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ESTIMATING TECHNICAL EFFICIENCY AND BOOTSTRAPPING MALMQUIST INDICES: ANALYSIS OF MALAYSIAN PRESCHOOL SECTOR

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ABSTRACT

This study is focused on conceptual paper and the purpose of this study is to conduct an empirical investigation into the Malaysian Preschool institutions, focusing on measuring their technical efficiency and productivity changes. This study is to examine the nature of productivity changes by means of bootstrapped Malmquist TFP indices. The study use a Three-year set of panel data (2009–2012) for analyzing the performance of 8307 KEMAS Preschools classes during the implementation of the (Government Transformation Program) GTP 1.0. The study considered all KEMAS Preschools classes operating in the sector. The input and output data were manually extracted from the Malaysia's Ministry of Rural and Regional Development (MRRD) and all KEMAS Preschools. Non-parametric DEA models are employed to estimate efficiency and productivity changes of the institutions. Thus, this study is expected makes significant contributions to the literature of efficiency and productivity changes in Early Childhood Care and education institutions.

Keywords: technical efficiency, productivity changes, bootstrapped Malmquist, preschool sector

INTRODUCTION

Every child is precious and children are assets to our society. They are the most valuable resource of the nation. Developing a nation and its people begins with early childhood education. While it is the duty of parents to ensure a child has the opportunities to develop, it is also the government's responsibility to help parents bring the potential to fruition. In developing a child's potential, we are in reality developing the human capital of the child and of the nation. Therefore, a child has to grow holistically so that the child is equipped with abilities, knowledge and skills to become a productive member of the nation. Economists have long believed that investment in early education is a good strategy in developing human capital which in turn, is an important source for economic growth (SMD, 2014). Cognitive and non-cognitive abilities are important for a productive work force. It is said that key workforce skills such as motivation, persistence and self-control are developed early. Children are the future generations who have the potential to drive the economy of the country as leaders, innovators, entrepreneurs, researchers and economists.

In the last decade, Malaysian preschools have mushroomed all over the country. Preschools in Malaysia are so diverse due to the country's multicultural society and individual needs (Dahari & Ya, 2011). Preschool act as an institution that prepares children to enter social and education based environment which can be considered. Preschool can also be considered as preparatory class before entering primary school. In Malaysia, the preschools usually accommodate children from early as three to six years old (Mustafa, Yunus, & Azman, 2014). Early Childhood Care and Education (ECCE) sector in Malaysia are divided into two age groups, which is 0-4 years and 4-6 years old. The first group (0-4 years), comes under the Ministry of Women, Family and Community Development (MWFCD) which coordinates national programmes on the growth and development of children. Through its Department of Social Welfare, MWFCD keeps a register of all childcare centres (also known as TASKA) in the country. Pre-school education for the second group (4-6 years) (known as KEMAS) comes under three ministries/agencies, i.e. the Ministry of Education, the Ministry of Rural and Regional Development, and the National Unity Department. The operation of KEMAS preschools is funded by the Ministry of Rural and Regional Development. Every child receives RM1.50 per day for food and RM100 per year for learning materials. An additional food allowance of RM150.00 per year is given to very poor families (SMD, 2014). KEMAS preschools have been using the National Preschool Curriculum since 2003 and emphasises on reading, writing and arithmetic, developing individual potential, instilling moral values, building character and self-awareness; and developing physical, health, cleanliness and safety skills (CDC, 2007).

Recently Malaysian ECCE sector in Malaysia is catching much more attention. In a country where governance is much consolidated, such attention has given rise to more quality preschool classes and initiatives. Comprehensive policies have been developed and implemented by the government in order to ensure quality preschools for all children in Malaysia because children are the nation’s most valuable asset, as ‘today’s children are leaders of tomorrow’(Boon, 2010). The Malaysian government places a strong emphasis on ECCE and has formulated the National Policy for Early Childhood Education (CDC, 2007). Under this policy, programmes have been introduced to meet the diverse needs of the crucial early years of newborns till the age of six. These programmes provide a solid foundation for healthy growth and development which expose them to activities in nation building and enhance their readiness for primary school education. The government's involvement in ECCE is evident from its numerous initiatives to make early childhood programmes more accessible especially for less fortunate children and those in rural areas. Malaysian government effort can also be seen through the Government Transformation Programme (GTP) 1.0 (2009-2012). Over the three years of GTP 1.0, the Improving Student Outcomes National Key Result Area (EDU NKRA) aims to meet its key areas: increasing pre-school enrolment, screening primary students for basic numeracy and literacy skills, recognising high-performing schools, closing the gap between high- and under- performing schools, and encouraging greater school leadership. The EDU NKRA oversaw the opening of 2,054 new pre-school classes 2008 and saw enrolment creep up to 80% of pre-school aged children. It also implemented the pilot for a quality-gauging programme in preparation for the enhancement of the initiative in GTP 2.0 (2013-2015) (PEMANDU, 2012). A significant amount of funds is also allocated for ECCE every year (SMD, 2014). Malaysia has always place great effort in ensuring education and care for all children. These efforts are manifested through the any sectors involving in ECCE and the amount of allocation given to ECCE each year. Therefore, this study aims to measure the performance of KEMAS preschool institutions despite the allocation of large funding into the ECCE sector and the implementation of GTP 1.0. Besides, little documentation found regarding the empirical study as to how the KEMAS preschool institution performed after the implementation of GTP 1.0.

In the literature, the Malmquist productivity index is a widely accepted tool for constructing a quantitative measure of changes in the efficiency and productivity in education. Johnes (2008), Worthington and Lee (2008), Agasisti and Johnes (2009) and Bradley, Johnes, and Little (2010) are among the most recent studies which have applied the Malmquist total factor productivity

(TFP) index to this area. Caves, Christensen and Diewert (1982) proposed the Malmquist productivity index as a theoretical index. Färe, Grosskopf, Lindgren, and Ross (1992) later combined Farrell's (1957) measurement of efficiency with the Caves et al. (1982) measurement of productivity to develop a new Malmquist index of productivity changes, demonstrating that this TFP index could be decomposed into two components: efficiency-change and technical-change. Subsequently, Färe, Grosskopf, Normis, and Zhongyang (FGNZ) (1994) further decomposed technical efficiency change into changes in pure technical efficiency and scale efficiency, a development that has popularized the Malmquist index as an empirical index of productivity change.

According to Simar and Wilson (1998a), the FGNZ model can be further improved in terms of estimating technical changes. They argue that the inaccuracies in the FGNZ model 'may be attributed to their confusion between unknown quantities and estimates of these quantities' (p. 4). Simar and Wilson (1998a) concluded that 'it is not meaningful to draw inferences from results obtained with these methods as it is otherwise impossible to know whether the numbers reflect real economic phenomena or merely sampling variation' (p. 18). They proposed an alternative method to decompose the Malmquist index, whereby changes in technology were estimated from changes in the VRS, and the technical changes were in turn decomposed into pure technical changes and changes in scale efficiency.

When constructing Malmquist indices, the Data Envelopment Analysis (DEA) models are problematic in estimating distance functions. The DEA does not allow for random errors and as such remains without a valid statistical basis, making it inadequate for testing the statistical significance of estimated distance functions, or for undertaking sensitivity analysis to examine their asymptotic properties. For a detailed account of this issue Simar and Wilson (1998b, 1999, 2000), Lovell (2000) and Coelli, Rao, O'Donnell, and Battese (2005). With mainstream DEA analysis, an inherent problem is that distances to the frontier are underestimated if the most efficient firms within the population are excluded from the sample. This leads to biased frontier estimation, which in turn affects the measurement of distances to all other units. Uncertainty is manifested in the estimated DEA-based indices so it is important to form the confidence intervals.

Simar and Wilson (1998b, 2000) solved this problem using the bootstrap simulation method, which determines the statistical properties of the non-parametric estimators in a multi-input and multi-output context. In this way one can express the DEA efficiency scores within confidence intervals. The bootstrap technique was subsequently applied to estimate confidence intervals for the Malmquist indices (Simar & Wilson, 1999) but its applications were in the areas not related to higher education. For example, *inter alia* Gilbert and Wilson (1998) and Wheelock and Wilson (1999) employed this technique in the banking industry; Assaf (2011), Galdeano-Gómez (2008) and Balcombe, Davidova, and Latruffe (2008) for airlines, marketing and farming, respectively.

For the first time this study employs the Simar and Wilson (1998a) approach in the Early Childhood Care and Education (ECCE) to measure the Malmquist TFP index and its components, via. Changes in pure technical efficiency, changes in scale efficiency, pure changes in technology and changes in the scale of technology. This approach allows us to provide a more comprehensive and robust analysis of productivity and technical changes within Malaysian Preschool. We also employ the bootstrap simulation method (Simar & Wilson 1998b, 2000) to determine whether the computed changes in productivity are statistically significant or not.

Objectives of the Study

The main aim of this study is to conduct an empirical investigation into the Malaysian Preschool institutions, focusing on measuring their technical efficiency and productivity changes. Furthermore, this study aims to address the following three questions:

1. What is the mean efficiency score of KEMAS Preschool in Malaysia?
   The aim of this research question is to analyse the efficiency of Malaysian KEMAS Preschool Classes by calculating their efficiency scores. More specifically, this will determinate whether Preschools in Malaysia are efficient.

2. What is the total factor productivity (TFP) change in Malaysia's Preschools institutions?

3. Has the implementation of the GTP 1.0 led to an improvement in efficiency and productivity growth of the Malaysian Eraly Childhood Care and Education sector?
   This study investigates the effect of current government policies, specifically the 2009-2012 GTP 1.0, on changes in technical efficiency and productivity growth.

Literature Review of the Related Studies

The literature on the efficiency of education institutions using non-parametric approaches has expanded rapidly during the last few decades. The focus of the literature has been mainly on efficiency disparities among universities. A large number of these studies have been predominantly undertaken in developed countries (e.g. Tomkins & Green, 1988; Beasley, 1990; Johnes & Johnes, 1993; Kao, 1994; Sinuany-Stern, Mehrez, & Barboy, 1994; Beasley, 1995; Johnes & Johnes, 1995; Athanassapoulos & Shale, 1997; Madden & Savage, 1997; Sarrico, Hogan, Dyson, & Athanassopoulos, 1997; Haksever & Muragishi, 1998; Hanke & Leopoldseder, 1998; Post & Spronk, 1999; Colbert, Levary, & Shaner, 2000; Sarrico & Dyson, 2000; Korhonen, Tainio, & Wallenius, 2001; Abbott & Doucouliagos, 2003; Warning, 2004; Carrington, Coelli, & Rao, 2005; Emrouznejad & Thanassoulis, 2005; Joumady & Ris, 2005; Johnes, 2006a; Johnes, 2006b; McMillan, & Chan, 2006; Tauer, Fried, & Fry, 2007; Tajnikar & Debevec, 2008; Abbott & Doucouliagos, 2009; Johnes & Schwarzenberger, 2010; Kempkes & Pohl, 2010). Only a few efficiency studies on universities were related to developing countries. For instance, Ng and Li (2000), examined the efficiency of 84 key Chinese higher education institutions in the post-reform period (1993–1995) using DEA. Focusing on their research performance, they found that performance of the institutions has on average, improved over time. Universities located in the eastern region have performed better than those in the central and western regions. In another study of developing countries, Cokgezen (2009) investigates the technical efficiency of faculties of economics in Turkey in 2004. His results indicate that overall the faculties are subject to low efficiencies with some significant variations. It is also found that the mean technical efficiency of the public faculties was higher than that of the private faculties (Cokgezen, 2009).

However, concentrating only on efficiency estimates can provide an incomplete view of Preschools performance over time. It is for this reason that changes in distance functions could be caused by either the movement of Preschools within the input-output space (efficiency changes); or the progress/regress of the boundary of the production set over time (technological changes). There are only a few studies in the existing literature that have attempted to distinguish changes in efficiency, productivity and technological changes using the conventional Malmquist index such as Abbott and Doucouliagos (2000), Flegg, Allen, Field, and Thurlow (2004), Carrington et al.

(2005), Johnes (2008), Worthington and Lee (2008), Agasisti and Johnes (2009) and Bradley et al. (2010).

Most of these studies commonly found some productivity enhancement in different sectors and these changes were mainly attributed to technological changes and/or efficiency changes. For example, Flegg et al. (2004) examined the changes in productivity of 45 British universities in the period 1980–1993. Their results provided convincing evidence that positive productivity changes were resulted from technological changes rather than efficiency changes. In a comprehensive study of 35 Australian universities, Worthington and Lee (2008) also found a similar source and pattern in productivity growth. Agasisti and Johnes (2009) provided cross-country efficiency and productivity comparisons of Italian and English universities over a four-year period (2002–2005). They attributed the overall productivity progress of the British and Italian universities to technological improvements and efficiency growth, respectively. Bradley et al. (2010) investigated the performance of 200 educational institutions in the UK in the period 1999–2003. Their results indicated that the overall productivity growth originated mainly from both technical efficiency and technological changes.

Despite a growing volume of literature surrounding the application of the conventional Malmquist index in the education sector, little is documented about the application of the bootstrap procedure on the Malmquist estimates. To the best of our knowledge, only Parteka and Wolszczak-Derlacz (2011) have applied the traditional bootstrapped Malmquist approach to compare productivity changes of higher education sectors in 7 European countries across the period 2001–2005. Their bootstrap analysis indicates that 90% of their estimates were statistically significant. Also they find an annual average growth of 4% in productivity, which was as a result of positive efficiency changes in the sector.

Our study is unique in the sense that the proposed bootstrap technique has not been utilized to measure the efficiency and productivity of preschools in a developing country. This was probably due to the lack of user-friendly software program. In this study we employ the FEAR package in R, which was introduced by Wilson (2006) to undertake our computations.

The Data

We use a Three-year set of panel data (2009–2012) for analyzing the performance of 8307 KEMAS Preschools classes during the implementation of the (Government Transformation Program) GTP 1.0. We considered all KEMAS Preschools classes operating in the sector. The input and output data were manually extracted from the Malaysia's Ministry of Rural and Regional Development (MRRD) and all KEMAS Preschools.

Non-parametric DEA models are employed to estimate efficiency and productivity changes of the institutions. The most important advantage of the DEA approach pertains to its ability to handle cases with small sample sizes as well as big sample. There are several studies which have possessed small sample sizes in the literature (e.g. Tomkins & Green, 1988; Sinuany-Stern et al., 1994; Sarafoglou & Haynes, 1996; Hanke & Leopoldseder, 1998; Haksever & Muragishi, 1998; Korhonen et al., 2001; Emrouznejad & Thanassoulis, 2005). Another advantage of this approach over parametric approaches is that we can analyze productivity changes while dealing with multiple inputs and outputs.

The crucial factor that needs to be considered in using the DEA approach is the right selection of inputs and outputs. However, there is no consensus in the literature on how to best specify them in education sector (Johnes & Johnes, 1993, 1995; Avkiran, 2001). According to Lindsay (1982, p. 176) some characteristics of the education sector such as the 'lack of profit motivation, goal diversity and uncertainty, diffuse decision making and poorly understood production technology' differentiate this sector from other industries and make the specification of the variables even more complicated. Carrington et al. (2005) also state that it is difficult to accurately define the education inputs and outputs as they are diverse and multi-faceted.

The inputs and outputs employed in this study are based on the production approach in which Preschools utilize labor and non-labor factors of production to produce various outputs such as teaching other educational services. This approach is most consistent with Worthington and Lee (2008) but also has a commonality with the work of Beasley (1990, 1995), Johnes and Johnes (1993, 1995), Madden et al. (1997), Athanassapoulos and Shale (1997) and Glass, McCallion, McKillop, Rasaratnam, and Stringer (2006).

Two inputs included in this article, are as follows: 1) KEMAS Preschool enrolments; 2) the number of full-time equivalent teaching staff members. We consider the total number of students enrolled instead of the more commonly used full-time equivalent student load, due to the unavailability of the data. In terms of outputs, we considered one outputs in our DEA model: 1) the number of KEMAS qualifications awarded.

There are a few points that should be noted here. First, regarding student inputs, there is no direct allowance for quality, and this is consistent with DEA models of previous studies (e.g. Athanassapoulos & Shale, 1997; Flegg & Allen, 2007; Johnes, 2008; Worthington & Lee, 2008). Second, in this study our focus is mainly on teaching as the most important outputs rather than community services. This is because there is no accepted way of evaluating community and consultation services in the literature primarily due to data limitations and definitions (see Ahn, Charnes, & Cooper, 1988; Ahn, Arnold, Charnes, & Cooper, 1989; Carrington et al., 2005; Johnes, 2008; Worthington & Lee, 2008).

Measuring the Malmquist Productivity Index

In measuring productivity change between periods t_1 and t_2, we need to know how *N* firms produce *q* outputs using *p* inputs over *T* time periods. A generic firm in period t_1 employs input x_{t_1} to produce output y_{t_1}, and in period t_2 quantities of input and output are x_{t_2} and y_{t_2}, respectively. The production–possibilities set at time *t* is then:

$$S_t = \{(x, y) \mid x \text{ can produce } y \text{ at time } t\} \quad (1)$$

where *x* is an input vector, $x \in \mathbb{R}_+^n$ and *y* is an output vector, $y \in \mathbb{R}_+^m$ at time *t*. This can be further described in terms of its sections. For example:

$$y_{t_2}(x_{it_1}) = \{y \in \mathbb{R}_+^m \mid (x, y) \in S_t\} \quad (2)$$

becomes the corresponding output feasibility set. Based on Shephard (1970), the output distance function for firm *i* at time t_1 is given by:

$$D^{o}_{it_1|t_2} \equiv \inf\left\{\theta > 0 \;\middle|\; y_{it_1}/\theta \in y_{t_2}(x_{it_1})\right\} \tag{3}$$

$D^{o}_{it_1|t_2}$ measures the distance from the i^{th} firm's position in the input-output space at time t_1 to the boundary of the production set at time t_2, where inputs remain constant and θ is a scalar equal to the efficiency score. If t_1 and t_2 are equal, it is a measure of efficiency relative to technology at the same time, and $D^{o}_{it|t} \leq 1$. When t_1 and t_2 are not equal, $D^{o}_{it_1|t_2}$ can be <, > or =1. According to Färe et al. (1992) the Malmquist index between periods t_1 and t_2 can be written as:

$$M_i^{o}(t_1, t_2) = \sqrt{\left(\frac{D^{oc}_{it_1|t_2}}{D^{oc}_{it_1|t_1}}\right)\left(\frac{D^{oc}_{it_2|t_2}}{D^{oc}_{it_2|t_1}}\right)} \tag{4}$$

Equation (4) shows a geometric mean of the Malmquist productivity indices for t_1 and t_2, as defined by Caves *et al.* (1982). That is, if $M > 1$, total factor productivity change between periods t_1 and t_2 is positive; if $M < 1$, the total factor productivity is negative; if $M = 1$ there is no change in productivity.

However, Simar and Wilson (1999) argued that as the production possibility set S_t is unknown, all defined distances are therefore unobservable. Hence, there is a need for the estimation of the Malmquist productivity index and the corresponding distance functions. To do so, we should estimate the production set, S_t, and the output feasibility set, $y(x)$. Burgess and Wilson (1995) expressed the estimated production set as:

$$S_t = \left\{(x, y) \in \mathbb{R}_{+}^{m+n} \middle| y \leq Y_t\gamma,\ x \geq X_t\gamma,\ \vec{1}\gamma = 1,\ \gamma \in \mathbb{R}_{+}^{N}\right\} \tag{5}$$

where $Y_t = [y_{1t}, y_{2t}, ..., y_{Nt}]$, y_{it} denotes the $(m \times 1)$ vector of observed outputs, $X_t = [x_{1t}, x_{2t}, ..., x_{Nt}]$ and x_{it} denotes the $(n \times 1)$ vector of observed inputs, and $\vec{1}$ and γ are a vector of one and an intensity variable, respectively. Hence, the corresponding output feasibility sets can be expressed as:

$$y_t^{c}(x) = \left\{y \in \mathbb{R}_{+}^{m} \middle| y \leq Y_t\gamma,\ x \geq X_t\gamma,\ \gamma \in \mathbb{R}_{+}^{N}\right\} \tag{6}$$

and,

$$y_t^{v}(x) = \left\{y \in \mathbb{R}_{+}^{m} \middle| y \leq Y_t\gamma,\ x \geq X_t\gamma,\ \vec{1}\gamma = 1,\ \gamma \in \mathbb{R}_{+}^{N}\right\} \tag{7}$$

Substituting $y_t^{c}(x)$ and $y_t^{v}(x)$ for $y_t(x)$ in Equation 2 yields the estimated distance functions by solving the following linear programs:

$$(\dot{D}^{oc}_{it_1|t_2})^{-1} = \max\left\{\lambda \,\middle|\, \lambda y_{it_1} \le Y_{t_2}\gamma_i,\ x_{it_1} \ge X_{t_2}\gamma_i,\ \gamma_i \in \mathbb{R}^N_+\right\} \tag{8}$$

and,

$$(D^{ov}_{it_1|t_2})^{-1} = \max\left\{\lambda \,\middle|\, \lambda y_{it_1} \le Y_{t_2}\gamma_i,\ x_{it_1} \ge X_{t_2}\gamma_i,\ \overrightarrow{1\gamma} = 1,\ \gamma_i \in \mathbb{R}^N_+\right\} \tag{9}$$

where $\dot{D}^{oc}_{it_1|t_2}$ incorporates an assumption of CRS and $D^{ov}_{it_1|t_2}$ allows for VRS. Given the estimates of the distance functions, the Malmquist index can be obtained by substituting the estimated distance function values in Equation 4:

$$\hat{M}^o_i(t_1,t_2) = \sqrt{\left(\frac{\dot{D}^{oc}_{it_1|t_2}}{\dot{D}^{oc}_{it_1|t_1}}\right)\left(\frac{\dot{D}^{oc}_{it_2|t_2}}{\dot{D}^{oc}_{it_2|t_1}}\right)} \tag{10}$$

Färe et al. (1992) decomposed this total factor productivity change into two components:

$$\dot{M}^o_i(t_1,t_2) = \underbrace{\frac{\dot{D}^{oc}_{it_2|t_2}}{\dot{D}^{oc}_{it_1|t_1}}}_{\Delta Eff} \times \underbrace{\sqrt{\left(\frac{\dot{D}^{oc}_{it_1|t_2}}{\dot{D}^{oc}_{it_2|t_2}}\right)\left(\frac{\dot{D}^{oc}_{it_1|t_1}}{\dot{D}^{oc}_{it_2|t_1}}\right)}}_{\Delta Tech} \tag{11}$$

where the term outside the square root sign, ΔEff, is an index of relative change in technical efficiency, and indicates how much closer (or farther away) a firm becomes to the best-practice frontier. The index can again be >, = or < unity depending upon whether the firm being considered improves, plateaus or deteriorates. The second component, $\Delta Tech$, is the technical-change component, which quantifies how much the frontier shifts, and indicates whether the best-practice firm is improving, plateauing, or deteriorating, thus permitting a comparison to the evaluated firm. Similarly it can be >, < or = unity depending on whether the technical change is positive, zero or negative.

Färe et al. (1994) demonstrated that the technical-change component can be divided into two components: pure technical efficiency and scale efficiency:

$$\dot{M}^o_i(t_1,t_2) = \underbrace{\left(\frac{\dot{D}^{ov}_{it_2|t_2}}{\dot{D}^{ov}_{it_1|t_1}}\right)}_{\Delta PureEff} \times \underbrace{\left(\frac{\dot{D}^{oc}_{it_2|t_2} / \dot{D}^{ov}_{it_2|t_2}}{\dot{D}^{oc}_{it_1|t_1} / \dot{D}^{ov}_{it_1|t_1}}\right)}_{\Delta Scale} \times \underbrace{\sqrt{\left(\frac{\dot{D}^{oc}_{it_1|t_2}}{\dot{D}^{oc}_{it_2|t_2}}\right)\left(\frac{\dot{D}^{oc}_{it_1|t_1}}{\dot{D}^{oc}_{it_2|t_1}}\right)}}_{\Delta Tech} \tag{12}$$

where $\Delta PureEff$ and $\Delta Scale$ are proxies for pure efficiency change and change in scale efficiency, respectively, and $\Delta Eff = \Delta PureEff \times \Delta Scale$. The factor $\Delta Tech$ remains unchanged from Equation 11, yielding a measure of the change in technology. While $\Delta Tech$ signifies that the CRS frontier shifts over time, changes in pure efficiency and scale efficiency correspond to VRS frontiers from two different periods.

Simar and Wilson (1998a), however, stated that if a generic firm's position in the input-output space remains fixed between time t_1 and t_2, and the only change that occurs is in the VRS estimate of technology (e.g., shift upward), then the $\Delta Tech$ presented in Equation 12 will be equal to unity, suggesting no change in technology. The $\Delta Tech$ in Equation 12 points to a change in technology if the CRS estimate of the technology changes. In this context, they concluded that the CRS estimate of the technology is statistically inconsistent. Since the VRS estimator is always consistent under the Kneip, Park, and Simar (1996) assumptions, Simar and Wilson (1998a) propose an alternative decomposition of the Malmquist index to estimate changes in technology ($\Delta Tech$) by using changes in the VRS estimate:

$$\dot{M}_i^o(t_1,t_2) = \underbrace{\left(\frac{\dot{D}^{ov}_{it_2|t_2}}{\dot{D}^{ov}_{it_1|t_1}}\right)}_{\Delta PureEff} \times \underbrace{\left(\frac{\dot{D}^{oc}_{it_2|t_2} \,/\, \dot{D}^{ov}_{it_2|t_2}}{\dot{D}^{oc}_{it_1|t_1} \,/\, \dot{D}^{ov}_{it_1|t_1}}\right)}_{\Delta Scale} \times$$

$$\underbrace{\sqrt{\left(\frac{\dot{D}^{ov}_{it_1|t_2}}{\dot{D}^{ov}_{it_2|t_2}} \times \frac{\dot{D}^{ov}_{it_1|t_1}}{\dot{D}^{ov}_{it_2|t_1}}\right)}}_{\Delta PureTech} \times \underbrace{\sqrt{\left(\frac{\dot{D}^{oc}_{it_1|t_2} \,/\, \dot{D}^{ov}_{it_1|t_2}}{\dot{D}^{oc}_{it_2|t_2} \,/\, \dot{D}^{ov}_{it_2|t_2}} \times \frac{\dot{D}^{oc}_{it_1|t_1} \,/\, \dot{D}^{ov}_{it_1|t_1}}{\dot{D}^{oc}_{it_2|t_1} \,/\, \dot{D}^{ov}_{it_2|t_1}}\right)}}_{\Delta ScaleTech} \qquad (13)$$

where $\Delta Tech$ is further decomposed into pure technical change – $\Delta PureTech$ – and change in the scale of technology – $\Delta ScaleTech$, and $\Delta Tech = \Delta PureTech \times \Delta ScaleTech$. Furthermore, $\Delta PureTech$ is the geometric mean of two ratios that measure the shift in the VRS frontier estimate relative to the firm's position at times t_1 and t_2. When $\Delta PureTech$ is greater than unity, it indicates an expansion in pure technology, or more specifically, an upward shift of the VRS estimate of the technology. $\Delta ScaleTech$ yields information concerning the shape of the technology by explaining the change in returns to scale of the VRS technology estimated at two fixed points, which are the firm's locations at times t_1 and t_2. When $\Delta ScaleTech$ is greater than unity, this suggests that the technology is moving farther from CRS and the shape of technology is becoming increasingly convex. Correspondingly, when this index is less than unity, it suggests that the technology is moving toward CRS; and when equal to unity implies no changes in the shape of the technology.

A similar decomposition of the Malmquist index was also proposed by Ray and Desli (1997), combining changes in the scale of efficiency and the scale of technology into a single term. Nevertheless, Simar and Wilson (1999) contend that Ray and Desli confuse changes in the shape of the technology and in the scale efficiency experienced by the production unit. Färe et al. (1997) also agrees that Ray and Desli's alternative decomposition of Malmquist incorrectly measures changes in scale efficiency.

Formulation of the Bootstrap

Simar (1992) and Simar and Wilson (1998b) pioneered the use of bootstrapping in frontier models to obtain non-parametric envelopment estimators. The underlying idea of bootstrapping is to approximate a true sampling distribution by mimicking the data-generation process. This procedure is based on constructing a pseudo-sample and re-solving the DEA model for each Decision Making Unit (DMU) with the new data. An iterative process yields an approximation of the true distribution. Simar and Wilson (1998b) demonstrate that consistent estimation of the confidence intervals is dependent upon consistent replication of the data-generation process. In other words, the most important problem of bootstrapping in frontier models relates to the consistent replication of the data-generation process. Since the distance estimation values approach unity, re-sampling directly from the original dataset (the so-called naive bootstrap) to construct pseudo-samples will generate an inconsistent bootstrap estimation of the confidence intervals.

To overcome this problem, Simar and Wilson (1998b) proposed a smoothed bootstrap procedure. They used a univariate kernel estimator of the density of the original distance function estimates, and constructed the pseudo-data from this estimated density. To estimate the Malmquist indices, they used panel data in lieu of a single cross-section of data with the possibility of temporal correlation. Simar and Wilson (1999), in adapting the bootstrapping procedure for Malmquist indices, proposed a consistent method using a bivariate kernel density estimate via the covariance matrix of data from adjacent years. This process can be summarized in the following five steps:

1. Calculating the Malmquist index $\dot{M}_i^o(t_1, t_2)$ for each Preschool $(i = 1, ..., N)$ at time (t_1 and t_2) by solving the linear programming models in Equations 8 and 9 and their reversals.
2. Constructing the pseudo-data set $\left\{\left(x_{it}^*, y_{it}^*\right); i = 1, ..., N; t = 1, 2\right\}$ to create the reference bootstrap technology using the bivariate kernel density estimation and the use of the reflection method developed by Silverman (1986).
3. Calculating the bootstrap estimate of the Malmquist index ${}^{*}M_i^o(t_1, t_2)$ for each university $(i = 1, ..., N)$ by applying the original estimators to the pseudo-sample attained in Step 2.
4. Repeating Steps 2 and 3 numerous times (for example in this study B=2000) to facilitate B sets of estimates for each firm.
5. Constructing the confidence intervals for the Malmquist indices accordingly.

The main issue in designing the confidence intervals of the Malmquist indices pertains to the distribution of $\dot{M}_i^o(t_1,t_2) - M_i^o(t_1,t_2)$ which is unknown and can be approximated by the distribution of ${}^{*}M_i^o(t_1,t_2) - \dot{M}_i^o(t_1,t_2)$, where $M_i^o(t_1,t_2)$ is the true unknown index, $\dot{M}_i^o(t_1,t_2)$ is the estimate of the Malmquist index and ${}^{*}M_i^o(t_1,t_2)$ denotes the bootstrap estimate of the index. If the distribution of $(\dot{M}_i^o(t_1, t_2) - M_i^o(t_1, t_2))$ was known, then it would be rather easy to calculate values a_α and b_α in the following interval:

$$\Pr(b_\alpha \le \dot{M}_i^o(t_1,t_2) - M_i^o(t_1,t_2) \le a_\alpha) = 1 - \alpha \tag{14}$$

But as the type of distribution is unknown, we use the bootstrap values to estimate a_α^* and b_α^* with high probability by Equation (15):

$$\Pr(b_\alpha^* \le {}^{*}M_i^o(t_1,t_2) - \dot{M}_i^o(t_1,t_2) \le a_\alpha^*) = 1 - \alpha \tag{15}$$

Thus, with $(1-\alpha)$ percentage confidence, one can argue that the *i*th Malmquist index lies between the following intervals:

$$\dot{M}_i^o(t_1,t_2) + a_\alpha^* \le M_i^o(t_1,t_2) \le \dot{M}_i^o(t_1,t_2) + b_\alpha^* \tag{16}$$

A Malmquist index for the *i*th firm is significantly different from unity (suggesting no productivity change) at the α % level, if the interval in Equation 16 does not include unity.

By utilising the calculated bootstrap value in Step 4, we can also correct for any finite-sample bias in the original estimators of the Malmquist indices with the application of the simple procedure outlined by Simar and Wilson (1999). The bootstrap bias estimate for the original estimator $\hat{M}_i^o(t_1,t_2)$ is given by:

$$\widehat{bias}_B\left[\hat{M}_i^o(t_1,t_2)\right] = B^{-1}\sum_{b=1}^{B}\hat{M}_i^{*o}(t_1,t_2)(b) - \hat{M}_i^o(t_1,t_2) \qquad (17)$$

Thus, a bias-corrected estimate of $M_i^o(t_1,t_2)$ can be computed as:

$$\begin{aligned}\hat{\hat{M}}_i^o(t_1,t_2) &= \hat{M}_i^o(t_1,t_2) - \widehat{bias}_B\left[\hat{M}_i^o(t_1,t_2)\right] \\ &= 2\hat{M}_i^o(t_1,t_2) - B^{-1}\sum_{b=1}^{B}\hat{M}_i^{*o}(t_1,t_2)(b)\end{aligned} \qquad (18)$$

This bias-corrected estimator may possess a higher mean-square error than the original estimator, and hence it will be less reliable (Simar and Wilson, 1999). The bias-corrected estimator should only be used if the sample variance (${}^{*}S_i^2$) of the bootstrap values $\left\{\hat{M}_i^{*o}(t_1,t_2)(b)\right\}_{b=1,\ldots,B}$ is not greater than one-third of the squared bootstrap bias estimate for the original estimator:

$${}^{*}S_i^2 < \frac{1}{3}\left(\widehat{bias}_B\left[\hat{M}_i^o(t_1,t_2)\right]\right)^2 \qquad (19)$$

We have conducted this procedure by using commands *malmquist.components* and *malmquist* in the FEAR software program. The above methodology can easily be adapted to efficiency scores. Only the time-dependent structure of the data must be changed (by replacing t_1 and t_2 with the period considered). This procedure can be undertaken by using command *boot.sw98* in the FEAR program.

DISCUSSION AND CONTRIBUTIONS OF THE STUDY

This study is expected makes four significant contributions to the literature of efficiency and productivity changes in Early Childhood Care and education institutions. First, this study is the first attempt to examine the issue of efficiency and productivity change by employing DEA and Bootstrap Malmquist TFP index on the multiple inputs and outputs of obtained from 8307 KEMAS Preschools institutions during the period from 2009 to 2012. Through the analyses efficiency of Malaysian KEMAS Preschool Classes by calculating their efficiency scores based on budget allocation, manpower and students outcome. For example, increasing student enrolments rate to KEMAS Preschool to improve students' outcomes. The outcomes of this study will determinate whether KEMAS preschools are efficient compared to Preschools in Malaysia.

Second, this is the first study to measure the KEMAS Preschools efficiency and productivity growth in response to significant policy changes in the Malaysian Early education sector during 2009. The effect of the GTP 1.0 on the performance of Malaysian Preschools institutions over the period of 2009–2012 in particular is investigated. The study significant for policy changes to educate & monitor teachers' competency in: Planning activities that involve interactions with every student; recording progress assessment & activity mastery in each aspect of development; develop individual Thematic Modules that is understandable and practical for each strand, and practice teaching in English as highlighted in national preschool curriculum (KSPK) for KEMAS, MOE, and JPNIN Preschools (Nordin Mamat, Maimunah Muda, Mohamad Sahari Nordin, 2014). Comprehensive policies have been developed and implemented by the government agency such as MOE, KEMAS and JPNIN in order to ensure quality preschools for all children in Malaysia and make sure no child left behind. The government's involvement in ECCE can be seen through the Government Transformation Programme (GTP) 1.0 (2009-2012) and GTP 2.0 (2013-2015). Over the three years of GTP 1.0, the Improving Student Outcomes National Key Result Area (EDU NKRA) aims to meet its key areas: increasing pre-school enrolment. A significant amount of funds is also allocated for ECCE every year for example 2015, Government allocation for ECCE RM711,000,000.00, and for KEMAS specifically RM130,000,000.00. Significant result show the enrollment rate increased since 2011 77.23 per cent to 84.6 in 2016.

Lastly, no previous study in developing countries has employed a bootstrapped Malmquist method under the assumption of VRS (Simar & Wilson, 1999) to measure efficiency and productivity changes in Preschools institutions. The aspect of the current study will use bootstrapped Malmquist TFP index to measure productivity change and to decompose change in productivity into efficiency change and technical change over the period 2009–2012 at KEMAS Preschools. There are two main reasons why the bootstrapped Malmquist TFP index has been employed in this study. First, these methods can analyse the productivity changes under the assumption of variable returns to scale (VRS) compared to the popular Malmquist indices, which assume constant returns to scale (CRS) conditions. The indicator to be used in this study such students' achievement, teacher qualification, learning facilities and resources. Second, the bootstrapped Malmquist index enables the decomposition of technical changes into changes of pure technology (frontier shifts), and changes in the scale of technology (changes in the shape of frontier). The traditional Malmquist index, on the other hand, is unable to analyse these changes in the shape of the technology frontier. Based on this study, there are two things to be considered whether to change of pure technology or changes in the scale technology there has been practices in KEMAS preschool.

In conclusion, through the GTP 1.0 and continues to GTP 2.0 the amount of allocation given to ECCE each year increased. Therefore, this study aims to measure the performance of KEMAS preschool institutions despite the allocation of large funding into the ECCE sector and the implementation of GTP 1.0 and GTP 2.0. On top of that this empirical study show how the KEMAS preschool institution performed after the implementation of GTP 1.0 and GTP 2.0 should be investigated.

REFERENCES

Abbott, M., & Doucouliagos, C. (2000). Amalgamations and the effficiency of Queensland TAFE Institute. *Australian and New Zealand Journal of Vacational Education Research*, 8, 1–19.

Abbott, M., & Doucouliagos, C. (2003). The efficiency of Australian universities: A data envelopment analysis. *Economics of Education Review*, 22, 89–97.

Abbott, M., & Doucouliagos, C. (2009). Competition and efficiency: Oversea students and technical efficiency in Australian and New Zealand Universities. *Education Economics*, 17, 31–57.

Agasisti, T., & Johnes, J. (2009). Beyond frontiers: Comparing the efficiency of higher education decision-making units across more than one country. *Education Economics*, 17, 59–79.

Ahn, T., Arnold, V., Charnes, A., & Cooper, W. W. (1989). DEA and ratio efficiency analysis for public institutions of higher learning in Texas. *Research in Governmental and Nonprofit Accounting*, 5, 165–85.

Ahn, T., Charnes, A., & Cooper, W. W. (1988). Some statistical and DEA evaluations of relative efficiencies of public and private institutions of higher learning. *Socio-Economic Planning Sciences*, 22, 259–69.

Assaf, A. (2011). A fresh look at the productivity and efficiency changes of UK airlines. *Applied Economics*, 43, 2165–175.

Athanassapoulos, A. D., & Shale, E. (1997). Assessing the comparative efficiency of higher education. *Education Economics*, 5, 117–34.

Avkiran, N. K. (2001). Investigating technical and scale efficiencies of Australian universities through data envelopment analysis. *Socio-Economic Planning Sciences*, 35, 57–80.

Balcombe, K., Davidova, S., & Latruffe, L. (2008). The use of bootstrapped Malmquist indices to reassess productivity change findings: an application to a sample of Polish farms. *Applied Economics*, 40, 2055–61.

Beasley, J. E. (1990). Comparing university departments. *Omega*, 18, 171–83.

Beasley, J. E. (1995) Determining teaching and research efficiencies. *The Journal of the Operational Research Society*, 46, 441–52.

Boon, N. S. (2010). Governance of education related ECCE policies in Malaysia. *International Journal of Child Care and Education Policy*, 4(1), 45–57.

Bradley, S., Johnes, J., & Little, A. (2010). Measurement and determinants of efficiency and productivity in the further education sector in England. *Bulletin of Economic Research*, 62, 1–30.

Burgess, J. F., & Wilson, P. W. (1995). Decomposing hospital productivity changes, 1985–1988: A nonparametric Malmquist approach. *The Journal of Productivity Analysis*, 6, 343–63.

Carrington, R., Coelli, T., & Rao, D. S. P. (2005). The performance of Australian universities: conceptual issues and preliminary results. *Economic Papers of the Economic Society of Australia*, 24, 145–63.

Caves, D. W., Christensen, L. R., & Diewert, W. E. (1982). The economic theory of index numbers and the measurement of input, output and productivity. *Econometrica*, 50, 1393–414.

CDC. (2007). Curriculum development centre, Ministry of Education Malaysia (Early Childhood Care and Education Policy Implementation Review 2007).

Coelli, T. J., Rao, D. S. P., O'Donnell, C. J., & Battese, G. E. (2005). *An Introduction to Efficiency and Productivity Analysis*, Springer Science and Business Media, New York.

Cokgezen, M. (2009). Technical efficiency of faculties of economics in Turkey. *Education Economics*, 17, 81–94.

Colbert, A., Levary, R. R., & Shaner, M. C. (2000). Determining the relative efficiency of MBA programs using DEA. *European Journal of Operational Research*, 125, 656–69.

Dahari, Z., & Ya, M. S. (2011). Factors that influence parents' choice of pre-schools education in Malaysia: An exploratory study. *International Journal of Business and Social Science*, 2, 115-128

Emrouznejad, A., & Thanassoulis, E. (2005). A mathematical model for dynamic efficiency using data envelopment analysis. *Applied Mathematics and Computation*, 160, 363–78.

Färe, R., Grosskopf, S., & Norris, M. (1997). Productivity growth, technical progress and efficiency change in industrialized countries: Reply. *American Economic Review*, 87, 1040–3.

Färe, R., Grosskopf, S., Lindgren, B., & Roos, P. (1992). Productivity changes in Swedish pharmacies 1980–1989: A nonparametric Malmquist approach. *Journal of Productivity Analysis*, 3, 85–101.

Färe, R., Grosskopf, S., Norris, M., & Zhongyang, Z. (1994). Productivity growth, technical progress and efficiency change in industrialized countries. *American Economic Review*, 84, 66–83.

Farrell, M. J. (1957). The measurement of productive efficiency. *Journal of the Royal Statistical Society*, 120, 229–53.

Flegg, A. T., & Allen, D. O. (2007). Does expansion cause congestion? The case of the older British universities, 1994–2004. *Education Economics*, 15, 75–102.

Flegg, A. T., Allen, D. O., Field, K., & Thurlow, T. W. (2004). Measuring the efficiency of British universities: A multi-period data envelopment analysis. *Education Economics*, 12, 231–49.

Galdeano-Gómez, E. (2008). Productivity effects of environmental performance: Evidence from TFP analysis on marketing cooperatives. *Applied Economics*, 40, 1873–88.

Gilbert, R. A., & Wilson, P. W. (1998). Effects of deregulation on the productivity of Korean Banks. *Journal of Economics and Business*, 50, 133–55.

Glass, J. C., McCallion, G., McKillop, D. G., Rasaratnam, S., & Stringer, K. S. (2006). Implications of variant efficiency measures for policy evaluations in UK higher education. *Socio-Economic Planning Sciences*, 40, 119–42.

Haksever, C., & Muragishi, Y. (1998). Measuring value in MBA programmes. *Education Economics*, 6, 11–25.

Hanke, M., & Leopoldseder, T. (1998). Comparing the efficiency of Austrian universities. *Tertiary Education and Management*, 4, 191–97.

Johnes, G. (1995). Scale and technical efficiency in the production of economic research. *Applied Economics Letters*, 2, 7–11.

Johnes, G., & Johnes, J. (1993). Measuring the research performance of UK economics departments: An application of data envelopment analysis. *Oxford Economic Papers*, 45, 332–47.

Johnes, G., & Schwarzenberger, A. (2010). Differences in cost structure and the evaluation of efficiency: the case of German universities. *Education Economics*, 19, 487–9.

Johnes, J. (2006a). Data envelopment analysis and its application to the measurement of efficiency in higher education. *Economics of Education Review*, 25, 273–88.

Johnes, J. (2006b). Measuring teaching efficiency in higher education: An application of data envelopment analysis to economics graduates from UK universities 1993. *European Journal of Operational Research*, 174, 443–56.

Johnes, J., & Johnes, G. (1995). Research funding and performance in UK university departments of economics: A frontier analysis. *Economics of Education Review*, 14, 301–14.

Joumandy, O., & Ris. C. (2005). Performance in European higher education: A nonparametric production frontier approach. *Education Economics*, 13, 189-205.

Kao, C. (1994). Evaluation of junior colleges of technology: The Taiwan case. *European Journal of Operational Research*, 72, 43–51.

Kaur, S., & Sirat, M. (2010). Going for global university ranking through the accelerated programme for excellence (APEX) in Malaysia: Full throttle ahead, in *Quality Assurance and University Rankings in Higher Education in the Asia Pacific*, (Eds) S. Kaur, M. Sirat and W.G. Tierney, Universiti Sains Malaysia Press, Pulau Pinang, pp. 194–217.

Kempkes, G., & Pohl, C. (2010). The efficiency of German universities – some evidence from nonparametric and parametric methods. *Applied Economics*, 42, 2063–79.

Kneip, A., Park, B., & Simar, L. (1996). Note on the convergence of nonparametric DEA efficiency measures, CORE Discussion Papers 1996039, Université catholique de Louvain, Louvain-la-Neuve.

Korhonen, P., Tainio, R., & Wallenius, J. (2001). Value efficiency analysis of academic research. *European Journal of Operational Research*, 130, 121–32.

Lindsay, A. W. (1982). Institutional performance in higher education: The efficiency dimension. *Review of Educational Research*, 52, 175–99.

Lovell, C. A. K. (2000). Editor's introduction. *Journal of Productivity Analysis*, 13, 5–6.

Madden, G., & Savage, S. (1997). Measuring public sector efficiency: A study of economics departments at Australia universities. *Education Economics*, 5, 153–68.

McMillan, M. L., & Chan, W. H. (2006). University efficiency: A comparison and consolidation of results from stochastic and nonstochastic methods. *Education Economics*, 14, 1–30.

Meho, L. I., & Yang, K. (2007) Impact of data sources on citation counts and rankings of LIS faculty: Web of Science versus Scopus and Google Scholar. *Journal of the American Society for Information Science and Technology*, 58, 2105–25.

Meho, L. I., and Rogers, Y. (2008). Citation counting, citation ranking and h-index of human-computer interaction researchers: A comparison of Scopus and Web of Science. *Journal of the American Society for Information Science and Technology*, 59, 1711–26.

Meng, W., Zhang, D., Qi L., & Liu, W. (2008). Two level DEA approaches in research evaluation. *Omega*, 36, 950–7.

Ministry of Higher Education Malaysia. (2007). *The National Higher Education Strategic Plan Beyond 2020*. Malaysian Government Press, Kuala Lumpur.

Ministry of Higher Education. (2009). Malaysia Higher Education Statistics, various years. Planning and Research Division, Malaysian Government Press, Putrajaya.

Mustafa, L. M., Yunus, N. K. Y., & Azman, M. N. A. (2014). An overview of private preschool in Malaysia: Marketing strategies and challenges. *Procedia - Social and Behavioral Sciences*, 130, 105–113. doi:10.1016/j.sbspro.2014.04.013

Ng, Y. C., & Sung Ko, L. (2000) Measuring the research performance of Chinese higher educations: An application of data envelopment analysis. *Education Economics*, 8, 139–56.

Nordin Mamat, Maimunah Muda & Mohamad Sahari Nordin. (2014). Laporan Kajian Perbandingan Pencapaian Kualiti Prasekolah KPM dengan prasekolah swasta, KEMAS dan JPNIN. Kementerian Pendidikan Malaysia.

Norris, M., & Oppenheim, C. (2007). Comparing alternatives to the Web of Science for coverage of the social sciences literature. *Journal of Informetrics*, 1, 161–9.

Parteka, A., & Wolszczak-Derlacz, J. (2011). Dynamics of productivity in higher education – Cross-European evidence based on bootsrapped Malmquist indices, Working Papers No. 2011–10, Department of Economics, University of Milan, Milan.

PEMANDU. (2012). Overview of the GTP (pp. 8–27).

Post, T., & Spronk, J. (1999). Performance benchmarking using interactive data envelopment analysis. *European Journal of Operational Research*, 115, 472–87.

Ray, S. C., & Desli, E. (1997). Productivity growth, technical progress and efficiency change in industrialized countries: Comment. *The American Economic Review*, 87, 1033–9.

Sarafoglou, N., & Haynes, K. E. (1996). University productivity in Sweden: A demonstration and explanatory analysis for economics and business programs. *Annals of Regional Science*, 30, 285–304.

Sarrico, C. S., & Dyson, R. G. (2000). Using DEA for planning in UK universities – an institutional perspective. *The Journal of the Operational Research Society*, 51, 789–800.

Sarrico, C. S., Hogan, S. M., Dyson, R. G., & Athanassopoulos, A. D. (1997). Data envelopment analysis and university selection. *The Journal of the Operational Research Society*, 48, 1163–77.

Shephard, R. W. (1970). *Theory of cost and production functions*. Princeton University Press, Princeton.

Silverman, B. W. (1986). *Density estimation for statistics and data analysis*. Chapman and Hall, London.

Simar, L. (1992). Estimating efficiencies from frontier models with panel data: A comparison of parametric nonparametric and semi-parametric methods with bootstrapping. *Journal of Productivity Analysis*, 3, 167–203.

Simar, L., & Wilson, P. W. (1998a). Productivity growth in industrialized countries. CORE Discussion Paper 036, Universite Catholique de Louvain, Louvain-la-Neuve.

Simar, L., & Wilson, P. W. (1998b). Sensitivity analysis of efficiency scores: how to bootstrap in nonparametric frontier models. *Management Science*, 44, 49–61.

Simar, L., & Wilson, P. W. (1999). Estimating and bootstrapping Malmquist indices. *European Journal of Operational Research*, 115, 459–71.

Simar, L., & Wilson, P. W. (2000). Statistical inference in nonparametric frontier models: The state of the art. *Journal of Productivity Analysis*, 13, 49–78.

Sinuany-Stern, Z., Mehrez, A., & Barboy, A. (1994) Academic departments efficiency via DEA. *Computers and Operations Research*, 21, 543–56.

SMD, School of Malaysia Directory (2014). Early Childhood Care & Education (ECCE) in Malaysia at a Glance (for newborns to 6-year-olds). Retrieved from School Malaysia Early Childhood & Pre-Tertiary Education. Retrieved from http://www.schoolmalaysia.com/resources/education_system.php

Tajnikar, M., & Debevec, J. (2008) Funding system of full-time higher education and technical efficiency: case of the University of Ljubljana, *Education Economics*, 16, 289–303.

Tauer, L. W., Fried, H. O., & Fry, W. E. (2007). Measuring efficiencies of academic departments within a college. *Education Economics*, 15, 473–89.

Tomkins, C., & Green, R. (1988). An experiment in the use of data envelopement analysis for evaluating the efficiency of UK university departments of accounting. *Financial Accountability and Management*, 4, 147–65.

Warning, S. (2004). Performance difference in German higher education: Empirical analysis of strategic groups. *Review of Industrial Organization*, 24, 393–408.

Wheelock, D. C., & Wilson, P. W. (1999). Technical progress, inefficiency and productivity change in US banking 1984–1993. *Journal of Money, Credit and Banking*, 31, 212–34.

Wilson, P. W. (2006). FEAR 1.0 User's Guide, Department of Economics, Clemson University, Clemson, USA.

Worthington, A. C., & Lee, B. L. (2008). Efficiency, technology and productivity change in Australian universities, 1998–2003. *Economics of Education Review*, 27, 285–98.