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Economies of Scale in Taiwan Higher Education: An Application of Quantile-on-Quantile Regression Approach

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Abstract

For the driven that the DEA conducted a series of researches on the efficiency of higher education insituitions (HEIs), yet the outcome of them is still incapable of guiding the higher education clearly to improve their efficiency and performance. For the purpose of capturing the performance and efficiency of higher education of Taiwan, which is regarded not only as a key information to inspect the efficiency of higher education, but also can be taken to direct the higher education reform, we first calculate the performances and productivity index by utilizing the DEA model. Further we shed new light on the intrigue relationship between total factor productivity and the technical efficiency by using a novel quantile-on-quantile regression approach so as to provide more information to discuss whether the technical efficiency has different impact on total factor productivity under different quantiles.

Keywords

Quantile-on-Quantile Regression, Taiwan's HEIs, Data Envelopment Analysis

1. Introduction

The quantity of university in Taiwan experienced rapid growth during the past two decades, mainly because of the Taiwan authority encourage the establishment of university. Taiwan has promoted university enrollment expansion policy since 1997, particularly, when in the era of Chen Shui-bian, the policy was even extended to "One county, one university" which resulted in the number of colleges and universities increased madly, reaching more than 160 at its peaks. The rapid expansion of university without hesitation has led to part of those universities are of poor quality and lack of features. Besides, due to the promotion of Taiwan's educational diversification policy and the liberalization of the education market, Taiwan's higher education has gradually changed from the elite education to the popular education, from the education statistics of the Ministry of Education that the net enrollment rate of higher education in Taiwan has reached 71.24% from 38.7% in 2000 to 2016, which led to the quality of teaching in universities further declined.

At the same time, since Taiwan's accession to the WTO in 2002, due to the principle of equality and reciprocity which means foreign educational institutions can also set up branch campuses in Taiwan has further increased the number of universities in Taiwan. Along with the boom of university, Taiwan has seen the trend of fewer children since 1990s,according to the statistic of Taiwan Ministry of the Interior Statistics Office , the number of births in Taiwan has dropped from more than 260,000 in 2001 to only 160,000 in 2010.

The low fertility rate directly reflects in the registration rate of higher education in Taiwan, referring to data released by the Taiwan Education Department at the end of 2017, 17 schools in all 157 colleges and universities in Taiwan suf-

fered a registration rate of less than 60%. In term of the situation that Taiwan's current state of higher education market saturation and the trend of declining birthrate, whether colleges and universities have the ability to effectively apply limited resources to operate and apply the least resources to achieve the most efficient output is now particularly urgent.

Literature concerning the higher education performance and efficiency issue is relatively abundant. Andersson & Sund (2022) investigates the technical efficiency and productivity of Nordic higher education institutions (HEIs) found that an average inefficiency of 10.1% and a yearly productivity increase of around 0.4% as well as the inefficiency scores are positively correlated with staff turnover. Chen (2021) adopts an extended two-stage network DEA approach to measure the operating efficiency of 52 universities in China, and proposes that to improve the operating efficiency of Chinese universities, the Chinese government should improve the financial allocation mechanism and introduce successful budget performance management. Salas-Velasco (2020) took the Spanish public universities as an example to demonstrate DEA can be an excellent benchmarking instrument in higher education, and found that universities with a higher percentage of grantees tend to be less inefficient, and a higher percentage of academics with tenure enhances the productive efficiency of the Spanish higher education sector. As for discussing the economies scale of HEIs, Taleb (2019) applied the integer-valued DEA model under the two technologies to the empirical data so as to study the return to scale (RTS) problem of public universities in Malaysia. Some study has been addressing the necessity of taking the quantile issue into consideration in term of education efficiency analysis, seeing, who extended the quantile regression methods to semi-parametric smooth coefficient models in studying the university cost structure where coefficients are an unknown function of the university's overall quality.

Out of the reason whether the efficiency will influence the productivity of Taiwan's HEIs, this article introduce the quantile-on-quantile regression model (QQ), which researchers do not need to sort different regimes, such as Markov-switching approaches, but can present the nonlinear link in an ad-hoc fashion (Han, 2019). Especially, the QQ model is able to solve the complexity and reveal some interesting characteristics of the relationship that classical econometric methods, such as ordinary least squares (OLS) and quantile regressions (QR) might hide (Y.-B. Chen, 2022).

In brief, this paper enriches the previous literature by using the comprehensive QQ to analyse the relationship between the technical efficiency and total factor productivity of Taiwan HEIs, especially show whether the technical efficiency has different impact on total factor productivity under different quantiles.

2. Materials and Methods

2.1 Methodology

In order to investigate the how technical efficiency (TE) impacts on the total factor productivity (TFP) under different quantiles conditions, this paper first calculate the two indices by applying the Malmquist DEA method. Second, this article introduces a non-linear method, the quantile-on-quantile approach (QQ) proposed by Sim and Zhou, to construct estimates of the effect that the quantiles of TE have on the quantiles of TFP.

The conventional quantile regression (QR) can merely capture the influence of X variable on the different quantiles of Y variable, but is unable to uncover the elaborate features of the impact, accounting for extreme observations, which are ignored by conventional OLS methods (Han, 2019). The QQ approach which is modified on conventional quantile regression (Adebayo, 2021) is able to capture the dependence between the distributions of Y variable and X variable and uncover two nuanced features in the Y–X relationship (Sim & Zhou, 2015). In short, that means the QQ approach could provide a lens for the complicated relationship among the Y–X relationship. The QQ model can start by incorporating the following nonparametric quantile regression model:

$$TFP_t = \beta^{\theta}(TE_t) + u_t^{\theta} \tag{1}$$

Where θ is the θ^{th} quantile of the conditional distribution of the TE_t and u_t^{θ} denotes an error term with a zero θ-quantile. Since there is no prior information about how TE_t and TFP_t are related, the function $\beta^{\theta}(TE_t)$ is allowed to be unknown. Then, to analyze the relation between the θ^{th} quantile of TFP_t and the τ^{th} quantile of TE_t, denoted by TE^{τ}, Eq. (1) is examined in the neighborhood of TE^{τ} employing local linear regression. Because $\beta^{\theta}(TE_t)$ is unknown, this function can be linearized by a first-order Taylor expansion around a quantile TE^{τ}, as following:

$$\beta^{\theta}(TE_t) = \beta^{\theta}\left(TE^{\tau}\right) + \beta^{\theta'}\left(TE^{\tau}\right)\left(TE_t - TE^{\tau}\right) \tag{2}$$

In Eq. (2) where $\beta^{\theta'}$ is the partial derivative of $\beta^{\theta}(TE_t)$ with respect to TE_t, also called marginal effect or response, and is similar in interpretation to the slope coefficient in a linear regression model. A prominent feature of Eq. (2) is that the parameters $\beta^{\theta}(TE^{\tau})$ and $\beta^{\theta'}(TE^{\tau})$ are doubly indexed in θ and τ. Given that $\beta^{\theta}(TE^{\tau})$ and $\beta^{\theta'}(TE^{\tau})$ are functions of θ and TE_t while the TE_t is a function of τ, that means $\beta^{\theta}(TE^{\tau})$ and $\beta^{\theta'}(TE^{\tau})$ are both functions of θ and τ. Therefore, Eq. (2) can be rewritten by redefining $\beta^{\theta}(TE^{\tau})$ and $\beta^{\theta'}(TE^{\tau})$ as $\beta_0(\theta,\tau)$ and $\beta_1(\theta,\tau)$:

$$\beta^{\theta}(TE_t) \approx \beta_0(\theta,\tau) + \beta_1(\theta,\tau)\left(TE_t - TE^{\tau}\right) \tag{3}$$

By substituting Eq. (3) in Eq. (1), we can obtain the following equation:

$$TFP_t = \beta_0(\theta,\tau) + \beta_1(\theta,\tau)\left(TE_t - TE^{\tau}\right) + u_t^{\theta} \tag{4}$$

2.2 DATA

We first describe our data set as well as specify our input and output variables for the Malmquist DEA model, the full-time teachers (X1) and number of students in school (X2) are taken as input, registration rate (Y1) is taken as output, the definition of each one is organized in Table 1. And the data of Taiwan universities and colleges is collected from 2020 to 2021 provided by Ministry of Education and Ministry of Science and Technology of Taiwan. The sample number of which is 294 including 147 universities and colleges, and the statistical descriptions of these variables are shown in Table 2. Second, we organize the statistical descriptions of TE and TFP which applied in the QQ approach and their unit root test result in Table 3.

Table 1. Variables' definition

Variable		Description of Variable	Unit
Output	Y1	Registration rate	Percentage
Input	X1	The full-time teachers mean compliance with the "Teacher's Law", "Methods for the Examination of Teachers' Qualifications in Colleges and Universities", "Selection Methods for Professional and Technical Teachers of the College", "Teaching of Professional and Technical Personnel as a Teaching Method" or "National University School Fund" Relevant regulations for the implementation of the Principles for the Implementation of Teaching Staff and Staff.	Person
	X2	"Number of students in school" means students of nationality, overseas Chinese, foreign students and terrestrial students who are studying and have a student status; withdrawal, enrollment, credits, exchange students (non-degree students), retention of admission or no student status is not included in the calculation.	Person

Table 2. The statistical descriptions of Input and Output

	Registration rate	The full-time teachers	Number of students in school
Mean	83.90	307.29	8112.96
SD	14.68	259.49	5937.46
Skewness	-1.19	2.96	1.41
Kurtosis	4.10	17.23	5.41
Observations	294	294	294

Table 3. The statistical descriptions of TE and TFP

	TE	TFP
Mean	0.622061	1.000531
SD	0.113252	0.092831
Skewness	-0.39315	-0.938179
Kurtosis	4.493327	17.36461
JB	17.45	1285.41
Observations	147	147
PP	-1.51***	-13.10***

Note: * p < 0.1, **p < 0.05, *** p < 0.01

From the results shown in Table 3, the numerical value of median and mean of the TE and TFP is 0.622061 and 1.000531. As for the skewness and kurtosis, the former descriptor reflects the asymmetry of the distribution, whereas the latter describes its steepness. Moreover, the Phillips-Perron test (PP) value unveiled that all the series are stationary at level.

3. Empirical Result

3.1 Quantile on Quantile regression approach result

Following most existing studies, this paper set the quantile interval of 0.05 to conduct empirical analysis, namely, 5^{th}, 10^{th}, 15^{th} ……, 90^{th} and 95^{th}. The QQ outcomes are graphically presented in Figure 1. The figure displays the slope estimates , which catches the influence of the quantile of TE on the quantile of TFP for a broad range of combinations. The slope coefficients lie on the z-axis, and the quantiles of TE and TFP are depicted on the x and y-axes, respectively.

In all quantiles (0.05-0.95) of the combination of TE and TFP, most of coefficient of TE on TFP ranges from -2 to 2, and it produces a flat-looking figure. The positive influence is especially strong where the TFP in the lower quantiles (0.05-0.25), combined with the TE in the middle tail (0.5-0.75) or in the middle low (0.25-0.5) quantiles. And when it comes to latter, its sign turns from positive to negative sharply.

Previous studies have generally believed that high technical efficiency promotes total factor productivity, however, from the results of the QQ model, the positive effect is greater only when the technical efficiency values of Taiwan's higher education industry are in the upper or lower middle quantiles and the TFP is in the lower quantiles.

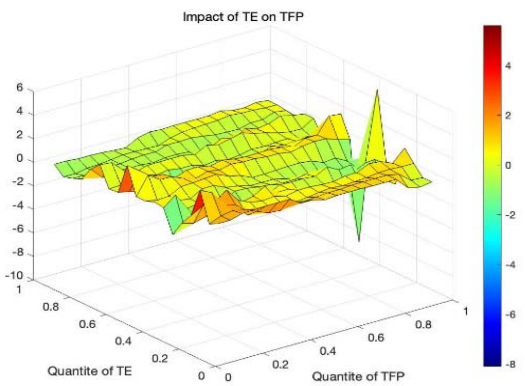

Figure 1. The Quantile on Quantile Regression (QQR) estimates.

3.2 Robustness check

In this portion, by comparing the results of QQ estimates with the quantile regression (QR), we can recognize the findings of QQ estimates are more or less consistent with the findings of QR.

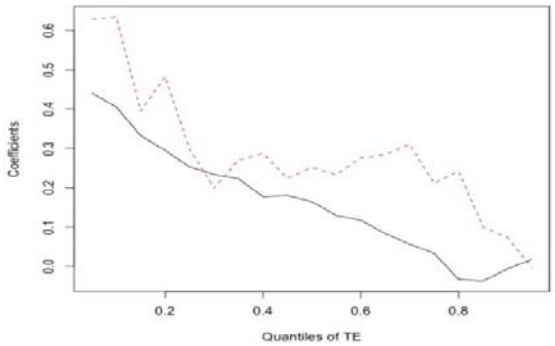

Figure 2. Comparison of quantile-on-quantile regression (QQ) and quantile regression (QR).

The QQ approach regresses the θ^{th} quantile of the TE on the τ^{th} quantile of TFP; therefore, its parameters can be explained by θ and τ. Because the QR parameters are only explained by θ, the QQ approach can be referred to as the "decomposition" of the QR estimates (Sim & Zhou, 2015). Based on this principle, approximate estimates of the QR should be recovered from the QQ estimates. Denoting the slope coefficient of QR as $\gamma_1(\theta)$, the impact of TE on TFP can be written as follows, where S = 20 is the number of quantiles θ = [0.05, 0.10, …, 0.95].

$$\gamma_1(\theta) \equiv \hat{\hat{\beta}}_1(\theta) = \frac{1}{S}\sum \hat{\beta}_1(\theta, \tau) \tag{6}$$

The estimate of TE on TFP is depicted in the figure 2, estimations of parameters for quantile regression arepresented by continuous black lines. Dashed red lines present the averaged quantile regression estimations at various quantiles of TFP.

4. Conclusion

To characterize performance and productivity of Taiwan's HEIs more accurately, this paper combines the DEA and the quantile-on-quantile regression approach to evaluate the efficiency of 147 universities and colleges directly subordinated to Ministry of Education and Ministry of Science and Technology of Taiwan of 2020-2021.

The findings of this paper reveal that a high technical efficiency does not necessarily mean it will boost productivity. Moreover, the results from the quantile-on-quantile regression specifically indicate that only when it comes to the situation where the total factor productivity (TFP) in the lower quantiles and the technical efficiency (TE) of Taiwan's HEIs are in the upper or lower middle quantiles, the positive impact of TE on TFP is greater. Especially, the most interesting thing is that in the combination of middle low quantiles of TE (0.05-0.25) and lower quantiles of TFP (0.05-0.25), the impact of TE on TFP turns from positive to negative sharply. In brief, only when productivity index of Taiwan's HEIs is in the lower quantiles, and the technical efficiency in the middle low or middle tail quantiles condition, the efficiency will has the positive impact.

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