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Decision Support

Combining the assumptions of variable and constant returns to scale in the efficiency evaluation of secondary schools

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ABSTRACT

Our paper reports on the use of data envelopment analysis (DEA) for the assessment of performance of secondary schools in Malaysia during the implementation of the policy of teaching and learning mathematics and science subjects in the English language (PPSMI). The novelty of our application is that it makes use of the hybrid returns-to-scale (HRS) DEA model. This combines the assumption of constant returns to scale with respect to quantity inputs and outputs (teaching provision and students) and variable returns to scale (VRS) with respect to quality factors (attainment levels on entry and exit) and socio-economic status of student families. We argue that the HRS model is a better-informed model than the conventional VRS model in the described application. Because the HRS technology is larger than the VRS technology, the new model provides a tangibly better discrimination on efficiency than could be obtained by the VRS model. To assess the productivity change of secondary schools over the years surrounding the introduction of the PPSMI policy, we adapt the Malmquist productivity index and its decomposition to the case of HRS model.

1. Introduction

Data envelopment analysis (DEA) is an established methodology used for the assessment of efficiency and performance of organizations (Cooper, Seiford, & Tone, 2006; Thanassoulis, Portela, & Despić, 2008). In the area of education, DEA has been widely used for the assessment of efficiency of the school provision at different levels (Färe, Grosskopf, Førsund, Hayes, & Heshmati, 2006; Grosskopf, Hayes, Taylor, & Weber, 1999; Portela, Camanho, & Borges, 2012; Portela & Thanassoulis, 2001), universities and their departments (Avkiran, 2001; Thanassoulis, Kortelainen, Johnes, & Johnes, 2011), and the impact of education policies (Bradley, Johnes, & Millington, 2001; Grosskopf & Moutray, 2001).

The two conventional models traditionally employed in DEA studies, including applications in education, are based on the variable and constant returns to scale (VRS and CRS) technologies. Even if the true (best practice) technology is assumed to be VRS, the reference, or benchmark, CRS technology is often used as a part of the scale efficiency calculations. For the assessment of a particular education policy, it is common to use the Malmquist productivity index based on observations collected over a period of time, with its subsequent decompositions into different components (Johnes, 2008; Ouellette & Vierstraete, 2010; Thanassoulis et al., 2011).

The purpose of this paper is to demonstrate that in some applications, an example of which is the focus of our study, *a better-informed model* of the education technology may be obtained by the combination of VRS and CRS characteristics in one single formulation. To put our argument in the school education context, suppose that we have both quantity and quality performance factors (inputs and outputs). The quantity factors would typically include teachers (or teaching time) and students, while the quality factors may include a measure of academic attainment on entry (input) and on exit (output). It is often a legal requirement and an accepted managerial practice that there should be a certain ratio between teachers and students – this may vary between different schools or school types. Therefore, for example, a 10% increase of the student numbers requires the same increase of the teaching time. This indicates that the relationship between teachers and students may be assumed to be of the CRS type. It may, however, be difficult to argue that the CRS assumption extends to the quality inputs and outputs, as there may be no simple proportional relationship between these factors, in line with the quantity factors.

The above scenario poses a dilemma. In the described setting, the use of the CRS model for the underlying education technology

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is clearly unsubstantiated. On the other hand, the VRS technology is too conservative and does not use the information that students and teachers satisfy the assumption of CRS. The latter implies that the VRS model underestimates the true technology and its use would lead to an overestimation bias of the efficiency scores.

In this paper we resolve the above dilemma by using the hybrid returns-to-scale (HRS) technology developed by Podinovski (2004a). The HRS technology is a convex polyhedral technology that exhibits CRS with respect to a subset of inputs and outputs (in the above scenario, with respect to teachers and students), and only VRS with respect to the remaining factors (quality inputs and outputs).

Our application concerns the performance of secondary schools in Malaysia in the provision of mathematics and science subjects. In 2003, the government of Malaysia initiated a new policy of teaching and learning these subjects in the English language (PPSMI). The policy was introduced in stages at different levels of school education and became a subject of wide debate within the Malaysian society (Ting, 2010).

In our study we focus on the upper secondary level of the school education and consider four cohorts of student. Two of these graduated in 2005 and 2006, and were educated before the PPSMI policy was introduced. The other two graduated in 2007 and 2008, and were educated under the new policy. Our data set includes 221 schools from three selected states in Malaysia that have complete data on the four cohorts.

This application is, to the best of our knowledge, the first reported application of the HRS technology with real-life data. Several contributions to the theory and methodology of DEA should be highlighted.

First, we extend the theoretical foundations of the HRS model by developing its new formulation. This is more intuitive than the original model and helps us to discuss the properties of the model and the assumptions behind it, in particular, in the context of school education. The original model is less intuitive but it is linear, and for this reason is used in the actual computations.

Second, we argue that the HRS model correctly represents our knowledge of the education technology, namely, that the quantity inputs and outputs satisfy the assumption of CRS, while the quality factors should be excluded. It is therefore a better-informed model than the standard VRS technology, in the described setting.

Third, our computations show that the HRS model produces a tangible practical improvement of the discrimination on efficiency scores, compared to the VRS model. This is because the HRS technology is an extension to the VRS technology and is, therefore, larger than the latter. Interestingly, the efficiency scores are also usually lower in the HRS model than in the CRS model (and the discrimination of the HRS model higher than that of CRS) although the opposite relationship is observed for some individual schools in our sample. This is consistent with the theory and is explored in detail below.

Fourth, in order to assess the productivity change of the secondary education sector in the years surrounding the implementation of the PPSMI policy, we use the Malmquist productivity index and its decomposition. Although the extension of the Malmquist index to the case of HRS technologies is straightforward in principle, there is a particular difficulty that needs to be overcome. The conventional Malmquist index decomposition requires the assessment of efficiency of productive units in the VRS production technology and its reference CRS technology, constructed for the given and reference years. In these computations, the CRS technology is the cone extension of the VRS technology – it serves as the reference in the assessment of scale efficiency change and boundary shift. If, as in our study, the underlying technology is HRS, its cone extension is not the CRS but the cone-HRS (C-HRS) technology developed by Podinovski (2009). The latter is generally larger than both the HRS and standard CRS technology (and their union). Our application demonstrates how the Malmquist index can be decomposed and interpreted using the C-HRS technology.

The results of our study are largely consistent with the current discussion of the implications of the PPSMI policy on the school education (Ting, 2010). In particular, we find evidence that the average productivity of secondary schools in the teaching of mathematics and science subjects declined in the two years following the introduction of the policy. The biggest drop in school productivity was observed in 2007 – the first year of implementation of the policy at the upper secondary level, followed by a tangible, but not full, recovery in the year 2008. Our analysis also shows that this decline in schools in rural locations was greater than in urban locations. Moreover, in the case of rural locations, it had already started before the implementation of the policy but was less pronounced than in the years after its implementation. This indicates that the decline of productivity over all these years might have had a more complex nature than previously thought.

2. Preliminaries

2.1. Application background

The secondary education in Malaysia spans a period of five years: three years at the lower secondary level and two years at the upper secondary level. At the end of the lower secondary level students' performance is evaluated through an examination referred to as Lower Secondary Assessment (PMR). This examination is partly school based and adheres to the national guidelines set by the Malaysian Examination Syndicate. Following this examination, students move to more specialized fields of study at the upper secondary level. At the end of the upper secondary level all students take the Malaysia Certificate of Education (SPM) examination. This examination is centrally administered and is considered to be equivalent to GCSE qualifications in England. A further one or two years of post-secondary education is required for entry to higher education.

Until 2003, all mathematics and science subjects at the secondary school level had been taught in the national language Bahasa Melayu. Starting in 2003, the Ministry of Education Malaysia introduced a new policy known as the Teaching and Learning of Mathematics and Science Subjects in English (PPSMI). The policy aimed at improving the English language skills of Malaysian students in the areas important for science, technology and international trade (Ting, 2010). Under the PPSMI policy, English became the medium of instruction in the teaching of all mathematics and science subjects. The implementation of this policy was carried out in stages beginning with the 2003 school year. At the upper secondary level the PPSMI policy was fully implemented starting in 2007.

Since its introduction, the purpose and benefits of the PPSMI policy became a subject of wide debate within the Malaysia society (Ting, 2010; Yahaya et al., 2009). Critics of the policy pointed, among other negative effects, poor students' performance in science subjects because of their weakness in the English language, and a disproportionate negative effect of the policy on schools in rural locations. The supporters of the policy highlighted the benefits of the policy and argued that the critics made unsubstantiated generalizations from limited studies of the effects of the policy.

Following the growing public pressure to reverse the PPSMI policy, in 2010 the Ministry of Education announced its decision to reinstate the national language for the teaching of mathematics and science subjects, starting in 2012. The main reason for this decision was the steady decline in the performance of students in these subjects as shown by the Ministry's own records and various studies (Ting, 2010).