SEMARAK ILMU PUBLISHING
202103268166(003316878-P)

Journal of Advanced Research in Applied Sciences and Engineering Technology

Journal homepage:
https://semarakilmu.com.my/journals/index.php/applied_sciences_eng_tech/index
ISSN: 2462-1943

A DEA-Based Malmquist Productivity Approach for Assessing Total Factor Productivity Change in Malaysian Public Universities

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ARTICLE INFO

Received 27 January 2024
Received in revised form 4 October 2024
Accepted 18 October 2024
Available online 18 November 2024

Keywords:

Data envelopment analysis (DEA); Higher education; Malmquist productivity index; Productivity change; Total factor productivity

ABSTRACT

This study uses the non-parametric frontier method to examine the productivity growth of Malaysian public universities from 2017 to 2021. It examines changes in productivity at university groups and individual institutions, using three inputs (academic staff, undergraduate student enrolment, and postgraduate student enrolment) and three outputs (undergraduate and postgraduate qualifications awarded and publications). This study analyses productivity changes and breaks them down into technical efficiency and technological change using the Data Envelopment Analysis (DEA)-based Malmquist productivity index (MPI). The analysis reveals that public universities in Malaysia have seen an average annual increase in MPI of 0.5% over the period of the study. However, when the components of this productivity change are examined, it becomes evident that Malaysian public universities have had an annual average 1.3% increase in technology along with a 0.8% decline in technical efficiency. Further evaluation of the indexes reveals disparities between Malaysian university groups. Technical, comprehensive, and research universities make up the group that performs the best to the worst. Although Malaysian public universities' productivity is increasing, it is mostly due to technology, which comes at the expense of decreased technical efficiency.

1. Introduction

Fostering a highly educated human capital is crucial for economic development, with Higher Education Institutions (HEIs) playing a pivotal role. The expansion of universities highlights education's critical role in cultivating a skilled workforce. There exists a pronounced interdependence between industry and higher education, where industries rely on well-trained, highly skilled workers for economic growth through innovation. Furthermore, strategic investments in higher education become imperative, not only arming individuals to meet industry demands but also fostering a reservoir of skills that propels economic advancement. The transformative impact of this investment becomes manifest as highly educated graduates empower industries to assert global

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https://doi.org/10.37934/araset.53.1.141152

competitiveness, catalyse job creation, and contribute significantly to economic progress. Hence, acknowledging that HEIs utilize public funds, it becomes paramount for them to manage resources, directing them toward optimal performance prudently. The effective oversight of resources by HEIs is not merely advisable. It is a necessity to ensure responsible utilization and uphold the institution's unwavering commitment to the community.

The higher education landscape in Malaysia has witnessed substantial growth since the establishment of the University of Malaya in 1949 as part of the Federation of Malaya [1]. Public universities in Malaysia operate as self-managed institutions with some degree of autonomy, being both funded and regulated by the government. The transition to autonomous status for Malaysian public universities began in 2012 under the National Higher Education Strategic Plan (NHESP). It is aimed at enhancing the management of higher education by providing public universities with more decision-making flexibility and aligning their goals with those of the Ministry of Higher Education (MOHE). Accordingly, this transition unfolded progressively, with all public universities in Malaysia attaining autonomous status by 2018.

Malaysia has 20 public universities classified into three groups: research universities, comprehensive universities, and technical universities. Prior to 2016, Malaysian universities were classified differently than they are now, with three types of universities: research, comprehensive, and focused. However, the classification of some universities changed in 2016. Comprehensive universities increased from 4 to 11 institutions, while focused universities became technical universities and decreased from 11 to 4 institutions. The five research universities in Malaysia include University Malaya, Universiti Kebangsaan Malaysia, Universiti Sains Malaysia, Universiti Putra Malaysia, and Universiti Teknologi Malaysia, which are known for their research focus and are often ranked among the top universities in the country. At the same time, the eleven comprehensive universities, also known as multi-disciplinary universities, aim to provide a well-rounded education. These include Universiti Teknologi MARA, Universiti Islam Antarabangsa Malaysia, Universiti Malaysia Sabah, Universiti Malaysia Sarawak, Universiti Utara Malaysia, Universiti Pendidikan Sultan Idris, Universiti Malaysia Terengganu, Universiti Sains Islam Malaysia, Universiti Sultan Zainal Abidin, Universiti Malaysia Kelantan, and Universiti Pertahanan Nasional Malaysia. The technical universities in Malaysia, initially part of the Malaysian Technical University Network (MTUN), began with four university colleges that later evolved into full-fledged universities - Universiti Malaysia Pahang, Universiti Malaysia Perlis, Universiti Teknikal Malaysia Melaka, and Universiti Tun Hussien Onn Malaysia. Specializing in practical, hands-on higher technical and technological programs, in 2015, MTUN was renamed MTU with the goal of forming a consortium.

In recent years, the Malaysian higher education system has experienced significant growth and success, marked by increased student enrolment and global recognition, attributable to enacted policies. Despite the progress achieved, there are areas where the Malaysian higher education system falls short. A 2014 report by Universitas 21 [2] ranked the country's higher education system 28th out of 50 nations. The report also emphasized that while Malaysia ranks high in terms of resources invested, it ranked low in terms of output, indicating a disparity between invested resources and outcomes. Moreover, recent studies have delved into the performance of the higher education system in Malaysia. One study by Arjomandi *et al.,* [3] utilized the Hicks-Moorsteen Total Factor Productivity (TFP) index to scrutinize efficiency and productivity changes in the three groups of Malaysian universities (research, comprehensive, and focused) before and after the implementation of NHESP in 2007. Another study by Lim *et al.,* [4] employed Data Envelopment Analysis (DEA) to assess efficiency in Malaysian universities, revealing inefficiencies in generating income and the presence of slacks in the utilization of government funding to produce graduates. Therefore, to attain global competitiveness and increase resilience towards globalization, Malaysia needs to enhance the quality of higher education provided by its universities. One way to measure the quality of higher education is by evaluating the productivity of HEIs.

1.1 The Malaysia Education Blueprint Higher Education 2015 – 2025

The 2015 Malaysia Education Blueprint Higher Education (MEB (HE)) proposes transformative changes, targeting increased tertiary enrolment from 36% (2012) to 53% by 2025 and a twofold rise in international students. Focused on fostering an entrepreneurial mindset, prioritizing outcomes, and ensuring financial sustainability, MEB (HE) seeks reduced dependence on government resources. The MEB (HE) outlines ten shifts, as illustrated in Figure 1.

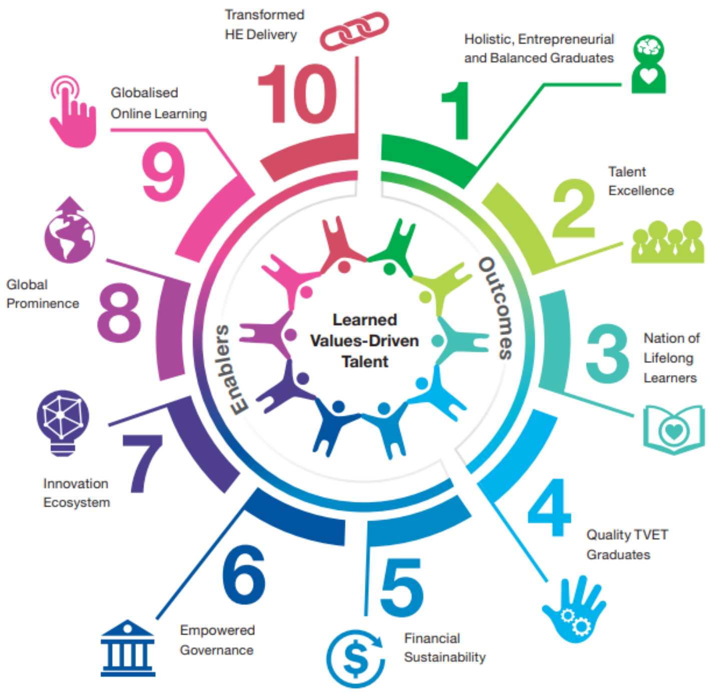

Fig. 1. The 10 shifts in MEB (HE). Source: Executive summary Malaysia Education Blueprint 2015 – 2025 (Higher education) [5]

The first four shifts concentrate on nurturing balanced and entrepreneurial graduates, encouraging talent excellence, advocating lifelong learning, and ensuring the quality of Technical and Vocational Education and Training (TVET) graduates. Simultaneously, the subsequent six shifts address broader themes such as financial sustainability, empowered governance, fostering an innovation ecosystem, achieving global prominence, implementing globalized online learning, and transforming higher education delivery.

This study addresses a literature gap by assessing the productivity of Malaysian public universities using the DEA-based Malmquist Productivity Index (MPI) during MEB (HE) implementation. The impetus for this research is rooted in the university classification adjustments observed in 2016. This aligned with the absence of empirical investigations into the productivity of Malaysian public universities employing the MPI throughout the MEB (HE) implementation. Thus, the revelations of this study hold the potential to offer profound insights, shedding light on whether HEIs are poised on a trajectory harmonious with the aspirations outlined in the MEB (HE).

The subsequent sections of the paper are organized as follows: Section 2 outlines the methodology, data, and variables used to analyse productivity changes at Malaysian public universities. Section 3 presents the results of the MPI analysis. The final section encompasses a discussion and conclusion.

2. Methodology, Data and Variables

2.1 DEA-Based Malmquist Approach

Performance is an indispensable aspect of any organization or industry, and universities are certainly no different. Evaluating the performance of an organization involves two critical concepts: efficiency and productivity, which are often used interchangeably [6]. Productivity can be gauged by assessing the ratio of output to input or by evaluating the TFP. Efficiency, on the other hand, refers to the organization's ability to minimize the inputs required to achieve a given output or to maximize the output generated from a given input of resources.

Amidst the plethora of tools available for performance measurement, DEA stands out among researchers for its ability to handle diverse inputs and outputs without prioritizing financial values. As a non-parametric approach, DEA utilizes linear programming methods to construct the production frontier as a piecewise linear convex envelopment of the observations. Its methodology is grounded in the concept that a Decision-Making Unit (DMU) is efficient if it can generate the same output level with fewer inputs or produce more output with the same level of inputs compared to other DMUs. Examples of DMUs span various units across sectors, including banks, factories, hospitals, airports, universities, and construction companies, to name a few. Accordingly, a DMU effectively utilizing inputs to produce outputs will be designated as a relatively efficient DMU and will earn an efficiency score of one.

The MPI stands as a widely acknowledged method for tracking productivity changes over time despite the availability of several indices such as Tornqvist, Fisher, Paasche, and Laspeyres. Tables 1 and 2 illustrate the use of MPI in measuring productivity changes in industries and higher education, respectively. Based on work by S. Malmquist [7] and Caves *et al.,* [8], they introduced what has been called the MPI, later developed by Färe *et al.,* [9] using DEA to construct an efficiency frontier and measure the distance of individual observations from the frontier based on input and output data. This method has proven successful across various fields, including seaports, manufacturing, banking, healthcare, and education.

Table 1
Literature related to the evaluation of productivity changes in different sectors

No.	Author	DMU	Method
1.	Färe *et al.,* [9]	Swedish pharmacies	MPI
2.	Ben Mabrouk *et al.,* [10]	Commercial seaports	MPI
3.	Grifell-Tatje *et al.,* [11]	Banks	Quasi- MPI, MPI
4.	Mei *et al.,* [12]	Health care institutions	MPI
5.	Koiry and Huang [13]	Farm	Stochastic Frontier Analysis (SFA)-based MPI
6.	Färe *et al.,* [14]	Manufacturing industries	MPI, Tornqvist Index
7.	Kittelsen and Førsund [15]	District courts	MPI
8.	Yu and Chen [16]	Airlines	Network DEA-based global MPI

As quantifying performance can serve as a basis for improving output, this study employs MPI to assess the productivity changes of twenty Malaysian public universities. However, measuring the performance of universities is a complex process that must consider the institution's unique characteristics. HEIs have various outputs (such as degrees awarded to students, publications, grants, consultation services, collaboration activities like knowledge transfer programs and university social responsibility, to name a few) and inputs (such as the number of staff, expenditure, floor space, student enrolment, amongst others). Therefore, a simple ratio of output to input may not accurately reflect a university's performance [10]. Hence, this study employs methodologies that consider all the necessary inputs to generate multiple outputs, referred to as TFP.

Table 2
Summary of literature on productivity change evaluation in higher education

No.	Author	Inputs and outputs	Methods
1.	Rahimian and Soltanifar [17]	Inputs: Number of students, university professors, and employees. Outputs: Number of educated people and research outputs.	MPI
2.	Salleh *et al.,* [18]	Inputs: Number of students enrolled, full-time equivalent teaching staff, and full-time equivalent non-teaching staff. Outputs: Number of qualifications awarded.	Bootstrapped MPI
3.	Arjomandi *et al.,* [3]	Inputs: Undergraduate enrolments, postgraduate enrolments, academic staff, and government research funding. Outputs: Undergraduate qualifications awarded, postgraduate qualifications awarded, and research output.	Hicks-Moorsteen index
4.	Carrington *et al.,* [19]	Inputs: Academic staff, non-academic staff, and other cost. Outputs: Equivalent Full-Time (EFTSL) Science student, EFTSL non-science student, and weighted publications.	Fare-Primont index
5.	González-Garay *et al.,* [20]	Inputs: Students entry standards, staff to student ratio, expenditure per student, and research intensity. Outputs: Research quality, student satisfaction, value-added score, and graduate prospects.	MPI
6.	Tran [21]	Inputs: Academic staff, non-academic staff, and other cost. Outputs: Enrolment of students and research income	MPI
7.	Zhang *et al.,* [22]	Inputs: The provincial educational fund, the number of newly enrolled students, and the number of full-time teachers. Outputs: The number of published papers, the number of students working on a Master's or Ph.D. degree, and the number of patents granted.	MPI.

The output-based MPI, following the approach of Färe *et al.,* [23], is calculated as the geometric mean of two quotients of output distance functions, as illustrated in Eq. (1):

$$m_o(x_{t+1}, y_{t+1}, x_t, y_t) = \sqrt{\frac{d_0^t(x_{t+1}, y_{t+1})}{d_0^t(x_t, y_t)} \times \frac{d_0^{t+1}(x_{t+1}, y_{t+1})}{d_0^{t+1}(x_t, y_t)}}\ . \tag{1}$$

By comparing each university in their respective groups to the best practice frontier, it is possible to obtain a measure of their progress in catching up in efficiency to that frontier, as well as a measure of the shift in the frontier (or innovation in technology). According to Färe *et al.,* [9,14], MPI can be broken down into two components, specifically the change in efficiency (EFFCH) and the change in technology (TECHCH). The calculation of the MPI, as presented in Eq. (2) and Eq. (3) involve the multiplication of these two components to assess changes in total factor productivity (TFPCH).

Malmquist TFP change = Change in efficiency x Change in technology, (2)

TFPCH = EFFCH x TECHCH. (3)

Mathematically, Eq. (2) and Eq. (3) can be expressed as:

$$m_o(x_{t+1}, y_{t+1}, x_t, y_t) = \frac{d_0^{t+1}(x_{t+1}, y_{t+1})}{d_0^t(x_t, y_t)} \sqrt{\left[\frac{d_0^t(x_{t+1}, y_{t+1})}{d_0^{t+1}(x_{t+1}, y_{t+1})} \times \frac{d_0^t(x_t, y_t)}{d_0^{t+1}(x_t, y_t)}\right]} \quad . \tag{4}$$

As outlined in Tran [21], *m* is the productivity of DMUs at the point of time $t+1(x_{t+1}, y_{t+1})$, using period $t+1$ technology, relative to earlier DMUs (x_t, y_t) using period *t* technology, *0* denotes the output orientation and d_0 is the output distance function. The ratio outside the square root represents the change in EFFCH or catching up between years t and $t+1$, or how far observed production is from the maximum potential production. The geometric means of the two ratios inside the square root indicate the shift in TECHCH between the two periods. Färe *et al.,* [23] stated that improvements in productivity are indicated by an MPI value greater than 1, and deterioration in productivity is represented by an MPI value less than 1. The overall TFP index follows the same interpretation. An index value above unity for efficiency signifies evidence of catching up (to the frontier), and a value above unity for technical change represents technological progress.

As expressed in Eq. (5), EFFCH can be further broken down into Pure Technical Efficiency Change (PECH) and Scale Efficiency Change (SECH).

EFFCH = PECH x SECH. (5)

PECH evaluates managerial performance in arranging inputs in a production process, representing the maximum level of technical efficiency that an organization can achieve. On the other hand, SECH evaluates the organization's capability to determine the optimal size of resources and the scale of production to achieve the expected production level. Also, when the size of an organization is not appropriate, whether it be too large or too small, inefficiencies can occur. For instance, a university may be more scale efficient if it is able to produce more graduates while using fewer resources as it grows in size. The Malmquist decompositions, represented by Eq. (2) to Eq. (5) aid in determining the source of a change in productivity. To summarize, the MPI can be expressed by Eq. (6):

MPI = PECH x SECH x TECHCH. (6)

2.2 Specifications of Data and Variables

This study investigates the productivity of twenty Malaysian public universities using a five-year panel dataset spanning from 2017 to 2021. The analyses are conducted to assess the productivity of each of the 20 universities individually and categorically within their designated groups: research universities, comprehensive universities, and technical universities. Detailed descriptions of the variables can be observed in Table 3.

Table 3
Statistical summary of input and output variables

Year	Statistics	Y_1	Y_2	Y_3	X_1	X_2	X_3
2017	Mean	3986.25	997.3	1463.1	16601.15	4625.5	1587
	Std. Dev.	4719.35	943.23	1327.61	14469.19	3858.06	1787.3
	Minimum	558	36	192	2291	279	389
	Maximum	23466	3108	4491	73405	12560	8756
2018	Mean	3757.8	965.7	1505.55	16928.15	4680.1	1576.4
	Std. Dev.	3446.07	885.54	1308.72	15603.07	4096.62	1763.05
	Minimum	524	54	237	2456	299	388
	Maximum	17594	2785	4084	78825	13977	8659
2019	Mean	3924.25	950.3	1627.5	17505.1	4665.9	1581.3
	Std. Dev.	4458.64	852.31	1385.63	16757.45	4139.96	1754.96
	Minimum	554	56	208	2795	335	389
	Maximum	22426	2447	4027	84408	14291	8625
2020	Mean	3430.3	838.35	1689.75	18465.6	4615.95	1575.4
	Std. Dev.	3155.19	836.97	1463.08	18293.3	3905.28	1813.26
	Minimum	775	67	252	2884	349	382
	Maximum	16127	2791	4421	91930	11722	8904
2021	Mean	4696.95	970.1	1881.65	18940.3	4974.1	1551.7
	Std. Dev.	7971.45	999.19	1619.73	19151.93	4335.33	1836.7
	Minimum	694	50	343	3125	463	288
	Maximum	38144	3155	4860	96390	13081	8957

Note: Y_1= Undergraduate degrees awarded, Y_2=Postgraduate degrees awarded, Y_3=Publications in Scopus, X_1 = Undergraduate student enrolment, X_2 = Postgraduate student enrolment, X_3 = Academic staff.

The study employed three inputs to determine productivity: academic staff, undergraduate student enrolment, and postgraduate student enrolment. Additionally, three outputs were considered: undergraduate and postgraduate qualifications awarded and publications. The data on undergraduate students only includes first-degree students. The selection of these inputs and outputs is grounded in the findings of previous research, as discussed by Arjomandi *et al.,* [3], who proposed that universities utilize a combination of labour and non-labour factors to produce outputs such as teaching, research, and other educational services.

Data for these variables were sourced from the MOHE website [24], with the exception of publications, which were obtained from the Scopus database. The choice to utilize the Scopus database was motivated by its broader coverage compared to other databases. This decision aimed to ensure that comparable information could be obtained from all universities, recognizing the significant variations in the reporting formats of different institutions.

3. Results

Table 4 illustrates the productivity changes generated by the MPI for groups of Malaysian public universities. The index indicates that these universities have achieved an annual average productivity growth rate of 0.5% between the years 2017 and 2021. The primary contributor to this growth is an increase in TECHCH rather than EFFCH. The decline in EFFCH is attributed to a decrease of 0.3% in SECH and 0.4% in PECH. This implies that while universities have an advantage in terms of innovation in teaching technology, they face challenges in adjusting their operations to reach optimal scale and utilizing their resources efficiently.

Table 4
Yearly MPI breakdown by university group classification

University groups	Year	EFFCH	TECHCH	PECH	SECH	TFPCH
Research	2017 - 2018	1.000	0.969	1.000	1.000	0.969
	2018 - 2019	1.000	0.943	1.000	1.000	0.943
	2019 - 2020	1.000	1.011	1.000	1.000	1.011
	2020 - 2021	0.997	1.056	1.000	0.997	1.053
Average		0.999	0.994	1.000	0.999	0.993
Comprehensive	2017 - 2018	1.009	1.001	0.999	1.011	1.010
	2018 - 2019	1.001	1.011	1.006	0.995	1.013
	2019 - 2020	0.978	0.914	0.979	0.999	0.894
	2020 - 2021	0.924	1.226	0.964	0.959	1.133
Average		0.978	1.032	0.987	0.991	1.009
Technical	2017 - 2018	1.000	0.971	1.000	1.000	0.971
	2018 - 2019	0.962	1.112	0.973	0.989	1.070
	2019 - 2020	1.010	0.891	1.002	1.008	0.900
	2020 - 2021	1.029	1.094	1.026	1.004	1.126
Average		1.000	1.013	1.000	1.000	1.013
Total Average		0.992	1.013	0.996	0.997	1.005

Upon further examination, it was revealed that research universities experienced growth in TFPCH due to TECHCH during the years 2019–2021 but witnessed a decline in the earlier years. PECH remained unchanged throughout these years. However, EFFCH and SECH began to decrease in the years 2020–2021 for research universities compared to previous years. In the case of comprehensive universities, it is observed that the growth in TFPCH is mainly driven by TECHCH during the study years, except for 2019–2020. These universities also demonstrated growth in EFFCH for two years, from 2017 to 2019, but experienced a decline in the subsequent years. A regression in PECH was also noticed, except for 2018–2019. Additionally, SECH demonstrated an increase in 2017–2018 but decreased in the following years. Technical universities, like research and comprehensive universities, exhibited fluctuations in TFPCH and its components. TFPCH demonstrated an increase in the years 2018–2019 and 2020–2021 but decreased in the other years. This growth is linked to TECHCH. These technical universities also experienced growth in EFFCH, except for the year 2018–2019. The changes in technical efficiency are associated with PECH and SECH. In the early years of 2017–2018, it was observed that PECH and SECH of technical universities reached the full frontier with a value of 1 in 2017–2018. However, a year later, a decline was observed, and finally, in the following years, growth was experienced.

The results of the productivity assessment of Malaysian public universities using the Hicks-Moorsteen TFP index by Arjomandi *et al.,* [3] aligned with the findings of this study. In their research, data from the period 2006–2009 were analysed, and it was determined that TFP improvements were mainly attributed to a combination of mix efficiency and TECHCH. However, these findings are at odds with previous research conducted by Castano and Cabanda [25] and Tran [21]. Castano and Cabanda [25] discovered that HEIs in the Philippines are lacking in teaching innovation, leading to variations in productivity. This is consistent with the findings of Tran [21], who observed a regression in technological innovation in the Philippines. Both studies also reported an increase in SECH for their respective HEIs.

When comparing the performance of three different groups of universities, it can be observed that technical universities perform the best, with all MPI values and components equalling unity or more. Comprehensive universities come in second, with an increase in TFPCH by 0.9% linked to TECHCH, yet a decrease in EFFCH of 2.2% caused by a decline in PECH and SECH. Research universities exhibit the lowest performance, with a decrease in TFPCH by 0.7%, resulting from a decrease in both TECHCH by 0.6% and EFFCH by 0.1%. The decline in EFFCH is primarily due to a decrease in SECH. This suggests that comprehensive and research universities must address issues related to achieving optimal scale in their operations, with comprehensive universities facing additional challenges in managing resources.

Table 5 summarizes the average MPI and ranking of Malaysian public universities organized by their respective groups. Generally, 45% of these universities have exhibited growth in productivity, while the remaining 55% have seen a decline. Notably, all universities that exhibited productivity growth had MPI values and components equal to or greater than one, indicating that these universities have been consistently performing efficiently over the years.

Table 5
Average MPI of Malaysian public universities and their ranks by university group

University groups	University	EFFCH	TECHCH	PECH	SECH	TFPCH	Rank
Research	U1	1.000	0.970	1.000	1.000	0.970	5
	U2	1.000	1.003	1.000	1.000	1.003	2
	U3	0.997	0.992	1.000	0.997	0.989	3
	U4	1.000	1.020	1.000	1.000	1.020	1
	U5	1.000	0.985	1.000	1.000	0.985	4
Comprehensive	U6	1.000	1.064	1.000	1.000	1.064	4
	U7	0.935	1.036	0.944	0.991	0.969	8
	U8	1.000	1.107	1.000	1.000	1.107	2
	U9	0.908	1.021	0.927	0.980	0.928	10
	U10	1.000	0.984	1.000	1.000	0.984	7
	U11	0.989	0.974	1.000	0.989	0.963	9
	U12	0.952	1.034	1.000	0.952	0.985	6
	U13	1.019	1.064	1.000	1.019	1.084	3
	U14	1.000	1.156	1.000	1.000	1.156	1
	U15	0.986	1.010	0.987	0.999	0.997	5
	U16	0.971	0.920	1.000	0.971	0.893	11
Technical	U17	1.000	0.971	1.000	1.000	0.971	4
	U18	1.000	1.005	1.000	1.000	1.005	3
	U19	1.000	1.057	1.000	1.000	1.057	1
	U20	1.000	1.020	1.000	1.000	1.020	2
Total Average		0.992	1.013	0.996	0.997	1.005	

An examination of research universities revealed that only 40% of these institutions, specifically U2 and U4, experienced productivity growth. The remaining universities that exhibited productivity regression were discovered to have TFPCH negatively impacted by TECHCH. Furthermore, only one university, U3, demonstrated a reduction in EFFCH in addition to TECHCH, with this decline primarily attributed to a deterioration in SECH. As for comprehensive universities, the majority of the institutions experienced productivity regression over the period under study. Only 36% of them experienced productivity growth, specifically U6, U8, U13, and U14. Most institutions that experienced productivity regression had their MPI brought down by EFFCH. For these institutions, their negative EFFCH is more a consequence of SECH than PECH. Finally, it is observed that 75% of technical universities have experienced productivity growth, with only 25% of one university, U17, experiencing productivity regression. The negative TFPCH is contributed to by TECHCH by 2.9%.

4. Discussions and Concluding Remarks

This study utilized MPI alongside DEA to assess the productivity changes in Malaysian public universities over the period 2017–2021. In contrast to the earlier study by Arjomandi *et al.,* [3], which focused on specific universities, this study included all 20 Malaysian public universities and covered a more recent time frame during the implementation of the MEB (HE).

The findings revealed that MPI increased by an annual average of 0.5%, driven by a combination of a positive annual average technology change of 1.3% and a negative annual average efficiency change of 0.8%. This raises questions about the underlying reasons for this pattern. The primary driver for the change in production activity at universities appears to be the increasing use of blended learning and e-learning in Malaysia, emphasized by the MEB (HE). The significance of digital literacy for lifelong learning highlighted by the MEB (HE) aligns with the study's results. Additionally, the exceptional outbreak of the COVID-19 pandemic has further fuelled the increase in e-learning. However, the negative EFFCH is concerning, suggesting that while universities have responded to the call for development in the higher education system by adopting new technologies, they may have acted so at the expense of technical efficiency.

The positive increase in technology change alongside a significant drop in technical efficiency is also observed in research and comprehensive groups of universities. Johnes [26] posited that factors pushing out the production frontier, such as the use of e-learning, may have a negative effect or may be accompanied by a decline in technical efficiency. The growing usage of e-learning may allow for larger class sizes and a higher student-to-staff ratio, potentially negatively impacting technical efficiency.

It is particularly concerning that productivity has affected university groups differently. Research universities, including the top universities in Malaysia, have experienced a much lower MPI compared to the other two groups, driven by negative annual averages of EFFCH and TECHCH, specifically 0.1% and 0.6%, respectively. Comprehensive universities, on the other hand, have seen an average annual increase in MPI of 0.9%, fuelled by an increase in TECHCH of 3.2% and a decrease in EFFCH of 2.2%. Technical universities stand out as the best-performing group, excelling in every MPI component, and TFPCH across groups is at its highest in the year 2020–2021.

This study shares some similarities with the findings of Arjomandi *et al.,* [3] but also presents some differences. According to their study, research and comprehensive universities experienced declines in productivity, while focused universities experienced growth in productivity prior to the implementation of NHESP. However, after the implementation of NHESP, all three groups of universities saw considerable increases in productivity. In contrast, in this present study, conducted during the period of MEB (HE) implementation, only comprehensive and technical universities experienced a positive change in productivity, while research universities experienced a decline in productivity. Furthermore, Arjomandi *et al.,* [3] concluded that improvements in TFP were attributable to a mix of efficiency and technological changes and that the positive changes seen after 2007 were related to the implementation of NHESP. They also claimed that during the time of their study, TECHCH appeared to be the same for all universities across all periods, indicating that all universities had equal access to the same production possibility set. This contradicts the findings of this study, which determined that there were variations in TECHCH by university group.

Since the rapid pace of technological advancement and the increasing demand for highly skilled workers in various industries, it is crucial for HEIs to adapt their programs to meet the needs of the job market. While this study discovered evidence of increased productivity at Malaysian public universities following the implementation of MEB (HE), strategies should be implemented to maintain this achievement in the future. Additionally, addressing the issue of technical efficiency, as indicated by both previous and present research, is imperative. Future research could examine the effects of MEB (HE) after its completion in 2025, providing a comparison of productivity changes before and after its implementation. Such studies would contribute to improving the higher education system in Malaysia. The findings of this study shed light on the sources of productivity growth in Malaysian public universities, and other industries can apply the methodology employed to scrutinize various topics requiring further exploration.

Acknowledgement
This research was funded by a grant from Universiti Sains Malaysia (Grant Number 304/PMATHS/6315380).

References

[1] Jamalludin, Jerrize Izah, and Shamsul Sarip. "A TQM Implementation in Higher Education Institutions: A Review." *International Journal of Advanced Research in Future Ready Learning and Education* 25, no. 1 (2021): 30-48.
[2] Williams, Ross, G. De Rassenfosse, P. Jensen, and S. Marginson. "U21 ranking of national higher education systems." *Melbourne: University of Melbourne* (2012).
[3] Arjomandi, Amir, Mad Ithnin Salleh, and Abbas Mohammadzadeh. "Measuring productivity change in higher education: an application of Hicks–Moorsteen total factor productivity index to Malaysian public universities." *Journal of the Asia Pacific Economy* 20, no. 4 (2015): 630-643. https://doi.org/10.1080/13547860.2015.1045323
[4] Hock-Eam, Lim, Fauziah Md Taib, Hiau Abdullah, Nur Adiana, and Yen Siew Hwa. "How efficient are Malaysian public universities? A comparative analysis using data envelopment analysis." *Asian Academy of Management Journal* 21, no. 2 (2016): 75-97. https://doi.org/10.21315/aamj2016.21.2.4
[5] Ministry of Education Malaysia. "Executive Summary Malaysia Education Blueprint 2015-2025." *Putrajaya, Malaysia: Kementerian Pendidikan Malaysia,* (2015).
[6] Coelli, Timothy J., Dodla Sai Prasada Rao, Christopher J. O'donnell, and George Edward Battese. *An introduction to efficiency and productivity analysis*. springer science & business media, 2005.
[7] Malmquist, Sten. "Index numbers and indifference surfaces." *Trabajos de estadística* 4, no. 2 (1953): 209-242. https://doi.org/10.1007/BF03006863
[8] Caves, Douglas W., Laurits R. Christensen, and W. Erwin Diewert. "The economic theory of index numbers and the measurement of input, output, and productivity." *Econometrica: journal of the Econometric Society* (1982): 1393-1414. https://doi.org/10.2307/1913388
[9] Färe, Rolf, Shawna Grosskopf, Björn Lindgren, and Pontus Roos. "Productivity changes in Swedish pharamacies 1980–1989: A non-parametric Malmquist approach." *Journal of productivity Analysis* 3, no. 1 (1992): 85-101. https://doi.org/10.1007/BF00158770
[10] Ben Mabrouk, Mohsen, Manel Elmsalmi, Awad M. Aljuaid, Wafik Hachicha, and Sami Hammami. "Joined efficiency and productivity evaluation of tunisian commercial seaports using dea-based approaches." *Journal of Marine Science and Engineering* 10, no. 5 (2022): 626. https://doi.org/10.3390/jmse10050626
[11] Grifell-Tatjé, Emili, and CA Knox Lovell. "A generalized Malmquist productivity index." *Top* 7 (1999): 81-101. https://doi.org/10.1007/BF02564713
[12] Mei, Kangni, Ruxin Kou, Yuqing Bi, Yuzhuo Liu, Jingwen Huang, and Wei Li. "A study of primary health care service efficiency and its spatial correlation in China." *BMC Health Services Research* 23, no. 1 (2023): 247. https://doi.org/10.1186/s12913-023-09197-x
[13] Koiry, Subrata, and Wei Huang. "Do ecological protection approaches affect total factor productivity change of cropland production in Sweden?." *Ecological Economics* 209 (2023): 107829. https://doi.org/10.1016/j.ecolecon.2023.107829
[14] Färe, Rolf, Shawna Grosskopf, and Wen-Fu Lee. "Productivity in Taiwanese manufucturing industries." *Applied Economics* 27, no. 3 (1995): 259-265. https://doi.org/10.1080/00036849500000109
[15] Kittelsen, Sverre AC, and Finn R. Førsund. "Efficiency analysis of Norwegian district courts." *Journal of Productivity Analysis* 3, no. 3 (1992): 277-306. https://doi.org/10.1007/BF00158357

[16] Yu, Ming-Miin, and Li-Hsueh Chen. "Productivity change of airlines: A global total factor productivity index with network structure." *Journal of Air Transport Management* 109 (2023): 102403. https://doi.org/10.1016/j.jairtraman.2023.102403

[17] Rahimian, M., and M. Soltanifar. "An application of DEA based Malmquist productivity index in university performance analysis." *Management Science Letters* 3, no. 1 (2013): 337-344. https://doi.org/10.5267/j.msl.2012.10.023

[18] Salleh, Mad Ithnin, Shariffah Nur Illiana Syed Ismail, Nurul Fadly Habidin, Nor Azrin Md Latip, and Salomawati Ishak. "Productivity changes in individual Malaysian polytechnics based on bootstrapping the Malmquist indices." In *AIP Conference Proceedings*, vol. 1635, no. 1, pp. 898-905. American Institute of Physics, 2014. https://doi.org/10.1063/1.4903689

[19] Carrington, Roger, Chris O'Donnell, and D. S. Prasada Rao. "Australian university productivity growth and public funding revisited." *Studies in Higher Education* 43, no. 8 (2018): 1417-1438. https://doi.org/10.1080/03075079.2016.1259306

[20] González-Garay, Andrés, Carlos Pozo, Ángel Galán-Martín, Clemens Brechtelsbauer, Benoît Chachuat, Deesha Chadha, Colin Hale *et al.,* "Assessing the performance of UK universities in the field of chemical engineering using data envelopment analysis." *Education for Chemical Engineers* 29 (2019): 29-41. https://doi.org/10.1016/j.ece.2019.06.003

[21] Tran, Carolyn-Dung Thi Thanh. "Is there a productivity growth in private universities in Vietnam? Revisiting the 2005 Higher Education Reform Agenda." *International Journal of Education Economics and Development* 11, no. 3 (2020): 292-313. https://doi.org/10.1504/IJEED.2020.10029584

[22] Zhang, Ganggang, Jie Wu, and Qingyuan Zhu. "Performance evaluation and enrollment quota allocation for higher education institutions in China." *Evaluation and Program Planning* 81 (2020): 101821. https://doi.org/10.1016/j.evalprogplan.2020.101821

[23] Fare, Rolf, Shawna Grosskopf, and CA Knox Lovell. *Production frontiers*. Cambridge university press, 1994. https://doi.org/10.1017/CBO9780511551710

[24] Ministry of Higher Education. “Statistik Pendidikan Tinggi 2022 - 01 - ISI Kandungan.” (2022). https://www.mohe.gov.my/en/downloads/statistics/2022-3

[25] Castano, Mary Caroline N., and Emilyn C. Cabanda. "Performance evaluation of the efficiency of Philippine Private Higher Educational Institutions: application of frontier approaches." *International Transactions in operational research* 14, no. 5 (2007): 431-444. https://doi.org/10.1111/j.1475-3995.2007.00599.x

[26] Johnes, Jill. "Efficiency and productivity change in the English higher education sector from 1996/97 to 2004/5." *The Manchester School* 76, no. 6 (2008): 653-674. https://doi.org/10.1111/j.1467-9957.2008.01087.x