


Does More Investment in Universities Improve Their Performances?

A Study on the Performance of Chinese Universities Using Data Envelopment Analysis

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ABSTRACT

Universities play a critical role in improving the economic prosperity and social well-being of a country. Many countries have invested heavily in higher education and funding university education for their citizens. Does more investment enhance universities' performances? What other factors contribute to universities' productivity? This research used the data envelopment analysis methodology to study the total factor productivity (TFP) of 60 Chinese universities from 2006 to 2016. The study found the values of TFP fluctuated between 0.950 and 1.050 and were relatively stable. Contrary to common belief about productivity improvements, universities with more investment from the Chinese government did not show better performances. Nevertheless, the study found evidence that human resources (e.g., postgraduate-teacher ratio), physical resources (e.g., campus areas), and policy factors (e.g., tenure of the presidents, mergers) have a positive impact on universities' productivity.

KEYWORDS

Chinese University, Data Envelopment Analysis, Impacting Factors, Investment in Universities, Productivity

INTRODUCTION

Colleges and universities have the potential to make a significant contribution to societal development (Owens, 2017). They educate people and produce different kinds of professionals—such as marketers, business executives, entrepreneurs, researchers, technologists, athletes, educators, doctors, engineers, scientists, and astronauts—to develop the economy of a country and promote diversity and social well-being. Furthermore, basic and applied research works are conducted in colleges and universities, especially in research-oriented universities, that can expand the frontier of human knowledge and advance the application of scientific knowledge (Chankseliani et al., 2021; Jasimuddin et al., 2019).

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The Human Capital Theory argues that educational investments can boost future production (Holden & Biddle, 2017). Mincer (1984) examined the impact of human capital on economic growth and found that the rate of accumulation of human capital and innovation was related to the rate of output growth. Human capital is undoubtedly a critical component of economic growth (Diebolt & Hippe, 2022), and educational attainment has an impact on labor productivity. Higher education institutions are viewed as organizations that expand human capital and discover new knowledge and technologies (Chankseliani & McCowan, 2021). Thus, both developed and developing countries have focused on promoting the development of higher education in recent years. Many policies are introduced to continuously increase investment in higher education, including these examples:

- Japan's Building a Nation Through Education (<https://www.mext.go.jp/>)
- China's Project 211, Project 985, and Double First-class Programs (<http://www.moe.gov.cn/>)
- The United States' Promoting Real Opportunity, Success, and Prosperity through Education Reform (<https://www.ed.gov/>)
- Britain's Higher Education and Research Bill (<https://www.gov.uk/>)
- Germany's Elite University Plan
- Australia's Higher Education Support Act (<https://www.bmbf.de/>)

Generally, the amount of expenditure as a percentage of gross domestic product (GDP) is used as an indicator of the effort made in practice by most national education financiers. Although a significant amount of public funds has been invested in higher education in many countries, the relationship between investment and education is perplexing (Grubb & Allen, 2011). Many colleges and universities are publicly funded. These public institutions are under pressure to report performance enhancements to the funding agencies and the public. With the pressure from both inside and outside to build world-class universities and achieve good international rankings (Vidal & Ferreira, 2020), these educational institutions must compete not only for domestic educational resources but also for academic staff and students on a global scale (Chirikov, 2016; Ma & Zhao, 2018). In such a hyper-competitive environment with limited resources, the governments and the general public demand that educational institutions operate as efficiently as possible (Johnes et al., 2017; Moncayo–Martínez et al., 2020). Hence, demonstrating and improving the efficiency and effectiveness of running a higher education institution is extremely critical (Hanushek, 2020; Mammadov & Aypay, 2020; Patrinos & Psacharopoulos, 2020).

China is regarded as the largest developing country worldwide, with the total economic output reaching 114.4 trillion CNY in 2021 (ranking second in the world). In 2020, there were 2,738 colleges and universities in China and a total of 41.83 million students. The gross enrollment rate in higher education was 54.4%. Over the past decade, research and development (R&D) spending by Chinese colleges and universities grew continually and gradually, reaching 188.25 billion CNY in 2020, which accounts for 7.7% of the total R&D spending in China. Chinese universities received approximately 119,000 patents in 2020, which accounts for 26.9 percent of the total patents in the country. Thus, the role of Chinese universities in scientific and technological innovation and talent training cannot be ignored.

In recent decades, the Chinese government has invested heavily in education to speed up higher education development. Project 211 and Project 985 are two of the most notable efforts and initiatives. The name for Project 211 comes from an abbreviation of the slogan "In preparation for the 21st century, successfully managing 100 universities." Project 211, which began in 1995, eventually grew to include 112 universities that had achieved a high level of personnel training and scientific research (Yaisawarng & Ng, 2014). Universities that have been selected for Project 211 were accompanied by special grants from both the central and local governments. From 1995 to 2005, a total of 36.83 billion CNY was invested in Project 211. From 2007 to 2011, over 10 billion CNY was allocated by the central government for Project 211.

Building on the foundation of Project 211, Project 985 was officially launched in 1998. The name, Project 985, derives from the date of the announcement, May 1998, or 98/5, according to the Chinese date format. With Project 211 and Project 985, the initiatives to develop Chinese universities into world-class universities have evolved into national strategies (Ying, 2011). Project 985 was divided into three phases and included 39 universities. (The “985” universities must be “211” universities, and “211” universities are not necessarily “985” universities; that is, “985” universities can obtain resources not only from Project 985, but also from Project 211. Therefore, the resources obtained by “985” universities from the government are much higher than “211” universities.)

The investment in Project 985 was greatly increased compared with Project 211. In the first phase (1998–2003), investment in Project 985 reached 22.77 billion CNY. Total investment in the second phase (2004–2009) decreased slightly to 22.58 billion CNY. Grants for the third phase (2010–2015) were as high as 45.12 billion CNY. As a result, substantial resources have been invested in Project 211 and Project 985 universities since the year 1995.

RESEARCH QUESTIONS

This research attempts to shed light on two key questions:

- Do more investments in universities enhance their performances?
- What are the factors affecting the performance of universities?

In this research, the performance of 60 Chinese higher education institutions from 2006 to 2016 was studied. These 60 universities are top-tier universities in the Chinese higher education system, and all of them are directly under the Chinese Ministry of Education. In addition, these 60 universities were selected because of the availability of data and their comprehensiveness in offering degrees (i.e., not specialized universities that offer limited degrees). Furthermore, some universities are tied to the defense industry, and the data for these universities were not available. These 60 universities received substantial investments from the Chinese government, and they provided a good representation of top-tier comprehensive universities in China. In 2006, the Chinese government invested about 84.19 billion CNY in these 60 universities, and in 2016, the government increased its investment to 195.75 billion CNY. In addition, these universities obtained continuous financial and resource support from Project 211 and Project 985.

Because the Chinese government targeted these 60 universities to lead the education transformation in China and they evolved rapidly in the last two to three decades, these universities provide an excellent sample to study the relationship between investment and university performance. In this research, we used data from 2006 to 2016. The reason for the time frame is that the Project 211 and Project 985 programs were replaced by the Project Double First-Class program in 2017. With the introduction of the Double First-Class program, which means World First-Class University and First-Class Academic Discipline Construction, the Chinese government stopped providing comprehensive data related to university performance in 2018.

LITERATURE REVIEW

Colleges and universities receive huge amounts of funding because of their potential to add value to national economic construction and social development (Ziberi et al., 2022). Furthermore, higher education disseminates and transforms knowledge into economic growth (Chang et al., 2016; Li & Wye, 2022). Because huge public funding is invested, Johnes et al. (2017) argued that it is essential for the education system to operate as efficiently as possible. Evaluating and improving university performance have long been a priority for educational research scholars and politicians. The simplest

operating measure is the conversion of educational inputs into educational outputs via a production process (Worthington, 2001), and efficiency occurs when educational outputs are produced at the lowest resource level. When panel data are available, researchers can use the Data Envelopment Analysis (DEA) to assess university performance (Agasisti et al., 2021; An, 2022).

Sustained and substantial investments in colleges and universities from the Chinese government have resulted in remarkable growth in personnel training and scientific research (Hu et al., 2020). China has established the world's largest higher education system. According to Trow (1974), the development of higher education can be conceptualized into three levels—elite, mass, and universal. At the elite education level, the higher education systems enroll up to 15% of secondary/high school graduates. At the mass education level, the systems enroll between 15% and 50% of secondary/high school graduates. Systems that enroll more than 50% are at the universal level.

From 2003 to 2019, China's higher education moved from the mass education level to the universal education level. In these 16 years (i.e., 2003–2019), China's gross enrollment rate in higher education increased from 15% in 2002 to 51.6% in 2019. The fast transformation of the Chinese education system and the rapid evolution of government policies on higher education in China make the Chinese higher education environment an excellent case for many education-related studies.

With the increase in educational funds from 32.68 billion CNY in 1996 to 212.98 billion CNY in 2004, the research efficiency of 109 Chinese universities was studied by Johnes and Li (2008). They found that those universities located in the coastal region were more efficient than those in the Western region, and comprehensive universities had higher efficiency than specialized universities. Although Chinese coastal universities received more resources (teaching staff, research staff, and research funding) than non-coastal universities, the social science research performance had no significant differences between those two regions (Ng & Li, 2009).

Another research study by Ding and Zeng (2015) examined the performance of 68 Chinese universities directly under the Ministry of Education. Although these 68 universities obtained more funding from the central government, the results surprisingly showed an inefficiency from 2002 to 2011 (Ding & Zeng, 2015). These studies' results were not intuitive to comprehend because additional funding did not result in enhanced performance. In other words, the results are contradictory to expectations. Nevertheless, some studies did show performance improvement with more investment.

With Project 211, additional funding of 130 billion CNY was allocated to Project 211 universities, which should theoretically strengthen their research capabilities and make them perform better than non-Project 211 universities (Yaisawarng & Ng, 2014). One research study showed that the huge investment provided by Project 985 increased the rate of growth of publications in international journals for "985" universities (Zhang et al., 2013). Similarly, another study showed that the productivity of "985" universities was much better than those of non-"985" universities during the period from 2010 to 2013 (Yang et al., 2018). However, Chen et al. (2021) reached the opposite conclusion that the productivity of non-"985" universities was significantly higher than that of "985" universities in terms of operating efficiency. These studies have different conclusions based on their data and analyses. Thus, the relationship between investment and university performance is unclear, complex, and convoluted.

Despite many research studies that have investigated the relationship between investments in universities and their performances (Chen et al., 2021; Yang et al., 2018; Zhang et al., 2013; Ziberi et al., 2022), the relationship is still fuzzy. It should be noted that existing research works mainly focus on short-term performance brought by sustainable investments. Comprehensive studies that are long term in scope are extremely rare. In addition, few researchers studied other influencing factors that impact university performance. This research aims to bridge these research gaps.

In this research, the correlation between investment and performance of 60 premier Chinese universities from 2006 to 2016 (i.e., a long-term view) is studied. Furthermore, this research investigates some key factors affecting university performances, and these factors may provide clues on the contradictory results thus far in the existing literature.

METHODOLOGY AND DATA

DEA

This study uses a DEA-based Malmquist productivity index developed by Fare et al. (1994). DEA is a non-parametric method that has been applied in analyzing the efficiency of universities (Agasisti & Wolszczak-Derlacz, 2016; Mammadov & Aypay, 2020; Veiderpass & McKelvey, 2016). The total factor productivity (TFP) changes of a given university between two periods are evaluated through Malmquist indices (Malmquist, 1953) that reveal productivity changes occurring among universities over various periods. Accordingly, a university's efficiency can be measured by the production set shown in equation (1):

$$\Psi^t = \{(x_t, y_t) : | y_t = f(x_t)\} \quad (1)$$

In this equation, x denotes a vector of N inputs, and y denotes the vector of M outputs in period t . The Malmquist index given in equation 2 is then calculated as the geometric mean of two indices: T_1 related to the period t_1 and T_2 related to the period t_2 :

$$MI_{i(t_1, t_2)} = \left[\frac{D_i^{t_1}(x_{t_2}, y_{t_2})}{D_i^{t_1}(x_{t_1}, y_{t_1})} \times \frac{D_i^{t_2}(x_{t_2}, y_{t_2})}{D_i^{t_2}(x_{t_1}, y_{t_1})} \right]^{1/2} = [T_1 \times T_2]^{1/2} \quad (2)$$

In equation (2), D_i represents the distance function of the given decision-making unit (DMU) that represents a university; x and y are input and output variables that are related to two periods of time t_1 and t_2 .

In the context of universities, output-oriented models are frequently used because the purpose of a university is to maximize outputs. The output distance function is calculated as the inverse of technical efficiency (Farrell, 1957), as shown in equation (3):

$$D_i^t(x_{t,i}, y_{t,i})^{-1} = \left(\sup \{ \theta \mid (x_{t,i}, \theta y_{t,i}) \in \Psi^t \} \right), t = t_1, t_2 \quad (3)$$

In equation (3), $x_{t,i} = (x_{t,i1}, \dots, x_{t,ip}, \dots, x_{t,iP})$ represents inputs, and $y_{t,i} = (y_{t,i1}, \dots, y_{t,iq}, \dots, y_{t,iQ})$ represents outputs of a given DMU. Under a constant return-to-scale (CRS) technology (Charnes, et al., 1978), the distance function can be expressed as a linear programming function shown in equation (4):

$$\hat{D}_i^t(x_{t,i}, y_{t,i})^{-1} = \max(1/\theta) \quad (4)$$

This programming function is subject to the calculations shown in equation (5):

$$\sum_{j=1}^N \lambda_{t,j} y_{t,jq} - \theta y_{t,iq} \geq 0, \quad q = 1, \dots, Q$$

$$x_{t,ip} - \sum_{j=1}^N \lambda_{t,j} x_{t,jp} \geq 0, \quad p = 1, \dots, P$$

$$\lambda_{t,j} \geq 0, j = 1, \dots, N \tag{5}$$

In equation (5), $\lambda_t = (\lambda_{t,1}, \dots, \lambda_{t,N})$ are the nonnegative weights that form a convex combination of observed DMUs relative to the efficiency of the subject’s DMU. $1/\theta$ is the technical efficiency score of the j_{th} DMU. The variable return to scale (VRS) requires an additional condition that $\sum \lambda = 1$ (Banker et al., 1984).

The equations in this section interpret the Malmquist index as the change in TFP. $MI > 1$ indicates positive TFP growth, while $MI < 1$ is a sign of TFP decline.

Dataset

Colleges and universities use multiple inputs (including academic staff and money) to produce multiple outputs (including students and research publications). Although many outputs of higher education institutions are difficult to measure and quantify (Brewer et al., 2010), the commonly accepted view is that universities tend to invest their limited resources in training students and improving research quality (Zhang et al., 2016). Thus, we assembled a panel dataset spanning 2006 to 2016 that consists of 60 universities that are directly managed by the Chinese Ministry of Education. These universities are all in China’s 211 program, and 28 of them are also in China’s 985 program. As a group, these universities have similar missions and goals. This similarity satisfies the homogeneity of the decision-making units requirement of the DEA method.

We extracted from the Compilation of Basic Statistics of Universities under the Ministry of Education, Essential Science Indicators (ESI) database, China National Knowledge Internet, and the National Natural Science Foundation of China. After removing universities with missing data on any of the defined inputs and outputs, we obtained a panel dataset consisting of 60 universities. The variables in the dataset are shown in Table 1 and discussed in this section.

We included two inputs in the analysis—Revenue and Teacher. Revenue represents materials investment, and the number of teachers is a measure of human investment. The variable Revenue is the sum of all financial sources and activities; this variable is a key input that affects university efficiency and has been used in many research studies (Chen et al., 2021; Katharaki & Katharakis,

Table 1. Definition of Variables Used in the Analysis

Type of variable	Variable	Description
Input variables	Revenue	Total government budget subsidy
	Teacher	Number of full-time academic teachers
Output variables	Graduate	Number of graduates
	ESI	Number of papers published in Essential Science Indicators
	CNKI	Number of papers published in China National Knowledge Internet
	NSF	Number of projects funded by the National Science Foundation
	Patents & Reports	Number of patents granted and reports adopted
Environmental variables	Prof_Teach	Percentage of teachers with professor title
	Grad_Teach	Postgraduate-teacher ratio
	CA_Stu	Average campus area per student
	AA_Stu	Average architectural area per student
	Merger	Dummy variable indicating whether the university has been merged
	Med	Dummy variable indicating whether the university has a medical school
	President	Average tenure of the university presidents

2010; Ng & Li, 2009; Yang et al., 2018). The vast majority of revenue for Chinese universities comes from government education grants. The variable Teacher is based on the number of full-time academic teachers employed and consists of four levels: professor, associate professor, assistant professor, and lecturer. Teaching and research are this variable's main responsibilities. In this study, we regarded full-time teachers as the main human resource input because they are the core force for student cultivation and scientific research. Some existing literature works include a broader set of input variables, such as teacher-to-student ratio, percentage of academic staff with a professor title, the proportion of postgraduate students, research expenditures, library books, and building space (Ding & Zeng, 2015; Johnes & Yu, 2008; Yaohua et al., 2018). However, Revenue and Teacher are the two most representative input variables and are highly correlated with other variables in the Chinese higher education system. These two input variables are critical to a university's performance.

The measurement of university outputs is less standardized. The measurements revolve mainly around teaching and research outputs. Most researchers focus on university research output because the data is easy to access. In this research, we defined the variable Graduates as the teaching output; this variable includes all undergraduate and graduate students (Chen et al., 2021; Yang et al., 2018). Considering that there is no systematic way to measure the quality of graduates, we used the number of graduates in this research. For this research, the research outputs are Publications, Patents, Funded Research Projects, and Prizes, all of which are commonly used in other studies as well (Chen et al., 2021; Yaisawarng & Ng, 2014; Yang et al., 2018; Zhang et al., 2016). We used these four variables as research outputs:

- ESI is an indicator of research production that emphasizes international publication outlets (Yaohua et al., 2018).
- CNKI is an indicator of research production that measures domestic research output.
- NSF represents the number of programs supported by the National Science Foundation. NSF is a competitive program for all universities and mainly includes the General Program and the Distinguished Young Scholars Program. Thus, the number of programs can reflect the overall research level of universities more than the amount of funding.
- Patents and Reports can be interpreted as an indicator of technology and knowledge transfer activities. This variable represents the degree of participation of a university in social service (Chen et al., 2021).

The input and output variables chosen in this research represent the commonly used human and physical resources that are generally used to study the efficiency and productivity of university operations. In addition, these chosen variables are similar to those used in other published literature (Chen et al., 2021; Wolszczak-Derlacz, 2017; Yang et al., 2018).

RESEARCH RESULTS

Data on Chinese Universities

Table 2 presents some descriptive statistics on the input and output variables over 11 years (i.e., 2006–2016). Rather than presenting all the raw data, we used the year 2006 as the base. For each subsequent year, the percentage changes compared with the base year are presented. This presentation provides the necessary insights into the dynamic changes over 11 years for the selected 60 universities.

Revenues and teachers are the two main resources for universities' development. In Table 2, note that Revenues more than doubled, and the number of Teachers increased steadily from 2006 to 2016.

On the output side, the number of graduates increased slightly every year. The institutional research output measures—namely, ESI and CNKI—serve as proxies for international and domestic research publications. The number of publications is usually used in the literature to indicate the overall “pool”

Table 2. Model Variables: Changes from 2006–2016 Academic Years (%)

Inputs (2)			Outputs (5)				
Year	Revenues	Teachers	Graduates	ESI	CNKI	NSF	Patents and reports
2006	100	100	100	100	100	100	100
2007	110.79	102.44	106.68	110.46	99.90	115.37	93.90
2008	116.38	104.87	111.49	126.13	104.40	133.42	83.01
2009	126.81	107.21	113.38	145.79	109.39	148.97	100.43
2010	138.72	109.29	114.00	159.18	106.13	196.00	125.76
2011	158.33	110.99	119.11	185.74	101.77	243.99	163.67
2012	171.87	150.88	124.28	216.15	97.57	254.01	212.18
2013	176.99	114.21	126.59	252.77	95.15	250.58	220.03
2014	194.36	116.14	127.39	291.51	93.23	242.91	214.67
2015	212.08	117.65	128.40	327.59	90.79	261.24	265.14
2016	232.52	118.77	128.52	362.47	88.13	255.54	302.97

of current expertise at an institution (Toutkoushian et al., 2003). The ESI data in Table 2 shows that the number of papers published in international journals increased every year—for example, the mean for 2016 is 362.47% of the mean for 2006. The CNKI data, on the other hand, indicates a decrease in the number of papers published in domestic journals from 2012 to 2016. Chinese universities focused more attention on publishing international papers for international academic reputation and higher ranking. Therefore, more research papers are published in international journals than in domestic journals. However, in recent years, Chinese universities may have changed their preferences in publishing venues. The Ministry of Science and Technology and the Ministry of Education of the People’s Republic of China published two official documents:

- Measures to Eliminate the Erroneous “Paper Only” Mentality in Science and Technology Evaluation (Trial, 2020).
- Suggestions on the Appropriate Usage of Relevant Indicators of SCI Papers to Establish Correct Evaluation Orientation (2020).

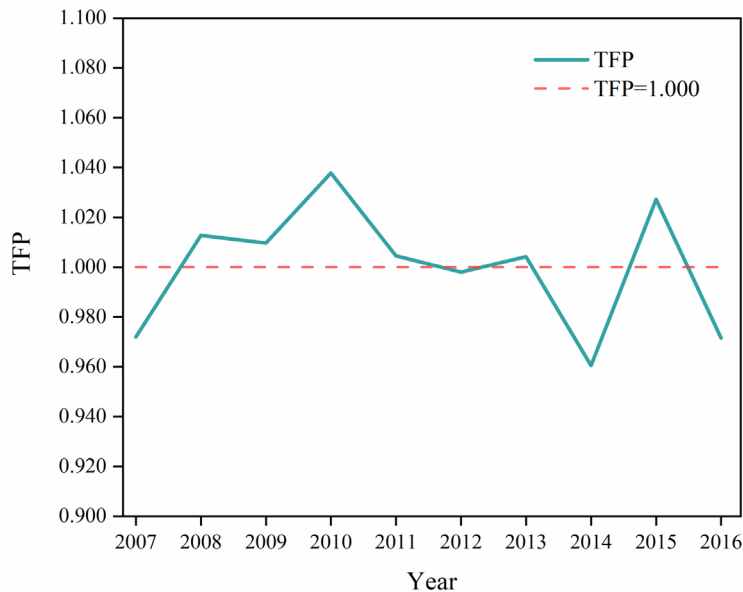
These documents were published to encourage teachers and researchers to pay more attention to high-quality and impactful research and focus on innovative research masterpieces. Chinese researchers are also encouraged to publish their research findings in domestic journals. The effects of these two official documents and how the universities will evolve their policies are still not clear at this time.

As expected, the number of patents and consulting reports, which is a measure of social service, shows an increase in the latter part of the period. In 2016, the number of patents and consulting reports was 302.97% of the number in 2006. This data demonstrates that Chinese universities emphasize the importance of both social and academic reputations in building first-class universities.

Assessment of Changes in Productivity Over Time

In the first stage, productivity scores are obtained by the DEA-based Malmquist index. Figure 1 presents the average annual changes in the TFP of 60 universities. Although revenue more than doubled and maintained continuous growth from 2006 to 2016, the values of TFP, which fluctuated between 0.950 and 1.050, did not achieve sustained growth. Note that a TFP greater than one indicates

Figure 1. Annual Changes in TFP for the Period 2007–2016



positive growth, whereas a TFP smaller than one is a sign of performance decline. Looking at the 60 universities as a whole, they achieved improvements in productivity in six out of 10 years and declined in four years. This pattern indicates that a continuous increase in annual investment can promote productivity growth, but not all the time. Other factors that affect university performance should be considered.

To understand the relationship between input variables and the TFP growth of every university over the period, we present in Table 3 the number of growth years. Sixteen universities had more than five years of growth (out of 10 years) in TFP from 2007 to 2016. The other 44 universities showed no more than five growth years in TFP. Almost all universities had a positive annualized growth rate of revenue, with SWU being the highest, reaching 14.25%, and JIANGNAN being the lowest, reaching only 4.86%. The annualized growth rate of the number of teachers in the 60 universities fluctuated between -1.77% (HUST) and 5.99% (CUFE). There is no obvious correlation between the number of TFP growth years and the annualized growth rate of revenue and teacher. This indicates that continuous large investments do not necessarily lead to the continuous growth of TFP.

Table 4 further presents the annual average values and annualized growth rates over the selected 11 years according to university project type (i.e., Project 985 or Project 211 university). For both Project 985 and Project 211 universities, the average revenue more than doubled in 2016 compared with 2006. The university's average revenue had an annualized growth rate of 8.90% for Project 985 universities and 8.53% for Project 211 universities. The teacher did not show as significant growth rates as revenue did. The average number of teachers at Project 985 and Project 211 universities grew by a small 1.59% and 2.02%, respectively. Although the average revenue and teacher of Project 985 universities was much higher than those of Project 211 universities, their annualized growth rates were similar. There was no significant difference in the average number of growth years of TFP between Project 985 universities and Project 211 universities, which are 4.69 and 4.54 years, respectively. Therefore, Project 985 universities did not show higher performance although they obtained more resources. The Independent Samples t-test = 0.729 > 0.05 indicates that there is no significant difference between Project 985 universities and Project 211 universities.

Table 3. Growth Years of TFP and Annualized Growth Rate of Input Variables in the 60 Universities

University in Project 985	Number of TFP Growth Year (TFP>1)	Annualized Growth Rate of Revenue	Annualized Growth Rate of Teacher	University in Project 211	Number of TFP Growth Year (TFP>1)	Annualized Growth Rate of Revenue	Annualized Growth Rate of Teacher
OUC	4	11.99%	4.06%	SWU	3	14.25%	1.40%
UESTC	1	11.37%	3.65%	BUCT	6	13.26%	2.80%
XMU	5	10.91%	1.96%	NJAU	1	12.09%	1.87%
XJTU	5	10.37%	2.58%	CUFE	6	11.10%	5.99%
TJU	5	10.35%	2.59%	HZAU	4	10.97%	2.04%
NANKAI	2	10.29%	1.89%	NENU	4	10.70%	1.16%
NEU	3	10.22%	2.93%	SNNU	3	10.10%	2.82%
NWSUAF	2	10.20%	3.48%	CCNU	3	9.43%	3.61%
TSINGHUA	4	9.69%	3.89%	HHU	5	9.34%	2.04%
ZJU	7	9.36%	-0.10%	SWUFE	5	9.34%	4.71%
LZU	3	9.23%	2.10%	XIDIAN	4	9.33%	1.73%
CSU	3	9.05%	1.48%	SHUFE	4	8.81%	0.93%
ECNU	3	9.02%	2.95%	BJTU	4	8.50%	2.48%
SDU	5	8.99%	1.53%	HFUT	6	8.30%	1.86%
NJU	4	8.96%	0.96%	BJFU	3	8.12%	2.33%
SYSU	6	8.93%	2.67%	SWJTU	4	8.10%	1.96%
SJTU	9	8.92%	-0.33%	DHU	4	8.02%	0.45%
BNU	3	8.89%	2.05%	ECUST	6	7.59%	1.78%
WHU	4	8.80%	0.90%	CUC	4	7.25%	1.41%
JLU	6	8.71%	1.04%	USTB	4	7.05%	2.12%
SCU	5	8.57%	1.59%	CHD	7	6.92%	2.73%
PKU	7	8.52%	1.05%	ZUEL	4	6.74%	0.93%
FUDAN	8	8.49%	1.50%	NCEPU	6	6.70%	1.59%
HNU	5	8.43%	0.11%	BUPT	5	6.46%	4.41%
HUST	5	8.39%	-1.77%	UIBE	5	6.27%	3.95%
DLUT	7	8.04%	3.69%	NEFU	5	5.96%	0.98%
RUC	2	7.71%	1.10%	WHUT	5	5.38%	0.29%
SEU	5	7.33%	3.01%	JIANGNAN	7	4.86%	1.60%
SCUT	5	7.13%	2.15%				
TONGJI	8	7.02%	0.17%				
CQU	7	6.77%	0.54%				
CAU	2	6.21%	1.51%				

Table 4. University Annual Average Values and Annualized Growth Rates over Selected Years

Project	Number of Universities	Average Revenue (10 million)		Annualized Growth Rate of Revenue	Average of Teacher		Annualized Growth Rate of Teacher	Average Growth Year of TFP
		Y2006	Y2016		Y2006	Y2016		
985	32	197.08	462.11	8.90%	2386	2793	1.59%	4.69
211	28	75.44	170.99	8.53%	1425	1740	2.02%	4.54

The first research question is related to whether more investments in universities enhance their performance. These research findings do not support the common expectations; the findings show that more investments in universities do not necessarily lead to consistent enhancement in TFP. Educational institutions are complex entities. University performance is also influenced by environmental factors, such as disciplinary structure, academic level, student-teacher structure, resource allocation, and management patterns. These factors are rarely studied in the existing literature. In this research, we investigate the factors that affect the performance of universities. In the following sections, we further explore factors that influence the performance of universities.

Determinants of TFP Growth

Based on the data and analysis of the first research question and to explore the determinants of TFP growth, we treated the TFP, which is estimated by equation (6), as the dependent variable in the regression equation. In the following analysis, we introduced and studied seven environmental variables (see Table 1) that may affect the universities' productivity growth.

Prof_Teach presents the percentage of teachers with a professor title. This allows us to discuss whether a higher percentage share of professors in the teacher body is associated with higher productivity (Quiroga-Martínez et al., 2018). Grad_Teach is a ratio of postgraduate enrollments to teachers. Although it is a time-consuming job to train postgraduate students to enhance research, postgraduate students can assist teachers in doing research and exploring new research areas. CA_Stu and AA_Stu are the basic indicators of a university's sustainable development, representing campus area (CA) and architectural area (AA) per student. Larger values indicate that more teaching rooms and laboratories can be accommodated and that more campus service facilities can be built. A dummy variable, Merger, indicates whether the university is a result of merger(s). Merging is equal to one if the current university is a result of merging and zero otherwise. From 1992 to 2004, to enhance education efficiency, effectiveness, and quality, there were more than 400 mergers in China's higher education (Cai & Yang, 2016). Merges enable universities to fully integrate their existing resources and realize economies of scale within a short period (Kang & Liu, 2021). Another dummy variable, Med, indicates whether the university has a medical school. Universities with medical schools could have a higher academic reputation and research outputs, but they must invest more resources to support medical schools' development. Therefore, the impact of having a medical school on TFP is complicated. The variable, President Months, measures the average number of months presidents stayed at a particular university starting from 1978. (Note that if the tenure of a president is less than 30 months, we did not include the tenure of that president because less than 30 months is too short of a time frame to have a lasting impact on the directions of a university.) We included this variable because university presidents are appointed directly by the Ministry of Education, and presidents play a guiding role in the direction of university development. In the first stage, we did not find that 985 universities showed better performances than 211 universities. Thus, the dummy variable, Project 985, was not considered in the following regression analysis.

According to the proposed variables, we established the model in the form shown in equation (6):

$$TFP_{i,t} = \alpha + \beta_1 Prof_Teach_{i,t} + \beta_2 Grad_Teach_{i,t} + \beta_3 CA_Stu_{i,t} + \beta_4 AA_Stu_{i,t} + \beta_5 Merger_i + \beta_6 Med_i + \beta_7 PresidentMonths_i + \chi_i + \nu_t + \mu_{i,t} \quad (6)$$

In equation (6), i refers to a single university, and t denotes the time. The dependent variable is TFP growth, and it is calculated as shown. Time dummies ν_t are included to incorporate time-specific effects (because of mergers and reforms). To pick up any unmeasurable institutional effects, we added individual institutional effects χ_i . $\mu_{i,t}$ is an error term. β_k ($k=1, 2, \dots, 7$) represents the coefficients.

We applied a feasible generalized least squares (GLS) estimator with a heteroskedastic error structure in this study. Table 5 presents the results when the TFP is used as the dependent variable. In Table 5, five alternative specifications are shown depending on the variables included. The four additional factors—Grad_Teach, CA_Stu, AA_Stu, and President Months—are expressed in natural logs for ease of interpretation.

The column labeled (1) in Table 5 lists the estimates obtained by using Prof_Teach and Grad_Teach as independent variables. Similarly, columns (2) to (5) include additional factors. For columns (1) to (4), a total of 600 data points each from the 60 universities from 2006 to 2016 were used. For column (5), only 490 data points re used because the President Months are not complete for all the universities.

Table 5 indicates that the variable Prof_Teach has a negative impact on TFP growth, but only column (1) is statistically significant. These results are different from those offered by Dundar (1998) and Quiroga-Martínez (2018); these researchers found that high-ranked professors have a positive and significant impact on efficiency levels. It could be the reason that high-ranked teachers have less motivation in teaching and research—some of them may do the bare minimum, and others may pursue basic research or research that is of interest to them without the pressure to publish regularly.

Except for column (5), the variable Grad_Teach has a significant positive impact on TFP growth. Usually, graduate students not only contribute to teaching output but also play an important role in research outputs. Hence, many universities are expanding the scale of graduate student enrollment.

For the next two variables (CA_Stu and AA_Stu), an interesting phenomenon is observed. The variable CA_Stu has a positive impact on the TFP (for columns 2–4), whereas the variable AA_Stu has a negative impact on TFP. Except for CA-Stu in column (5), the others are all statistically significant at the 0.1 or 0.05 level. In other words, the campus areas and architectural areas affect a university’s productivity, but these two factors have the opposite effect on the growth of TFP. Generally, more campus areas made it possible for the universities to expand during the 11 years of the rapid development of higher education in China. However, architectural areas require financial resources to maintain.

When the dummy variable Merger is included, the coefficients are positive and significant in the last three columns. This finding indicates that university mergers at the beginning of the 21st century promote the long-term development of universities. For the dummy variable Med (medical school), the coefficient is negative and significant in column (5). In other words, the benefit of having a medical school for a university is uncertain and should be carefully studied. The medical school may consume a lot of resources, and this may delay the development of other units in the university. The inherent relationship should be balanced carefully.

Finally, the last variable, President Months, turns out to be positively correlated with TFP growth. This finding is not surprising because consistent leadership promotes growth. This finding also indicates that the effective and sustainable development of a university is associated with stable management.

Table 5. Determinants of TFP Growth

Variables	(1)	(2)	(3)	(4)	(5)
Prof_Teach _{<i>i,t</i>}	-0.338**	-0.220	-0.220	-0.220	-0.180
Ln(Grad_Teach) _{<i>i,t</i>}	0.077***	0.063***	0.063***	0.063***	0.041
Ln(CA_Stu) _{<i>i,t</i>}		0.023*	0.023*	0.023*	0.021
Ln(AA_Stu) _{<i>i,t</i>}		-0.050*	-0.050*	-0.050*	-0.056**
Merger _{<i>i</i>}			0.108***	0.066*	0.142***
Med _{<i>i</i>}				0.042	-0.103***
Ln(President Months) _{<i>i</i>}					0.237***
Obs	600	600	600	600	490

Note: Estimations were performed using GLS. Constants were not reported. Year and institution dummies were included in all models. Consider heteroscedasticity with no autocorrelation. ****p*<0.01, ***p*<0.05, **p*<0.1.

DISCUSSIONS AND RESEARCH CONTRIBUTIONS

To summarize, the research results show that increased investments in higher education institutions do not necessarily lead to better performance. Other factors, such as the number of postgraduate students and stable leadership, can affect the outcomes, and these factors need to be further studied, understood, and managed.

This research differs from other studies in at least two key aspects:

- It investigates the relationship between investment and higher education institutions' performances over a long period of 11 years compared with much existing research work that only used a few years of data.
- It studies other factors, which have been ignored in prior research, that may affect a university's performance.

This research contributes to the literature in the area of educational investment and provides insights to develop a theoretical and conceptual model of higher education investment. The model can help other countries in developing their investment strategies. Investment in higher education is an investment that benefits the development of human capital and promotes economic growth, which is the reason why countries around the world pay attention to investment in higher education. However, the relationship between investment in a university and university performance is not necessarily positively correlated all the time; that is, more investments need not result in better university performance. Some internal factors in universities—such as management systems, faculty and student structure, discipline settings, and resource allocation methods—can affect university performance.

Practically, the results of this research help higher education administrators and officials develop implementation and managerial plans. Based on the research results, we believe one possibility is for the government to allocate higher education resources more evenly instead of concentrating the investments on specific universities because this study indicates that more investments do not necessarily lead to better performance. Investing in universities with special features and those with high-growth potential could improve the use of educational funds and enhance competition among universities. Top universities should also be able to solicit funding and donations from private entities and alumni to supplement their public funding. Public funding is limited, and universities should improve their performance by improving their management effectiveness and optimizing resource allocation, such as the application of big data analytics in investment management (Eachempati & Srivastava, 2022), building management information systems to track the use of resources, adjustment of resource allocation strategy, and improvement in the efficiency of resource use.

The law of diminishing marginal returns of university investments is a possible explanation for some of the surprising results. The law of diminishing returns is an economic principle, and it argues that as investment increases, the rate of return from that investment, after a certain point, cannot continue to increase at the same rate if other variables remain constant. As such, it is important to study other factors when considering the relationship between investment and the performance of higher education institutions. In this research, we included other possible factors that affect the university's performance and investigated the relationship using a regression model. The research shows that the university's performance is also influenced by various factors such as student population, land area, and management structure and policies. The ceiling effect is another possible explanation. The top universities may already be functioning at close to the optimal level. Thus, the continuous investment may not produce additional performance enhancement.

How to improve university performance has become a global concern for higher education institutions. With advances in science and technology, such as big data, artificial intelligence, online education, and metaverse (Wan et al., 2022), universities can draw on these technologies to improve their traditional delivery models to enhance performance (Wang & Siau, 2019). We offer four suggestions to improve university performance.

First, big data and data science techniques can be used to provide valuable reference data for university management decisions by measuring, recording, storing, counting, and analyzing data on a large scale and over time. With a large amount of data, prediction, clustering, and relationship-mining techniques can be used (Yang et al., 2022). Prediction technology allows administrators to better evaluate the possibility of various outcomes, such as enrolment and placement trends, and the development and growth of various disciplines. Clustering technology helps administrators to discover naturally concentrated data points, such as population movement and the popularity of certain disciplines. Relationship-mining technology can discover relationships between various variables, which is useful for exploring and understanding the complex relationship between university investments and multiple outputs. Information technologies that are used to record, analyze, and manage financial data can be enhanced to manage money at the source and monitor how well a university is spending the investment. In short, advanced information systems and techniques can be better used to improve a university's performance.

Second, artificial intelligence (AI) can provide personalized education for students according to their aptitude, learning style, and progress (Siau, 2018). AI can provide teachers with a powerful teaching tool and assist teachers in creating smart content, automating testing, and monitoring student progress. AI can also help to manage the campuses by automatically adjusting the temperature levels and switching off lights to conserve energy. This is the dawn of the AI age (Hyder et al., 2019; Siau & Wang, 2020), and AI technologies can potentially greatly improve the performance of student learning, pedagogy, and administrative management.

Third, online education has alleviated time and space constraints and enabled quality education to be delivered at any time and to any place (Chen & Siau, 2016; Erickson & Siau, 2003). It also circumvents the limit of a university's land area, the number and size of classrooms, and the number of students. With online education, a higher education institution can now serve students beyond its traditional geographical area and can provide quality education to remote regions of the country and the world. Also, online education has been widely used during the COVID-19 pandemic, and many teachers and students are now accustomed to online education (Xie et al., 2020). The post-pandemic years provide golden opportunities to further enhance and develop online education to boost university performance.

Four, the metaverse is the blending of the virtual world and the real world (Wang et al., 2022). Metaverse or its predecessors (e.g., Second Life) is especially suitable for immersive learning to better interact with and engage the students (Siau et al., 2010). For example, in learning history, metaverse technology allows students to walk in the streets of ancient times, witness the social custom of the time, and even have a dialogue with the sages. In learning science, metaverse technology can simulate expensive reagents and equipment to enable practical hands-on training for students. For scientific studies that are dangerous (e.g., mining or nuclear engineering or explosive engineering), metaverse technology can protect the lives of teachers and students and provide a realistic training experience at the same time. Metaverse technology and its application to education are at a budding stage. It has the potential to greatly save education costs, provide more educational opportunities, and create better educational conditions. All of these can be useful paths to improve a university's productivity.

CONCLUSION, LIMITATIONS, AND FUTURE RESEARCH DIRECTIONS

Budget reduction in many higher education institutions is currently a norm across the world. In the wake of the COVID-19 pandemic, many governments have reduced their spending on universities. Ensuring that higher education institutions are providing an excellent return on investments is vital to getting continuing government support and instilling public confidence. Based on the DEA model, we used a set of comprehensive panel data over a considerable length of time (2006–2016) to explore the relationship between investment and performance of 60 Chinese universities.

We carried out a two-stage analysis, combining non-parametric and parametric methods, to study two research questions: Do more investments in universities enhance their performances? What are the factors affecting the performance of universities?

For the first question, the results of the first stage analysis showed steady and modest growth in productivity over the years, with the TFPs fluctuating between 0.950 and 1.050. In general, we expect that more investments can bring performance growth. But Project 985 universities, which have more investments, did not show better performance than Project 211 universities. In other words, there were no observable differences in TFP between Project 985 and Project 211 universities, even though Project 985 universities obtained more capital and human resource investments. Some possible explanations, such as the law of diminishing marginal returns, were discussed in the paper.

For the second question, we investigated the possible factors that have a positive effect on the university's performance using a regression model. The results revealed four key findings:

Finding 1: Postgraduate enrollment has a positive effect on the productivity of a university. This is especially true for Ph.D. students because they can contribute to research. The competition between countries is a talent competition. National education policies should pay more attention to postgraduate student cultivation.

Finding 2: Land is a basic physical resource that is necessary for university expansion. The scarcity of land resources can be alleviated by the efficient use of campus areas, but short-term construction to increase campus architecture areas will crowd out teaching and research resources. Online education and the metaverse were discussed as possible ways to alleviate the land constraint.

Finding 3: For the management structure of a university, the results show a positive impact of university mergers on productivity growth. The initiative of merging universities and colleges at the beginning of the 21st century demonstrates a profound and lasting impact on the development of higher education in China. Some small colleges with unique characteristics and those that catered to a specific discipline (e.g., accounting, agriculture, medicine) have been merged, making many Chinese public universities more comprehensive. Consequently, merged universities can take advantage of larger and varied resource inputs to achieve rapid growth and enhance competitiveness.

Finding 4: Research results show that the tenure of presidents has a positive impact on productivity growth. This finding demonstrates that the stability of university management is important. This research, like others, has its limitations. First, the research is based on data from 60 premier Chinese universities. The results may not be generalizable to other Chinese universities or universities in other countries. Replicating this research using data from other Chinese universities or higher education institutions in other countries will be the next step in this stream of research. Second, these 60 premier Chinese universities receive funding from the Chinese government. Thus, the results may not be the same for private institutions. Premier private universities may have more financial resources than these 60 Chinese public universities. On the other hand, smaller private higher education institutions may face more financial constraints. Studying the relationship between financial resources and the performance of private institutions is another possible extension of this research. Third, because of the unavailability of the data for some years, the research conclusions are based on a single block of years (2006–2016). Using multiple multiyear blocks (e.g., a comparison of the years 2006–2016 with 2005–2015, 2004–2014, and so on) to run the same analysis can enhance the robustness of the research. Fourth, this research studied only certain environmental factors that affect university performance (e.g., economic factors). Future research can explore economic factors and other factors in a society that may have a positive or negative impact on a university's productivity.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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