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Productivity Change in Higher Education Sector: A Case Study of Malaysian Universities

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Abstract

This study is the first to apply the Malmquist total factor productivity index and its components under a variable-returns-to-scale (VRS) assumption to the higher education sector. By using this approach, we provide a more realistic and accurate shape of the production frontier than the traditional one, which is obtained using the constant-returns-to-scale (CRS) assumption in previous analyses of productivity changes in higher education institutions. In order to demonstrate the value of this approach, we use data on Malaysian public universities.

Keywords: Efficiency change, Malmquist indices, technological change, TFP indices, universities

Introduction

The Malmquist total factor productivity (TFP) index has been widely adapted to measure dynamic changes in the efficiency and the productivity of higher-education institutions (Johnes, 2008; Agasisti & Johnes, 2009; Bradley, Johnes, & Little, 2010; Paudel, 2014; Drew & Dollery, 2015). Almost all prior studies have tended to assume that higher education institutions face CRS and hence used a CRS decomposition of the Malmquist productivity index, proposed by Fare, Grosskopf, Norris, and Zhongyang (1994). However, since many decision-making bodies, including universities, are not operating at optimal scale and face barriers such as imperfect competition, government budgetary and financial regulations, the CRS assumption does not seem realistic.

Moreover, Simar and Wilson (1998) show that, under CRS assumption, the TFP decomposition of Fare et al. (1994) and Dai and Delpachitra (2015) can be inaccurate and demonstrate that if a generic firm's position remains unchanged between two different periods, and the only change that occurs is in the VRS measure of technology (for example, shift upward), the technological change component of Fare et al. (1994) TFP decomposition will be equal to one, incorrectly suggesting no technological effect. To address this shortcoming, this study applies a VRS Malmquist TFP index, proposed by Simar and Wilson (1999), to provide a comprehensive and robust analysis of productivity changes within higher education institutions.

Materials and Methods

A production–possibilities set (PPS) at time *t* can be defined as $S_t = \{(x,y) \mid x \text{ can produce } y \text{ at time } t\}$ where *x* and *y* are, respectively, non-negative input and output vectors at time *t*. In an output-oriented approach, S_t can be completely characterized by the output distance function which can be defined as:

$$D^{o}_{t|t}(x_t, y_t) = \inf\{\theta : (x_t, y_t/\theta) \in S^t\}$$

This function is the reciprocals of Farrell's (1957) output-oriented technical efficiency and measures the technical efficiency of firm *i* at time *t* relative to the technology existing at time *t*. The function can be estimated using data envelopment analysis (DEA). Caves, Christensen, and Diewert (1982) define the Malmquist TFP index as ratios of such distance functions. Simar and Wilson (1999) propose an output-oriented Malmquist index between time period t_1 and t_2 which can be estimated as:

$$\widehat{\Delta TFP^{t_1,t_2}} = \underbrace{\underbrace{\left(\frac{\widehat{D^{ov}_{t_2|t_2}}}{\widehat{D^{ov}_{t_1|t_1}}}\right)}_{\Delta PureEff} \times \underbrace{\left(\frac{\widehat{D^{oc}_{t_2|t_2}} / \widehat{D^{ov}_{t_2|t_2}}}{\widehat{D^{oc}_{t_1|t_1}} / \widehat{D^{ov}_{t_1|t_1}}}\right)}_{\Delta Scale}}_{\Delta Eff} \times \underbrace{\underbrace{\sqrt{\left(\frac{\widehat{D^{ov}_{t_1|t_2}}}{\widehat{D^{ov}_{t_2|t_2}}} \times \frac{\widehat{D^{ov}_{t_1|t_1}}}{\widehat{D^{ov}_{t_2|t_1}}}\right)}}_{\Delta PureTech} \times \underbrace{\sqrt{\left(\frac{\widehat{D^{oc}_{t_1|t_2}} / \widehat{D^{ov}_{t_1|t_2}}}{\widehat{D^{oc}_{t_2|t_2}} / \widehat{D^{ov}_{t_2|t_2}}} \times \frac{\widehat{D^{oc}_{t_1|t_1}} / \widehat{D^{ov}_{t_1|t_1}}}{\widehat{D^{oc}_{t_2|t_1}} / \widehat{D^{ov}_{t_2|t_1}}}\right)}}_{\Delta ScaleTech}}_{\Delta Tech}$$

where $\dot{D}^{oc}_{t|t}$ and $\dot{D}^{ov}_{t|t}$ incorporate the assumptions of CRS and VRS, respectively. The interpretation of the Δ*TFP* index and its components is straightforward: an estimated value of greater than unity indicates an improvement in corresponding measure, and a value below unity is indicative of deterioration. $\mathrm{V}Eff$ is an index of relative change in technical efficiency, indicating the relative distance of a firm from the best-practice frontier between periods. $\mathrm{V}PureEff$ and $\mathrm{V}Scale$ are components of $\mathrm{V}Eff$ and proxies for pure efficiency change and change in scale efficiency such that $\mathrm{V}Eff = \mathrm{V}PureEff \times \mathrm{V}Scale$. $\mathrm{V}Tech$ is an index of technical change, quantifying the shift in the frontier. $\mathrm{V}Tech$ is decomposed into pure technical change— $\mathrm{V}PureTech$ —and change in the scale of technology— $\mathrm{V}ScaleTech$, that is, $\mathrm{V}Tech = \mathrm{V}PureTech \times \mathrm{V}ScaleTech$. $\mathrm{V}PureTech$ measures the shift in the VRS frontier (relative to the firm's position) from time t_1 to time t_2. $\mathrm{V}ScaleTech$ yields information concerning the shape of the technology. When $\mathrm{V}ScaleTech$ is greater than unity (less than unity), this suggests that the technology is moving farther from (toward) CRS and the shape of technology is becoming increasingly convex, and when equal to unity implies no changes in the shape of the technology. The bootstrap simulation method suggested by and Simar and Wilson (2000) is also used in this study to obtain bias-corrected estimates of efficiency cores and their confidence intervals.

We chose to study Malaysian public universities as the Malaysian government has placed a great emphasis on their productivity over the past decade. Malaysia is keen to be recognized as a major regional hub for higher education and has introduced policies supporting the internationalization and improvements in the quality of teaching and learning, along with enhancements in research and competition in the sector. In 2006, the government started providing public universities with greater institutional independence from the central government (largely in terms of governance), and increased the expenditure on research and development as a proportion GDP. During our study period, Malaysian public universities thus faced new challenges and opportunities which had the potential to contribution to rapid expansion. This study, therefore, uses the Malmquist TFP index under VRS and a four-year panel dataset (2006 to 2009) to evaluate productivity changes of 17 Malaysian public universities. Extension of the data set past 2009 was not possible due to limited data availability. The four-year panel dataset is sufficient, however, for us to demonstrate the benefits of the use of the VRS Malmquist index in the area of higher education.

All universities (except three due to availability of data) were categorized into three main subgroups: 1) research universities—research intensive and well-established institutions; 2) comprehensive universities—multi-disciplinary universities that focus on a wide range of courses and fields of specialisation; 3) focused universities—discipline-focused universities. In this study, we include four inputs: 1) undergraduate enrolments; 2) postgraduate enrolments; 3) the number of full-time equivalent academic staff members; 4) the amount of government funds. In terms of outputs, we consider three following types of outputs in our model: 1) the number of undergraduate qualifications awarded; 2) the number of postgraduate qualifications awarded; 3) the number of refereed articles as a proxy for research output. In the process of generating the universities' research output data set, care was taken to ensure the accuracy of the data.

Empirical Results

Before delving into productivity results, it is useful to provide an overall picture of the sectors' efficiency performance (Table 1). In all cases, the estimated means of bias-corrected efficiency lie toward the upper bound of the estimated confidence intervals. This is consistent with the theory underlying the construction of the confidence intervals (Simar & Wilson, 2000). It is also noteworthy that the bias mean is quite small, thereby indicating that the results are quite stable. Overall, Table 2 results show that the sector bias-corrected efficiency level declined between 2006 and 2007, improved significantly between 2007 and 2008, and then declined slightly during 2008–2009. This approach of analysing technical efficiencies, however, does not reveal the changes in performance over time. To do this, we use the measurements of productivity growth over time, distinguishing between the movement in the input–output space (technical efficiency change) as well as the efficient frontier's shift over time (technological change). We estimated Δ*TFP* change and its components for the three sub-groups of universities (Table 2).

Table 1. Aggregate Mean Efficiency Scores Based on the Bootstrap Method, 2006–2009

Year	Estimated Efficiency	Bias-Corrected Efficiency	Bias	95% CI Lower Bound	95% CI Upper Bound
2006	0.9817	0.9542	0.0276	0.8531	0.9810
2007	0.9507	0.8635	0.0872	0.7127	0.9487
2008	0.9991	0.9974	0.0016	0.9837	0.9989
2009	0. 9904	0.9439	0.0374	0.8682	0. 9813
Mean	0. 9771	0.9397	0.0385	0.8544	0. 9762

Over the study period, the sector as a whole experienced improvement in productivity changes, with Δ*TFP* greater than unity in all years (Table 2). In all periods, the major contributor to sectoral TFP change was Δ*Tech* representing change in the PPS. Any changes in the environment (for example, government regulations) can influence Δ*Tech*, so the considerable increases in 2007–2008 and 2008–2009 was likely to reflect the higher-education policies expanding the efficient frontier, and thereby boosting productivity changes in the sector.

Table 2. The Estimated Malmquist Indices for Different University Sub-Grouping, 2006–2009

University	Period	Δ*TFP*	Δ*Eff*	Δ*Tech*	Δ*Pure Eff*	Δ*Scale*	Δ*Pure Tech*	Δ*Scale Tech*
Research Universities	2006–2007	1.0943	1.0063	1.0791	1.0231	1.0480	1.0480	1.0297
	2007–2008	1.2679	0.9960	1.2725	1.0000	1.2412	1.2412	1.0253
	2008–2009	1.6488	0.9915	1.6510	0.9718	1.6681	1.6681	0.9898
Comprehensive Universities	2006–2007	0.9153	0.9934	0.9198	1.0003	0.9932	0.9069	1.0143
	2007–2008	1.1132	1.0731	1.0689	1.0726	10005	1.0140	1.0542
	2008–2009	1.0607	0.9108	1.1728	0.9557	0.9530	1.2074	0.9713
Focused Universities	2006–2007	1.2030	1.1480	1.1275	0.9267	1.2387	INF	INF
	2007–2008	1.0180	1.0459	1.6018	1.1749	0.8902	INF	INF
	2008–2009	1.3418	1.1984	0.9584	1.0021	1.1958	INF	INF
The Sector	2006–2007	1.1033	1.0754	1.0259	0.9724	1.1059	INF	INF
	2007–2008	1.1139	1.0414	1.3058	1.0994	0.9473	INF	INF
	2008–2009	1.3659	1.0678	1.3888	0.9823	1.0871	INF	INF

Notes:
ΔTFP = ΔEff × ΔTech,
ΔEff = ΔPureEff × ΔScale
ΔTech = ΔPureTech × ΔScaleTech.
The infeasible computations are shown by INF as discussed in the text

During the period from 2006 to 2007 the improvement in the sector's productivity growth stemmed from the focused and research universities, while comprehensive universities showed productivity regress over this period, with 8.47% deterioration. However, between 2007 and 2009, all of the university sub-groups showed increases in the TFP index. Although $\Delta Tech$ was the largest contributor to ΔTFP in the sector, the results also show considerable improvements in the sectors' ΔEff for the entire study period.

In some cases, estimated $\Delta PureTech$ and $\Delta ScaleTech$ could not be computed, due to the infeasibility of the imposed constraints in the linear programming.[1] The estimated $\Delta PureTech$ show an outward shift of the frontier in periods 2007–2008 and 2008–2009 for Research Universities and Comprehensive Universities. The estimated $\Delta ScaleTech$ are more than unity in 2006–2007 and 2007–2008 but less than unity in 2008–2009. These indicate that the shape of the frontier moved toward VRS to become more convex and variable in the first two periods and then moved towards CRS in the last period.

Conclusion

This study demonstrates the use of a unique approach in the analysis of university productivity based on more realistic assumptions than those usually applied in prior Malmquist studies. We illustrate the advantages of this approach using Malaysian public universities for the period 2006 to 2009. We found that the sector as a whole experienced positive improvements in productivity. Between 2006 and 2007, TFP improvements were achieved only within the focused universities, whereas in period 2007–2009 all three university sub-groups (research universities, comprehensive universities and focused universities) benefited from significant TFP rises.

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