage of the knowledge generated by the institution (Audretsch, Lehmann & Warning, 2005). Small and medium-sized firms, which are regarded by many as crucial to stimulating innovation, seem to benefit particularly from the spillovers from university research (Rodríguez-Pose & Refolo, 2003). The result that efficiency in producing research varies by region is therefore of serious concern. What then can universities in the less developed region do to improve their performance? The advantage of the DEA methodology is the amount of managerial information which can be derived for DMUs which are not efficient. As discussed in Section 2, each inefficient DMU is provided with a list of efficient peers which most closely resemble the inefficient DMU in terms of its production (for example, DMUs B and C are the efficient peers for DMU E in Fig. 5). In addition, DEA assigns to each of the efficient peers a weighting which indicates just how the inefficient DMU should emulate its peers. Thus, a peer which is assigned a high weight (relative to the weights of the other efficient peers) is one which the inefficient DMU should most closely emulate (for example DMU B is the more important peer for DMU E in Fig. 5).

As an example, Southwestern University of Finance and Economics, located in the western region of China, has an efficiency score (in model 2, 2004) of 81.5%, and this is representative of its relative performance over time and across model specification. Table 11a shows the actual input and output values for this DMU along with the HEIs which it should emulate in order to become efficient. Each of the peers is assigned a weighting and this is used to construct target input and output values for the inefficient DMU, the target value for a particular input (output) being the weighted sum of the values of that input (output) for each of the peers. The university which is weighted most highly in constructing these targets (and hence the university which Southwestern University of Finance and Economics should most closely emulate) is the Capital Medical University (although it should be noted that these are two universities with different specialisms and so the comparison may not be entirely appropriate) which has higher output values, combined with considerably lower values for all but one of the inputs. The precise target values are also displayed in Table 11a, and it can be seen that an efficient Southwestern University of Finance and Economics would have generally higher output values combined with lower input values with the exception of the staff inputs which would remain at the same levels. It should be noted that all the peers for Southwestern University of Finance and Economics are located outside of the western region of China, but they are considered to be the most comparable of the efficient DMUs to Southwestern University of Finance and Economics in terms of input and output mix.

Table 11b shows the actual input and output values for Dongbei University of Finance and Economics, along with the HEIs which it should emulate in order to become efficient. In contrast to the previous example, this is an inefficient university located in the coastal region of China. The main peer for this university is also Capital Medical University, located in the central region. The target input and output values are also displayed, and these suggest that an efficient Dongbei University of Finance and Economics could generally increase its outputs whilst reducing all but three of its inputs (FUNDS, BOOKS and STAFFT being the exceptions). Not all the peers for Dongbei University of Finance and Economics are located in the coastal or central regions: Lanzhou University, in the west, produces considerably more output than Dongbei University of Finance and Economics, but also uses more inputs. Thus universities can look at the inputs and outputs of peer institutions in order to try to increase their own efficiency.

6. Conclusions

There are few empirical studies of efficiency in Chinese higher education, 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 four DEA models to a sample of 109 top Chinese HEIs in an attempt to measure the efficiency of Chinese HEIs in producing research. The analysis shows that mean research efficiency in Chinese higher education varies between 83% and 92% depending on whether or not student-related variables are included as inputs. The difference between the best- and worst-performing HEIs is significant (regardless of model or time period), and this therefore begs the question of what might cause such differences.

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 research efficiency than those in either the coastal or central regions. The difference is significant at the 10% significance level. Thus 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 poor regional economic performance may then have adverse knock-on effects on university research performance, and so on. The mean research efficiency of HEIs administered centrally is generally higher than that for HEIs which are administered locally, but the difference is not significant when all inputs are included in the DEA model. Finally, comprehensive universities appear to outperform the specialist institutions, and the difference is significant when all inputs (including student-related variables) are included in the analysis. Thus China's recent policy of merging universities should be encouraged on the basis of this result.

This study has concentrated on efficiency of universities in the production of research only. This is important in its own right, particularly since university research is known to have spillover effects on to local businesses and could therefore be a key tool in regional economic development. However, universities have an additional mission, namely teaching, and it would be valuable to measure universities' efficiency in both their activities. There is therefore a need for reliable objective measures of both research and teaching outputs of Chinese HEIs. In addition, any study of efficiency should include a detailed analysis of all possible factors which might affect performance.

Appendix A

DEA results for models 2 and 4 (sorted by rank on model 2)

	Model 2				Model 4			
	2004	2003	Average	Rank	2004	2003	Average	Rank
Beijing University	100.00	100.00	100.00	1	100.00	100.00	100.00	1
Shenyang Pharmaceutical University	100.00	100.00	100.00	1	100.00	100.00	100.00	1
Shantou University	100.00	100.00	100.00	1	100.00	100.00	100.00	1
Beijing Normal University	100.00	100.00	100.00	1	100.00	100.00	100.00	1
Beijing aerospace University	100.00	100.00	100.00	1	100.00	100.00	100.00	1
Tsinghua University	100.00	100.00	100.00	1	100.00	100.00	100.00	1
Lanzhou University	100.00	100.00	100.00	1	100.00	100.00	100.00	1
Beijing Foreign Studies University	100.00	100.00	100.00	1	100.00	100.00	100.00	1
University of Science and Technology Beijing	100.00	100.00	100.00	1	100.00	100.00	100.00	1
Capital Medical University	100.00	100.00	100.00	1	100.00	100.00	100.00	1
Nanjing University	100.00	100.00	100.00	1	100.00	100.00	100.00	1
Shanghai Jiaotong University	100.00	100.00	100.00	1	100.00	100.00	100.00	1
Harbin Medical University	100.00	100.00	100.00	1	100.00	100.00	100.00	1
University of Science and Technology of China	100.00	100.00	100.00	1	100.00	100.00	100.00	1
International relational institute	100.00	100.00	100.00	1	100.00	100.00	100.00	1
Tianjin Medical University	100.00	100.00	100.00	1	100.00	100.00	100.00	1
Harbin Institute of Technology	100.00	100.00	100.00	1	100.00	100.00	100.00	1
China Pharmaceutical University	100.00	100.00	100.00	1	100.00	100.00	100.00	1
Nanjing Medical University	100.00	100.00	100.00	1	100.00	100.00	100.00	1
Zhengzhou University	100.00	100.00	100.00	1	97.49	100.00	98.75	20
Fudan University	100.00	100.00	100.00	1	100.00	96.60	98.30	21
Shanghai Jiaotong University	100.00	100.00	100.00	1	100.00	95.09	97.55	23
Shanghai International Studies University	100.00	100.00	100.00	1	92.12	100.00	96.06	25
Shandong University	100.00	100.00	100.00	1	96.57	93.45	95.01	27
Beijing University of posts and telecommunications	100.00	100.00	100.00	1	93.24	95.52	94.38	29
Zhejiang University	100.00	100.00	100.00	1	97.02	90.00	93.51	31
Beijing University of Chemical Technology	100.00	100.00	100.00	1	91.52	92.63	92.08	35
China University of Political Science and Law	100.00	100.00	100.00	1	88.85	89.90	89.38	42
Fuzhou University	100.00	100.00	100.00	1	78.89	80.52	79.71	67
Shanxi University	100.00	100.00	100.00	1	67.99	71.05	69.52	92
South China Normal University	100.00	100.00	100.00	1	64.89	63.35	64.12	103
Henan University	100.00	100.00	100.00	1	61.17	60.72	60.95	107
Renmin University of China	99.25	100.00	99.63	33	95.30	100.00	97.65	22
Jilin University	97.13	100.00	98.57	34	95.25	90.89	93.07	33
Shanghai University of Finance & Economics	96.47	100.00	98.24	35	83.44	100.00	91.72	36
Xidian University	96.23	100.00	98.12	36	87.48	79.03	83.26	56
Tianjin University	100.00	95.79	97.90	37	91.23	88.75	89.99	39
Wuhan University	97.92	97.69	97.81	38	97.30	90.93	94.12	30
Hunan Normal University	95.05	100.00	97.53	39	64.68	63.50	64.09	104
China Medical University	93.12	100.00	96.56	40	92.71	100.00	96.36	24
Anhui University	100.00	92.87	96.44	41	66.16	66.24	66.20	101
Southeast university	92.38	100.00	96.19	42	89.60	90.71	90.16	38
Nanjing Normal University	91.83	100.00	95.92	43	68.84	67.55	68.20	97
Tongji University	94.60	97.00	95.80	44	87.53	87.50	87.52	45
Central Conservatory of Music	95.50	95.98	95.74	45	93.70	95.94	94.82	28
Nankai University	98.18	93.06	95.62	46	93.59	93.06	93.33	32
Xiamen University	95.47	95.59	95.53	47	95.47	95.30	95.39	26
University of International Business and Economics	100.00	90.48	95.24	48	94.87	85.81	90.34	37
Beijing Chinese Medicine University	100.00	89.58	94.79	49	93.54	86.37	89.96	40
Northwest University	87.74	100.00	93.87	50	83.71	84.86	84.29	52
Sun Yat-sen University	95.94	91.65	93.80	51	95.33	83.19	89.26	43
Xi'an Jiaotong University	93.72	93.79	93.76	52	92.37	92.90	92.64	34
Northeast Forestry University	87.30	100.00	93.65	53	72.17	70.41	71.29	87
East China Normal university	96.22	90.53	93.38	54	92.19	83.79	87.99	44
Yunnan University	100.00	86.34	93.17	55	75.00	70.97	72.99	82
China Agricultural University	96.35	89.45	92.90	56	86.05	80.62	83.34	55
Chinese Oceanography University	91.60	93.81	92.71	57	87.56	84.24	85.90	47
Zhongnan University of Economics and Law	85.27	100.00	92.64	58	73.27	69.71	71.49	84
The Central University For Nationalities	100.00	83.86	91.93	59	75.32	72.87	74.10	79
Hefei University of Technology	85.21	97.62	91.42	60	71.75	76.95	74.35	77
Sichuan University	92.15	90.32	91.24	61	86.93	80.87	83.90	54
Beijing Institute of Technology	90.62	90.99	90.81	62	90.62	89.12	89.87	41
Huazhong University of Science and Technology	92.70	88.50	90.60	63	86.49	82.89	84.69	50
Hunan University	85.14	96.06	90.60	63	76.56	76.03	76.30	73
Nanjing University of Science & Technology	88.48	92.39	90.44	65	83.71	85.15	84.43	51
Nanjing University of Aeronautics and Astronautics	85.19	95.08	90.14	66	81.56	84.01	82.79	58

Appendix A (*continued*)

	Model 2				Model 4			
	2004	2003	Average	Rank	2004	2003	Average	Rank
Beijing Forestry University	94.05	86.05	90.05	67	75.31	75.19	75.25	74
Suzhou University	88.45	89.97	89.21	68	68.16	65.61	66.89	100
Northwestern Polytechnical University	90.52	87.63	89.08	69	83.80	81.07	82.44	61
Beijing Jiaotong University	90.84	87.08	88.96	70	85.45	84.53	84.99	49
Capital Capital University	92.22	85.39	88.81	71	61.50	57.77	59.64	108
Northeast Agricultural University	77.34	100.00	88.67	72	66.47	82.25	74.36	76
University of Electronic Science and Technology of China	87.71	89.39	88.55	73	85.05	80.91	82.98	57
Huazhong Normal University	90.01	86.70	88.36	74	70.67	68.19	69.43	93
Nanjing industrial university	100.00	76.20	88.10	75	61.64	63.47	62.56	105
Chongqing University	84.39	91.16	87.78	76	78.91	82.35	80.63	65
Harbin Engineering University	93.51	81.39	87.45	77	93.35	76.78	85.07	48
Shanghai Chinese medicine university	73.42	100.00	86.71	78	73.42	100.00	86.71	46
Central South University	88.77	84.55	86.66	79	79.68	78.23	78.96	68
Southwest Jiaotong University	85.84	87.46	86.65	80	79.93	84.92	82.43	62
Donghua University	71.86	100.00	85.93	81	68.02	100.00	84.01	53
Dalian technical University	86.23	84.71	85.47	82	79.27	80.83	80.05	66
Shaanxi Normal University	80.81	89.88	85.35	83	68.89	65.83	67.36	98
Northeast Normal University	83.89	86.63	85.26	84	83.20	81.82	82.51	60
Guangzhou Chinese medicine university	100.00	69.31	84.66	85	100.00	63.25	81.63	64
South China University of Technology	85.98	81.76	83.87	86	82.85	81.44	82.15	63
Beijing University of Technology	88.44	77.42	82.93	87	77.48	69.34	73.41	81
China Foreign Affairs University	85.14	80.67	82.91	88	84.85	80.67	82.76	59
Chinese Mining Industry University	82.92	82.86	82.89	89	74.92	73.34	74.13	78
Huazhong Agricultural University	80.57	83.83	82.20	90	74.54	79.30	76.92	71
Jinan University	76.91	86.43	81.67	91	70.34	70.32	70.33	90
East China University of Science & Technology	78.06	85.23	81.65	92	76.31	76.37	76.34	72
Nanjing Chinese Medicine University	92.65	69.27	80.96	93	89.03	65.96	77.50	70
Liaoning University	80.28	81.56	80.92	94	71.24	62.94	67.09	99
Shanghai University	77.42	84.40	80.91	95	61.43	62.59	62.01	106
Chinese Geology University	77.92	83.60	80.76	96	73.92	73.11	73.52	80
Southwestern University of Finance and Economics	81.53	79.51	80.52	97	69.76	72.92	71.34	86
Northeastern University	77.64	82.47	80.06	98	71.50	77.53	74.52	75
Chongqing medical college	81.37	77.20	79.29	99	80.30	75.15	77.73	69
Northwest farming and forestry scientific and technical university	80.46	76.36	78.41	100	70.32	67.10	68.71	94
Nanjing agricultural University	78.50	78.02	78.26	101	71.00	71.27	71.14	88
Wuhan University of Technology	78.15	77.46	77.81	102	66.55	63.93	65.24	102
South China Agricultural University	76.55	79.01	77.78	103	69.13	70.56	69.85	91
Hohai University	76.63	76.80	76.72	104	69.49	72.17	70.83	89
Chinese Petroleum University	70.55	80.32	75.44	105	67.70	76.79	72.25	83
Inner Mongolian University	73.42	77.18	75.30	106	67.01	70.36	68.69	95
Dalian Maritime University	73.61	72.47	73.04	107	71.67	71.12	71.40	85
Dongbei University of Finance & Economics	70.61	72.46	71.54	108	68.75	68.49	68.62	96
Southwest Petroleum Institute	74.00	62.08	68.04	109	54.86	58.12	56.49	109

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