IMPLICATIONS OF THE PPSMI POLICY FOR THE PERFORMANCE OF MALAYSIAN SECONDARY SCHOOLS IN MATHEMATICS AND SCIENCE SUBJECTS

By

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DECLARATIONS

I declare that I am responsible for the work submitted in this thesis, it is written by me and it has not previously been submitted within a degree programme at this or any other institution.

During the preparation of this thesis a number of conference presentations have taken place. The materials in Chapter 3, 4, 5 and 6 have formed the basis of the presentations.

1. Ismail, I. (2009). Using Hybrid Returns to Scale Data Envelopment Analysis Model to Assess an Education Policy in Malaysia. Paper presented at the Young OR 16 Conference, 24-26 March, Warwick, England.

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ABSTRACT

The introduction of the Teaching and Learning Mathematics and Science Subjects in English (PPSMI) policy to change the medium of instruction in mathematics and science subjects from Bahasa Melayu to English has raised many debates on the effectiveness of the policy and the ability of the schools, teachers and pupils to adapt to the new medium of instruction. This study evaluates the implications of the PPSMI policy for the school performance in mathematics and science subjects. The school performances before and after the implementation of the policy were assessed and compared according to school types, states, and locations by developing an advanced technique in measuring school efficiency based on hybrid returns to scale (HRS) data envelopment analysis (DEA). A new methodology of measuring change in performance over time based on the Malmquist index was also developed to measure the difference in performance before and after the implementation of the policy. The aim of developing the methodologies is to provide an alternative assessment of the implications of the PPSMI policy for the school performance in mathematics and science subjects thus helping the Ministry of Education Malaysia to decide on the direction of the PPSMI policy.

The HRS DEA model is a new extension in DEA based on the concept of selective proportionality in the relationship of input-output variables. It gives a better estimate compared to the original convex models, the constant returns to scale (CRS) and the variable returns to scale (VRS), when some of the inputs and outputs have proportional relationship while others do not. In this study, an HRS-based DEA model utilising 10 inputs and 8 outputs was developed to assess the efficiency of schools from three states i.e. Kedah, Penang, and Perlis. The schools comprise of three different types i.e. the national, fully residential, and religious school-types. The efficiency was also assessed by using the CRS and VRS models to compare the results.

The Malmquist index is a popular productivity index for measuring efficiency over time. The Malmquist index can be calculated from the CRS-based or the VRS-based DEA efficiency scores. This study developed a new productivity index called the HRS-based Malmquist index. This is similar to the VRS-based Malmquist index but the calculation of the index is based on the efficiency scores from the HRS DEA model.

The efficiency scores and Malmquist indices of schools in different categories (i.e. school-types, states, and locations) were tested for significant difference by using nonparametric statistical tests. Nonparametric statistical tests were used due to the nonparametric nature of DEA. The statistical tests used in this study are Mann-Whitney U Test and Kruskal-Wallis Test to look at independent samples such as samples from different school-types, and Wilcoxon Signed Ranks Test and Friedman's Two-Way Analysis of Variance to examine dependent samples such as the difference in performance before and after the implementation of the policy.

ABBREVIATIONS

BCC	Banker, Charnes and Cooper
CCR	Cooper, Charnes and Rhode
C-HRS	Cone Hybrid Returns to Scale
CRS	Constant Returns to Scale
DEA	Data Envelopment Analysis
DMU	Decision Making Unit
EMIS	Educational Management Information System
EPRD	Educational Planning and Research Division
EPU	Economic Planning Unit
ETeMS	English for the Teaching of Mathematics and Science
HRS	Hybrid Returns to Scale
ICT	Information and Communication Technology
MES	Malaysian Examination Syndicate
MOEM	Ministry of Education Malaysia
PAGE	Parents Action Group
PMR	Lower Secondary Assessment
PPSMI	Teaching Mathematics and Science Subjects in English Policy
SD	School Division
SED	State Education Department
SFA	Stochastic Frontier Analysis
SPM	Malaysia Certificate of Examination
TE	Technical Efficiency

TIMSS	Trend in Mathematics and Science Study
UPSR	Primary School Achievement Test
VRS	Variable Returns to Scale

CHAPTER 1

INTRODUCTION

1.1 Introduction

In the era of globalisation and information explosion in science and technology, English is seen as a universal language, which must be acquired to be able to gain knowledge and compete effectively (Gill, 2005). English is widely used in educational institutions and most of the reference materials for science-based courses in the universities are published in English (Pillay and Thomas, 2004). In fact, it has been estimated that 80 percent of all scientific and technological publications in the world today are written in English (Ramlan, 2009). To ensure that students can obtain the latest development in science and technology from various sources especially from the internet, the Ministry of Education Malaysia (MOEM) had introduced a new policy known as English in the Teaching of Mathematics and Science (PPSMI) with the objectives of providing skilled and learned human resources that can compete in and contribute to the international arena (Ministry of Education Malaysia, 2002).

The PPSMI policy is a decision made by the Malaysian Government as a result of the Minister's Council Meeting held on 19 July 2002 (Ministry of Education Malaysia, 2002). Under this policy, English is used as the medium of instruction in the process of teaching and learning all mathematics and science subjects. Prior to this, the medium of instruction for all subjects was Bahasa Melayu. The implementation of the policy was carried out in stages beginning with the 2003 schooling session.

The implementation of the policy was explained in a Professional Circular 11/2002 issued by the MOEM. The circular stated that the PPSMI policy was drafted based on the awareness that the field of science and mathematics is very dynamic with many new findings but most of the information is in English. The main objective of this policy is to enable the pupils to acquire knowledge in science and mathematics, where most of the references are in English, and thus become more competitive at the international level as well as producing a generation which is proficient in English. This change in policy is considered as very important to ensure that Malaysians are able to keep abreast with scientific and technological development that is mostly recorded in English. At the same time, this move would provide opportunities for pupils to use English and therefore increase their proficiency in the language (Ministry of Education Malaysia, 2002).

However, the announcement of the new policy instantly sparked off a heated debate in the newspapers especially with regard to the use of English as the medium of instruction where Malay nationalists saw this as affecting the status of Bahasa Melayu as the national language (Pillay, 2003). The Malay nationalists argued that science and technology are not dependent on the language and are best acquired and taught using the mother tongue where concept formation and understanding among learners will be significantly better (Abdullah and Yahaya, 2006). In general, many people including parents and teachers were sceptical about the effectiveness and success of the policy owing to poor English language proficiency among teachers and pupils (Alwis, 2005; Idris et al, 2006). In 2009, six years after the policy was implemented, various groups still strongly opposed the implementation of the policy and are determined to force MOEM to revert to the use of the national language as the medium of instruction (Yassin et al., 2009).

A Movement for the Abolition of Teaching and Learning Science and Mathematics in English was set up by these groups to put pressure on MOEM and the government to do away with the policy The movement claimed that many pupils especially in rural location could not cope with English and as a result their performance in mathematics and science subjects was deteriorating. The demand by this movement was backed up by findings from many studies that show PPSMI is detrimental to the performance of pupils particularly in rural locations. A study by Long (2005) found that the gap between the performance of schools in urban and rural locations was widening after the implementation of the policy. A study by Haron et al. (2008) involving 1703 pupils reveals that 75 percent of them found it hard to understand the teaching in English. Other studies also show that schools in urban location performed better than schools in rural locations (Hamzah and Abdullah, 2009; Kiong et al., 2005; Surif et al., 2006). This has prompted the MOEM to review its stand on the policy. Several series of expert and other stakeholder roundtable meetings were held to analyse and review the policy (Yassin et al., 2009). Based on the discussions and research findings, the MOEM would decide whether or not to revert to the use of Bahasa Melayu as the medium of instruction for mathematics and science.

The reactions to the move by MOEM to reconsider its stand on the policy are mixed. Those who oppose the policy are relieved by the move but those who prefer the teaching and learning process in English are not pleased. Jantan (2008) in his presentation in one of the meetings argued that the study by Haron et al. (2008) was flawed because it was only a descriptive study that did not offer any kind of hypothesis that can be tested. Furthermore, the instrument used by them is questionable as there was no discussion of its validity and reliability. Other studies regarding the PPSMI policy cited in their paper were also of descriptive research and most did not discuss the validity and reliability of their instruments. Hence, Jantan (2008) stressed that using the mean scores from these tests to claim that the PPSMI policy is a failure is illogical and invalid. Many parents from urban areas especially in major cities like Kuala Lumpur want the policy to continue. A group known as Parent Action Group for Education (PAGE) was formed to support the PPSMI policy and to seek exemption for schools that support the policy should the policy be discontinued (PAGE, 2008).

In summary, the implementation of the PPSMI policy is an effort by the MOEM to upgrade the level of mathematics and science education in Malaysia and to produce a workforce that is equally competent at the international arena. However, many people do not agree with the policy due to various reasons ranging from the issue of the supremacy of Bahasa Melayu as the national language (Pillay, 2003; Abdullah and Yahaya, 2006) to the poor pupils' performance because of their weaknesses in English (Alwis, 2005; Idris et al, 2006). Some studies showed that pupils especially in rural locations were adversely affected by the policy (Hamzah and Abdullah, 2009; Surif et al., 2006; Kiong et al., 2005; Long, 2005). On the other hand, there are people who support the policy and would like the MOEM to continue with the policy implementation. They argued that the studies used by people who oppose the policy to back up their demand are flawed and cannot be generalised (Jantan, 2008; PAGE, 2008).

Motivated by this situation, this study will focus on the evaluation of the implications of the PPSMI policy for the school performance in mathematics and science subjects by using an advanced technique in measuring efficiency. The school performance, before and after the implementation of the policy, will be assessed and compared according to school type, state, and location. A new methodology of measuring school efficiency and change in efficiency over time will be developed specifically for this purpose. The aim of developing the new methodology is to provide an alternative assessment of the implications of the policy for the school performance in mathematics and science subjects and thus helping the MOEM to decide on the direction of the PPSMI policy.

1.2 Education in Malaysia

In this section, a short description of education in Malaysia is given. This is to provide an insight into the Malaysian education system. Most of the content in this section is drawn from Education in Malaysia by the Educational Planning and Research Division (2008a). The Malaysian education system covers education from pre-school to university including 11 years free schooling at primary and secondary levels. Primary education in Malaysia has been compulsory since 2003. Children begin their education at preschool between the age of four and six years. Primary education (a period of 6 years) begins at seven years of age and is divided into two levels. At level one (Year 1 to Year 3), the emphasis is on acquiring strong reading, writing and arithmetic skills. At level two (Year 4 to 6), the mastery of these basic skills is reinforced and emphasis is given to building a strong foundation in content and basic sciences. An assessment examination at Year 6, known as Primary School Achievement Test (UPSR), is a centralised examination and used to evaluate pupils performance. Besides that, continuous school-based assessments are carried out at all levels (EPRD, 2003). There are three main types of primary schools namely national, national-type (Chinese), and national-type (Tamil) schools. National schools use Bahasa Melayu as the medium of instruction, while in the Chinese and Tamil national-type schools, the medium of instruction is Chinese and Tamil respectively.

Secondary education (a period of 5 years) consists of 3 years of lower secondary (Form 1 to Form 3) and 2 years of upper secondary (Form 4 to Form 5). However, pupils from national-type schools are required to go to Remove class before they could go to Form 1 to prepare them for the change in medium of instruction, which is Bahasa Melayu. There are four main types of secondary schools in Malaysia. They are national, technical, fully residential, and religious school types. National is the main type of secondary school in Malaysia and consists of over 90 percent of the total secondary schools. The fully residential school type has the same structure as the national secondary school type but the pupils are selected and highly talented. All pupils in the fully residential school type have to stay in the school's hostel and adhere to the rules implemented by the school. The pupils are provided with many facilities to help them in their school life. The technical secondary school type offer education at upper secondary level only. It plays a significant role in preparing pupils to pursue technical and scientific education as well as for careers as technicians and semi-skilled workers. The religious secondary school type initially offered

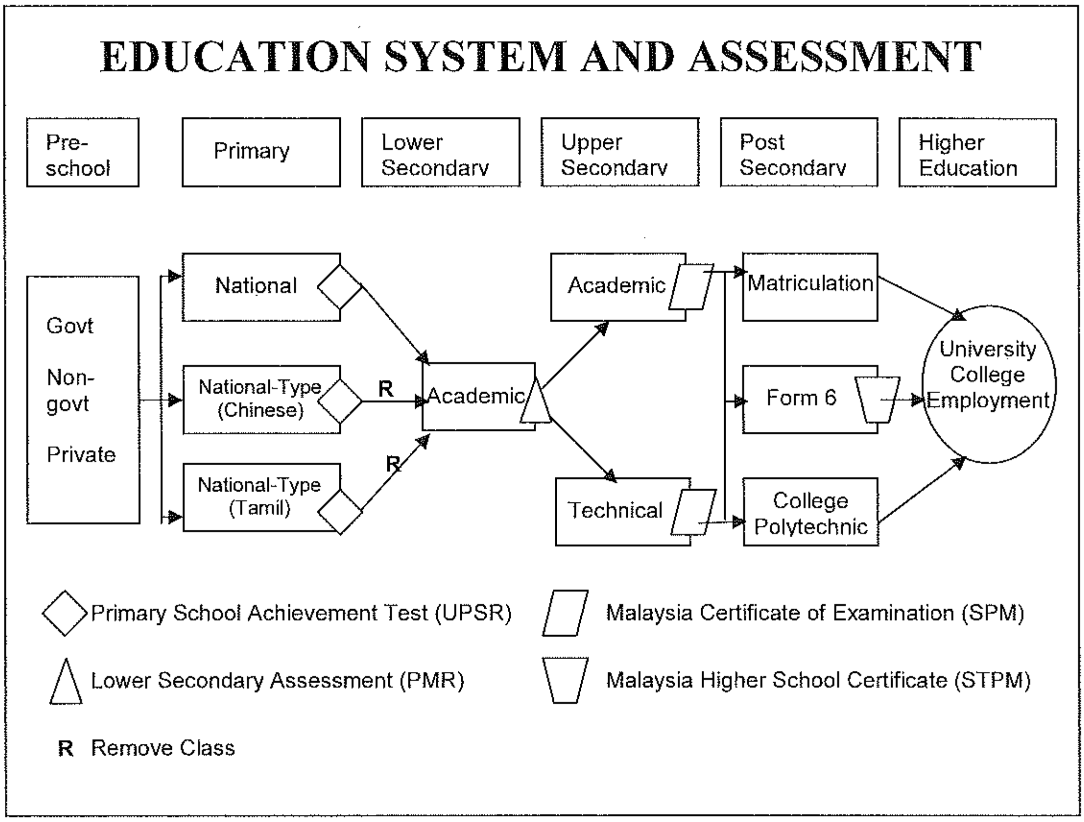
Islamic Religious Education and Arabic Studies preparing pupils for professions in Islamic religious affairs, education, and law. Today religious secondary schools have expanded their programme to include science and technology related subjects. These schools still maintain their uniqueness in offering specialised elective courses in Islamic Studies that are not available in other schools.

At the end of the lower secondary level (Form 3), pupils' performance is evaluated through another centralised examination, which is known as Lower Secondary Assessment (PMR). This examination is partly school-based and follows guidelines set by the Malaysian Examination Syndicate. Following the PMR examination at Form 3, pupils move into more specialised field of studies at the upper secondary level. Based on choice and ability, pupils enter either arts or science streams in academic schools or religious schools whereas technical schools provide technically biased academic education and pre-employment skills.

All schools prepare pupils for the Malaysia Certificate of Education (SPM) examination at the end of Form 5. The examination is centrally administered at the end of secondary schooling and is a requirement for further education or entry into the job market. Upon completion of secondary education, pupils can opt to pursue 1 to 2 years of post-secondary education. This is the university entrance preparatory course. In total, the 12 to 13 years of school education serves as the basic entry requirement into Year 1 of a bachelor's degree programme in higher educational institutions.

The Malaysian education system and assessment is summarised in Figure 1.1.

Figure 1.1: Malaysian Education System



Malaysia consists of thirteen states and three federal territories. The educational administration system in Malaysia is centralised with the MOEM acting as the central agency and the state education department (SED) as the regional arm (Educational Planning and Research Division, 2008a). Altogether, there are fourteen SEDs where the three federal territories are combined to make one SED. The implementation of educational policies and plans made at the federal level are carried out at the state level through the fourteen SEDs. The SEDs coordinate and monitor the implementation of national education programmes, projects, and activities, besides providing feedback to the MOEM for overall planning (Educational Planning and Research Division, 2008a). All states (except the three federal territories) can be divided into urban and rural locations. The three federal territories are considered as urban areas. In Malaysia, areas with a population of 10 000 and more and their adjoining built-up areas are considered as urban while areas other than that are considered as rural (Department of Statistics Malaysia, 2006).

In this study, schools with pupils at upper secondary level will be assessed. The PMR examination at the end of lower secondary level will be used as an indicator of pupils' achievement on entry while the SPM examination at the end of upper secondary level will be used as an indicator of pupils' achievement on exit. The performance of schools from different types, states and locations will be compared to see whether the policy benefited or was detrimental to certain types of schools or schools in certain states and locations only. The choice of inputs-outputs and the selection of schools to be evaluated in this study will be discussed in chapter three. In the next section, the aim and objectives of this study are set out.

1.3 Research Aims and Objectives

The aim of this study is to assess the implications of the PPSMI policy for the performance of Malaysian secondary schools in mathematics and science subjects. To do that, a new methodology of measuring school efficiency will be developed by taking into account suitable inputs-outputs to measure the efficiency of Malaysian secondary schools in the process of teaching and learning mathematics and science subjects. This study is in line with the MOEM action plan to encourage research of the fact-finding type and to enable decision-makers to use the research findings in decision-making. With regard to the policy of teaching mathematics and science in English, several studies have been published (e.g. Hamzah and Abdullah, 2009; Haron et al., 2008; Surif et al., 2006; Kiong et al., 2005; Long, 2005) to find out the effectiveness of the policy. This study will add to the literature by using an innovative technique of measuring school efficiency and assessing the implications of the policy for the school performance.

A more specific objective of this study is to assess the implications of the PPSMI policy for the schools performance in mathematics and science subjects by:

i. Developing a new methodology to assess school efficiency in the process of teaching and learning mathematics and science subjects.
ii. Using the methodology developed in this study with real data to assess school efficiency in the process of teaching and learning mathematics and science subjects and compare the efficiencies of schools in different categories.
iii. Developing a new methodology that can be used to assess the change in school efficiency over time (before and after the implementation of the policy).
iv. Using the methodology developed in this study with real data to assess school's efficiency change over time (before and after the implementation of the policy) and compare the change in efficiencies of schools in different categories.

1.4 Motivation

As mentioned in section 1.1, the motivation behind this study is to assess the implications of the PPSMI policy for school performance by developing an advanced technique of measuring school efficiency based on Data Envelopment Analysis (DEA) and the Malmquist index. It is hoped that findings from this study will offer the MOEM some useful insight, into how school performance has been affected by the policy. A new methodology of measuring schools performance based on hybrid returns to scale (HRS) DEA model will be developed for this purpose. Then, the Malmquist index will be modified to be used for the first time with hybrid returns to scale DEA model to measure efficiency change over time (HRS-based Malmquist index). These techniques will be discussed in detail in Chapter 2.

DEA has been used in many studies to measure school efficiency (e.g., Bessent and Bessent, 1980; Bessent et al., 1982; Bessent et al., 1984; Färe et al. , 1989; Thanassoulis and Dunstan, 1994; Grosskopf et al., 1999; Mante and O'Brien, 2002; and Ouellette and Vierstraete, 2005). The primary advantage of DEA is the ability to handle multiple inputs and multiple outputs, which is appropriate for measuring school efficiency (Mancebon and Bandres, 1999). However, the technique is not well known in Malaysia especially in education sector where there was only one study that used DEA to measure school efficiency (Kiong et al., 2003). Thus, this study is motivated to utilise DEA to measure the school performance in Malaysia, in particular performance after the implementation of the PPSMI policy.

There are two basic convex models that have underpinned DEA studies. The two models are Constant Returns to Scale (CRS, also known as CCR) introduced in Charnes et al. (1978) and Variable Returns to Scale (VRS, also known as BCC) model introduced in Banker (1984). CRS models assume full proportionality between all input-output variables but VRS models do not. VRS is suitable for measuring education efficiency because the input-output variables in the model are not normally proportional, for example, the number of pupils with good grade on entry is not necessarily proportional to the number of pupils with good grade on the output side. However, some of the input-output variables do have a proportional relationship; for example, an input such as the number of teachers is proportional to the number of pupils on the output side. If only the number of pupils who passed certain criteria is taken as output, what has been learned has no value for those who did not get a good grade (Ouellette and Vierstraete, 2005, 2010). Since the number of teachers is determined from the number of pupils (e.g. one teacher for every 30 pupils), their relationship is proportional.

Hybrid Returns to Scale (HRS) DEA model and the concept of selective proportionality in the relationship of inputs and outputs is a new extension by Podinovski (2004, 2009), In measuring the efficiency of a decision making unit that has selective proportionality in the relationship of input-output variables, the HRS model would give a better estimate of the efficiency (Podinovski, 2004). This study will develop a new methodology of assessing the efficiency of schools in the process of teaching and learning mathematics and science subjects based on the HRS DEA model. The previous studies of measuring school efficiency by using DEA were based on either CRS or VRS DEA models.

The Malmquist index has been a popular tool for measuring efficiency over time since the work of Färe et al. (1994) and has been applied in many studies such as Grosskopf and Moutray (2001), Liu et al. (2004), Färe et al. (2006), Ouellette and Vierstraete (2008), and Barley et al.(2010). The Malmquist index can be calculated from CRS-based or VRS-based DEA efficiency scores. Since this study is the first to employ the HRS model in calculating school efficiency scores, an HRS-based Malmquist index will be developed to measure the change in efficiency over time. A literature review on DEA and the Malmquist index will be discussed in Chapter 2 while the HRS-based DEA methodology for measuring school efficiency and the HRS-based Malmquist index for measuring change in school efficiency developed in this study will be given Chapter 3.

1.5 Thesis Structure

Altogether, there are six chapters in this thesis. This chapter has introduced the context of the study and described the education system in Malaysia as well as the PPSMI policy, which is the motivation for this study. The aim and objectives were set out and the indication of methodological tools to be employed in this study was given.

Chapter 2 will introduce the concept of efficiency measurement and the techniques for measuring it. A more detailed description of the DEA technique and its extension will be given and the literature on the use of DEA to measure school efficiency will be reviewed. This chapter will also introduce the concept of efficiency change over time and will review the use of the Malmquist index in studies to measure the change in school efficiency. It will also review the issue of statistical testing in DEA and the relevant DEA studies that utilised statistical tests. The contribution of the study and the gap in literature will be stressed at the end this chapter.

The DEA models and the Malmquist index for the assessment of school performance in the process of teaching mathematics and science subjects will be presented in Chapter 3. It will also describe the statistical tests to compare the performance of schools in different groups. Data collection and data analysis procedures including computer programming to compute the efficiency scores and the Malmquist index will be explained here. Chapter 4 applies the methodology outlined in Chapter 3 to the selected schools and presents the overall result of the schools as well as according to the school type, state, and location.

Chapter 5 will discuss the research findings in terms of the implications of the PPSMI policy for the performance of secondary schools in mathematics and science subjects. The findings from Chapter 4 will be elaborated and discussed based on the overall school performance, performance by school type, performance by state, and performance by location.

Lastly, Chapter 6 will summarise the previous chapters and give key conclusions. It will also draw attention to the contributions of this study and provide directions for future research.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Chapter 1 introduced the context of the study and described the Malaysian education system as well as the PPSMI policy, which is the main motivation behind this study. The objectives of the study, that is to develop a new methodology to find the implications of the PPSMI policy for the schools performance, were set out in details. The use of hybrid returns to scale (HRS) DEA model and Malmquist index as the methodological tools in this study was indicated.

In this chapter, the literature concerning efficiency measurement in general and the techniques for measuring it, especially data envelopment analysis (DEA) and stochastic frontier analysis (SFA), are introduced. As DEA is the preferred technique, more explanation about the DEA technique and the new extension in DEA i.e. the hybrid returns to scale (HRS) model are given. Then, the measurement of school efficiency based on the concept and the techniques of measuring efficiency is described. After that, a review on the use of DEA in measuring school efficiency is given. This is followed by the explanation on the concept of change in efficiency over time and the technique for measuring it and the review on studies that employed the Malmquist index to measure school efficiency over time.

Next, the non-parametric statistical tests employed to examine statistically the difference in the efficiency scores and the Malmquist index of schools in different groups (different types, states and locations) are described. This is followed by the review on the use of these statistical tests in efficiency measurement studies and the review on studies related to the PPSMI policy.

The contribution of this study and the gap in the literature that this study is intended to fill are elaborated before the conclusion and summary of the chapter. In particular, the following three areas of contribution will be highlighted. First, the development of a new methodology to measure school efficiency based on the HRS DEA model. Second, the development of a new HRS-based Malmquist index to measure change in efficiency over time. Third, this study contribute to studies on the PPSMI policy by taking a different approach to measure the implications of the policy for school performance in Malaysia, which has never been done before.

2.2 Efficiency Measurement

2.2.1 Concept

This section reviews the key concepts of efficiency measurement. Much of the material in this section is based on Coelli et al. (2005), Johnes (2004), Thanassoulis (2001), and Worthington (2001). Drawing upon the work of Debreu (1951) and Koopmans (1951), Farrell (1957) defined a simple measure of DMU efficiency that could account for multiple inputs. Farrell (1957) developed three types of efficiency, namely technical efficiency, allocative efficiency, and overall efficiency (also known as economic or productive efficiency). The technical efficiency reflects the ability of a decision making unit (DMU) to achieve maximum possible output from a given set of inputs. Given their respective prices and the production technology, allocative efficiency reflects the ability of a DMU to use the inputs in optimal proportions. The product of technical and allocative efficiency will result in the overall efficiency. However, it is not easy to measure allocative efficiency of an education institution since the prices are not available. Thus, in this study, only technical efficiency will be used to measure the school efficiency.

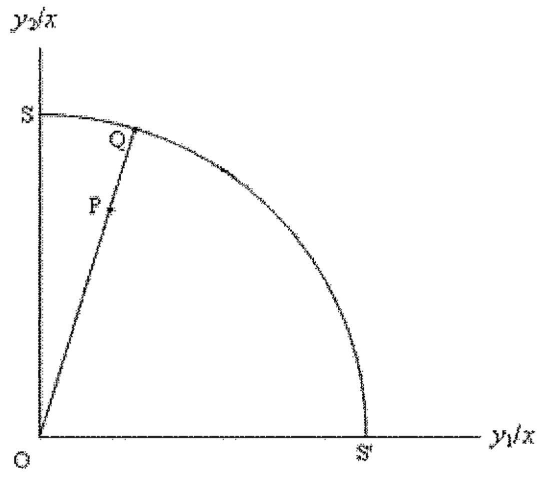
In explaining the concept of efficiency measurement, Farrell adopted an input-oriented approach to answer the question: how much can inputs be proportionally reduced by without changing the quantity of output produced? Farrell illustrated his ideas using a simple example involving DMUs that use two inputs to produce a single output under the assumption of constant returns to scale (CRS). In this study, an output-oriented approach is more suitable to measure school efficiency because inputs are fixed. An output-oriented approach seek to answer the question: how much can output be proportionally increased by for a given set of inputs?

The measurement of efficiency by using the output-oriented approach is illustrated in Figure 2.1. In this case, two outputs, y_1 and y_2 are produced from a given level of input, x, under the assumption of CRS. Let us suppose that the DMU is a school producing the outputs of number of pupils (y_1) and number of pupils with good grade in mathematics (y_2) from one input, i.e. number of teachers (x). The curve SS' represents the isoquant joining all combinations of y_1 and y_2 of the fully efficient DMUs. The technical efficiency (*TE*) of the DMU produced at point P is defined as the proportion of outputs observed at point *P* to the maximum possible output produced by the fully efficient DMU at point *Q*. It can be written as:

$$TE = \frac{OP}{OQ} \qquad (2.1)$$

The technical inefficiency is equal to $1 - TE$. The proportion by which outputs could be increased without increasing the level of input used at the observed production point *P* is equal to $\frac{1}{TE}$.

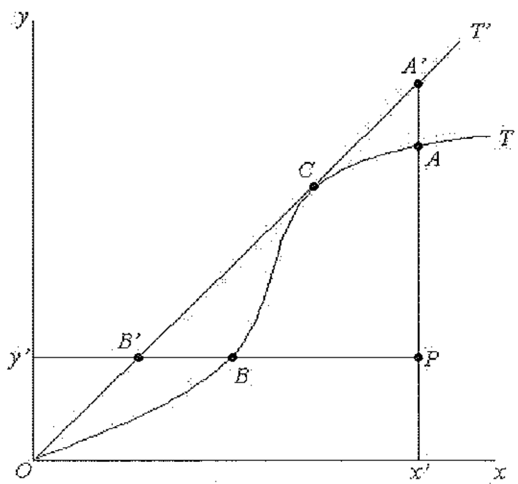
Figure 2.1: Measuring technical efficiency in an output-oriented framework



The technical efficiency measures obtained from output and input orientations are the same under the assumption of CRS but vary under the assumption of variable returns to scale (VRS). When the DMUs being assessed operate under the assumption of VRS, the change in efficiency of a DMU may be impacted by changes in scale size (Thanassoulis, 2001). To illustrate this point, let us consider a DMU that faces a VRS production frontier *OT*, produces one output, *y* from one input, *x*, and produces at point *P* as shown in Figure 2.2. The CRS production frontier, *OT'*, is given for comparison.

In a CRS situation, the input oriented technical efficiency of the DMU *P* is measured using the horizontal distance of *P* from the frontier *OT'*. This is given by $TE^{I}_{CRS} = y'B'/y'P$. Conversely, the output-oriented technical efficiency is measured using the vertical distance of *P* from the frontier *OT'* and is given by $TE^{O}_{CRS} = x'P/x'A'$. In a VRS situation, the technical efficiency is measured by using the distance of DMU *P* from the VRS frontier *OT*. Thus, the input oriented technical efficiency is given by $TE^{I}_{VRS} = y'B/y'P$ and the output oriented technical efficiency is given by $TE^{O}_{VRS} = x'P/x'A$.

Figure 2.2: Measuring scale efficiency



From Figure 2.2, the distance of P under both input and output orientation are the same from the CRS production frontier but vary from the VRS production frontier. Another difference between CRS and VRS is that the technical efficiency (distance of P from the production frontier) under the VRS assumption is always higher than under the CRS assumption except at point C where they are the same. In addition, it can be shown that at point P,

$$TE_{CRS}^{O} = \frac{x'P}{x'A'} = \frac{x'P}{x'A} \cdot \frac{x'A}{x'A'} \tag{2.2}$$

where the first component $\frac{x'P}{x'A}$ is equal to TE_{VRS}^{O} (the output-oriented measure of technical efficiency under VRS) and the second component is the output-oriented CRS efficiency measure of a hypothetical DMU A. It is called scale efficiency and can be defined as the ratio of the efficiency of a DMU under CRS to its efficiency under VRS. In other words, the overall technical efficiency under the assumption of CRS can be decomposed into a measure of pure technical efficiency (or a technical efficiency under the assumption of VRS) and a measure of scale efficiency. From Equation (2.2), scale efficiency can be represented as

$$SE^{o} = \frac{TE_{CRS}^{o}}{TE_{VRS}^{o}} \tag{2.3}$$

2.2.2 Techniques for Measuring Efficiency

The efficiency measures discussed in the previous section assume the production function of the fully efficient DMU is known. However, this is not usually the case. The efficient isoquant has to be estimated by using sample data (Worthington, 2001). There are two main approaches for estimating the efficient isoquant in order to measure efficiency. First, the parametric approach, which uses econometric methods to estimate the parameters of a specific functional form of the production function, and second, the non-parametric approach, which place no conditions on the functional form, and uses observed data to infer the shape of the frontier (Worthington, 2001; Sarafidis, 2002; Ruggiero, 2007). The common form of parametric method now in use is Stochastic Frontier Analysis (SFA), while the non-parametric method is commonly known as Data Envelopment Analysis (DEA) (Chakraborty et al., 2008; Mizala et al., 2002; Sarafidis, 2002; Hjalmarsson, 1996). The main difference between the two approaches lies in their underlying assumptions where they make different adjustment for random noise and for flexibility in the structure of the production technology (Johnes, 2004).

According to Coelli et al. (2005) and Khumbakar and Lovell (2000), the original SFA model was developed by Meeusen and van den Broeck (1977) and Aigner et al. (1977). Another paper on SFA appeared shortly after the first two papers and was written by Battese and Corra in 1977 (Khumbakar and Lovell, 2000). These three original SFA models were developed in a production frontier context and have a combined error term that accounts for statistical noise and technical inefficiency (Khumbakar and Lovell, 2000). The ability to measure efficiency in the presence of statistical noise is the main advantage of SFA (Ruggiero, 2007). However, the requirement of a priori assumption about the shape of the efficiency frontier is the major disadvantage of SFA (Jacobs, 2001). SFA is similar to conventional regression analysis except for the combined error term. A more detailed description of SFA can be found in Coelli et al. (2005) and Kumbhakar and Lovell (2000).

DEA was developed by Charnes et al. (1978) following work by Farrell (1957). Before that, several authors (Boles, 1966; Shephard, 1970; and Afriat, 1972) suggested mathematical programming methods suitable for frontier estimation but these did not receive wide attention (Coelli et al., 2005). In their seminal paper, Charnes et al. (1978) generalised and extended Farrell's concepts of empirical efficiency, by using a mathematical programming model to obtain empirical estimates of production functions and efficient production possibility surfaces (Cooper et al., 2004). In contrast to SFA, the DEA model does not require a priori assumption about the shape of the efficiency frontier and is based on the production possibility set induced by the observed DMUs (Cooper et al., 2007; Sarafidis, 2002). As a result, the problem of wrongly specifying the frontier can be avoided. The primary advantages of DEA are the non-parametric nature and the ability to handle multiple outputs and multiple inputs (Ruggiero, 2007). Econometricians however, have argued that the DEA approach produces biased estimates in the presence of measurement error and other statistical noise (Ruggiero, 2007; Schmidt, 1985). A comprehensive description of DEA can be found in Thanassoulis et al. (2008), Cooper et al. (2007), Coelli et al. (2005) and Cooper et al. (2004).

As mentioned above, both DEA and SFA methods have their own strengths and weaknesses. Allowing for statistical noise is the main advantage of SFA but being parametric and requiring strong assumptions about the form of the frontier is a disadvantage. On the other hand, DEA have the strength of being non-parametric and requiring few assumptions about the underlying technology but have the disadvantage of assuming no statistical noise which might lead to biased estimates of efficiency. Nevertheless, the ability of DEA to handle multiple outputs and multiple inputs is particularly appropriate in the area of education management, given the special characteristics of the production process that takes place in schools. These advantages allow researchers to capture a school's multidimensional performance without the need to specify a single functional form to explain the production process in all schools (Mancebon and Bandres, 1999). A further review of these approaches and their strengths and weaknesses can be found in Lovell and Schmidt (1988) and Coelli et al. (2005).

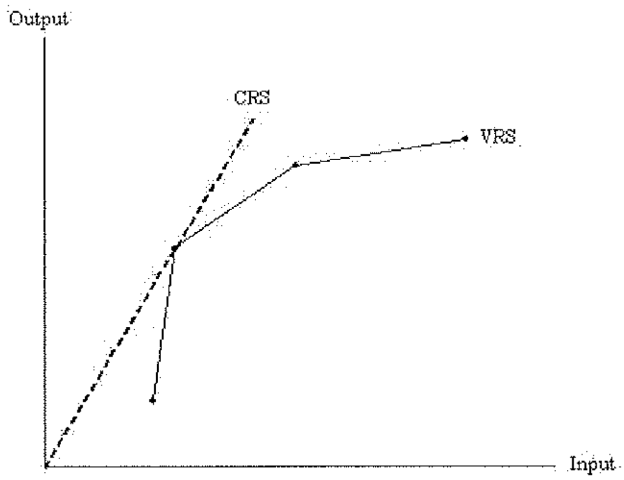
The techniques of measuring efficiency that have been presented here can be used to evaluate the efficiencies of many different kinds of entities such as educational institutions, hospitals, business firms, banks, and others. This study is trying to evaluate the efficiencies of Malaysian schools in implementing a new educational policy. Thus, the focus of the review is on the studies that involve educational institutions only. There is a remarkable amount of literature on measuring school efficiency using either DEA or SFA, or both, as well as how they compare. The use of DEA to measure school efficiency can be found, among others, in Bessent and Bessent (1980), Bessent et al. (1982), Bessent et al. (1984), Färe et al. (1989), Thanassoulis and Dunstan (1994), Grosskopf et al. (1999), Mante and O'Brien (2002), and Ouellette and Vierstraete (2005). SFA was used to measure school efficiency, for example, in Adkins and Moomaw (2003), Dodson and Garret (2003), Franta and Konecny (2009), Pereira and Moreira (2007) and Tanja (2007). Examples of studies that used both methods are Ruggiero and Vitaliano (1999), Chakraborty et al. (2001), Mizala et al. (2002), and Chakraborty and Poggio (2008). A detailed review of the school efficiency measurement and the use of DEA in measuring school efficiency will be given in section 2.3 and 2.4 respectively .

Given the advantages of DEA in measuring educational institution efficiency, a DEA methodology is employed to measure the efficiency of Malaysian schools in implementing the PPSMI policy. As mentioned in the previous chapter, the methodology is based on a new development in DEA i.e. hybrid returns to scale (HRS) that was introduced by Podinovski (2004). This is the first study to employ the HRS DEA model to measure school efficiency. In the following section, more elaboration on the HRS model while be given whilst the DEA methodology for this study will be presented in chapter three.

2.2.3 A new Extension in DEA (Hybrid Returns to Scale)

The two basic convex DEA models are the constant returns to scale (CRS or CCR) model introduced in Charnes et al. (1978) and the variable returns to scale (VRS or BCC) model introduced in Banker (1984). The CRS models require the assumption of full proportionality between all inputs and outputs while the VRS ignores the information regarding any proportional relationship between variables (Podinovski, 2004). Figure 2.3 shows the difference between the CRS and VRS frontiers for a single input-single output DEA model. In measuring school efficiency, many recent studies employed the VRS model since the relationship of inputs and outputs in education production is not normally proportional (e.g. Waldo, 2007; Ouellette and Vierstraete, 2005; Banker et al., 2004; Mizala et al., 2002; Mante and Brien, 2002; Portela and Thanassoulis, 2001; Mancebon and Molinero, 2000; Mancebon and Bandres, 1999). Nevertheless, some studies employed CRS model and there are studies that used both models (e.g. Hu, et al., 2009; Kirjavainen and Loikkanent, 1998; Soteriou et al., 1998). A review of the use of VRS and CRS DEA models in measuring school efficiency will be given in section 2.4.

Figure 2.3: CRS and VRS Frontier



In assessing school efficiency, Thanassoulis and Dunstan (1994) stressed that neither the assumption of CRS nor VRS is totally satisfactory. It is not easy to clearly assume whether inputs and outputs in education production are proportional or not as some do have a proportional relationship while others do not. For example, the numbers of teachers and pupils are usually proportional to each other but the number of pupils with good grade on entry is not normally proportional to the number of pupils with good grade on exit. In this situation, the use of the CRS model is not valid since the full proportionality cannot be assumed, while the use of VRS technology will result in an over-optimistic measurement (Podinovski, 2004).

A new extension by Podinovski (2004) regarding selective proportionality between subsets of inputs and outputs in the DEA model can be used to solve this issue. Motivated by the issue of selective proportionality, Podinovski (2004) developed a hybrid returns to scale (HRS) technology that is based on the assumption that only some of the inputs and outputs are proportional to each other while the other are not (selective proportionality). This new technology exhibits CRS with respect to the inputs and outputs that are proportional to each other and VRS with respect to the remaining inputs and outputs. The CRS and VRS models are special cases of the HRS model: in the case of CRS, all inputs and outputs are proportional, and in the case of VRS none of the inputs and outputs is proportional. Podinovski (2004) demonstrated that the HRS model is certainly more discriminating than the VRS model and in some cases, its discrimination can exceed that of the CRS model. VRS is a subset of CRS and based on Podinovski (2004), VRS is also a subset of HRS but neither the HRS nor CRS technology is the subset of the other.

Shortly after Podinovski introduced the concept of selective proportionality, Kuosmanen (2005) introduced a new model incorporating the concept of weak disposability of undesirable outputs. In his paper, Kuosmanen suggests a simple formulation of weak disposability that allows for non-uniform abatement factors and preserves the linear structure of the model. These two concepts, although different in context, are similar in terms of suggesting a concept of selective proportionality where Podinovski suggesting a technology that combined the CRS and VRS technologies while Kuosmanen suggesting a technology that allows for non-uniform reduction of harmful factors but preserves the linear structure of the model. This shows that the concept of selective proportionality is realistic and can be applied in the real world.

Podinovski (2009), in a further development of the HRS technology, has shown that there are cases where some technologies exhibit both full (when all outputs are proportional to all inputs) and selective proportionality. In these cases, we might use either CRS or HRS models to measure the efficiency. However, any of the models would use only part of the available information regarding the technology, i.e. full or selective proportionality, and ignore the other part of the information, which would generally result in the same DMUs having different efficiencies from the two models. Thus, in order to utilise all available information about the underlying technology and to produce a better efficiency measure, Podinovski (2009) suggested an approach that combined both types of proportionality in the same model. This is achieved by the combination of the axioms of the CRS technology in Banker et al. (1984) and the axiom of selective proportionality in Podinovski (2004). The result is a technology known as C-HRS (Cone-HRS) that includes both CRS and HRS technologies as subsets.

The C-HRS technology can be viewed as the minimal technology where units in HRS technology can be expanded by full proportional scaling. C-HRS is the cone extension of the HRS technology, similar to the CRS technology being the cone extension of the VRS technology. As such, it is more discriminating than both CRS and HRS technologies. By following the definition of scale efficiency given in (2.5), the scale efficiency of any DMU operating in HRS technology is defined as the ratio of $TE^{O}_{HRS}/TE^{O}_{C-HRS}$. C-HRS technology is important to this study because it is part of the HRS-based Malmquist index to measure the change in efficiency over time. A detailed description of the HRS and C-HRS models in this study will be given in Chapter 3.

2.3 Measurement of school efficiency

Measuring school efficiency is a difficult task due to conceptual challenges, multiple objectives, and great scope for measurement error (Smith, 2006). Developing a valid and reliable measure of school performance is very important so that the objectives of the assessment can be achieved. One approach is to apply production function and the techniques for measuring it that have been developed in the field of economics and operations research (Bifulco and Bretschneider, 2001).

According to Deller and Rudnicki (1993), the most influential study employing an educational production function is the Coleman Report (1966). Using the conceptual framework of input-output analysis, Coleman was the first to introduce the connection between school inputs and pupil achievement (or output). The framework took the form of educational production functions when economists started to seek insight into the notion of human capital (Hanushek, 1979). The conceptual difference between Coleman's input-output analysis and the production function is the concept that the production function describes the maximum likelihood of feasible output given various input combinations. In the education process, this concept can be seen as schools maximising pupil achievement given various inputs available to them (Hanushek, 1986).

When measuring school efficiency by applying the production function technique, the efficiency model must be specified first. The fundamental step in developing any efficiency model is the specification of the inputs used and outputs produced by the DMU (Smith, 2006). Boussofiane et al. (1991) stressed that in selecting inputs and outputs, any resources used by a unit should be included as an input while output may include a range of performance and activity measures. In addition, the identification and inclusion of environmental factors which may affect the production of these outputs is also necessary. Hanushek (1986) states that at least the following three aspects should be taken into account when assessing the efficiency of a school: academic results, school inputs, and environmental factors. Thanassoulis (1996) came up with three generic drivers of school efficiency. They are school related factors, family and external environment influences (such as school location), and the abilities of the pupils themselves. The three aspects listed by Hanushek and Thanassoulis, (i.e. school related, academic results/pupils' ability, and environmental factors) are the general form of input-output specification. They can be represented by many variables such as the number of pupils and teachers, the quality of teachers and funding for teaching material (school related), the number of pupils with good grade on entry and exit (pupils' ability), and socioeconomic status, as well as location of school (external environment). Some of the school related and pupils' ability variables can be on the input side while some can be on the output side. The external environment variables are normally used on the input side.

Teachers are obviously an important resource on the input side and can be measured by just the number or the level of experience or the salary cost (Boussofiane et al., 1991). Among the studies that used the number of teachers as input are Färe et al. (1988), Lovell et al. (1994), Grosskopf and Moutray (2001), Maragos and Despotis (2003), Primont and Domazlicky (2006), and Alexander et al. (2010). Examples of studies that utilised teachers experience are Kirjavainen and Loikkanent (1998), Alexander et al. (2010), and Hu et al. (2009). The variable of teachers' salaries were used, among others, in Duncombe et al. (1997), Ruggiero (1996, 2000), and Grosskopf and Moutray (2001). The number of pupils with good grade on entry is also an important resource and can be used to measure the value added to pupils on exit (Boussofiane et al., 1991). This input has been used in many studies that measure school efficiency, for example Bessent and Bessent (1980), Thanassoulis and Dunstan (1994), Portela and Camanho (2009), and Khalili et al. (2010).

The number of pupils with good grade on exit or the academic performance based on the standardised test score has been used the most as a measure of educational output (Nesbit and Palardy (2007). Hanushek (1986) agrees with the use of this variable for three reasons i.e., it has value, most people use it as a measure of how well schools are performing, and it is important for access to further education. Instances of studies that utilised this variable are Bessent and Bessent (1980), Bessent et al. (1982), Färe et al. (1988), Ganley and Cubbin (1992), Chalos and Cherian (1995), Engert (1996), Kirjavainen and Loikkanent (1998), Mancebon and Molinero (2000), Ramanathan (2001), Kiong et al. (2003), Rassouli-Currier (2007), Nesbit and Palardy (2007), Kantabutra (2008), and Morgan (2010).

The number of pupils is usually taken as input to education (Johnes, 2004). However, there are many cases where the number of pupils (or students/enrolment) is used as proxy for output (Ahn and Seiford, 1993; Avkiran, 2001; Abbott and Doucouliagos, 2003; Ouellette and Vierstraete, 2005, 2010; Millimet and Collier, 2008; Franta and Konečný, 2009). Ouellette and Vierstraete (2005, 2010) stressed that the total number of pupils must be considered as one of the outputs because schools help to socialise children and also that what has been learned has no value for those who did not get a good grade if only the number of pupils who passed certain criteria is taken as output. Inputs from family and external environment influence, such as socioeconomic status, race, gender, parental occupation, and income, are all essential inputs into the education production process (Johnes, 2004). Environment factors were used in most of the studies that measure school efficiency. For examples, Bessent and Bessent (1980), Smith and

Mayston (1987), Sengupta (1990), McCarty and Yaisawarng (1993), Chalos and Cherian (1995), Chalos (1997), and Soteriou et al. (1998) used input on parents' socioeconomic status or income. Some studies used percentage of pupils not receiving school meals as a proxy for parents' socioeconomic status (Thanassoulis and Dunstan, 1994; Thanassoulis, 1996; Yang et al. 1999; Mancebon and Mar Molinero, 2000; Bradley et al., 2001). There are many more external environment variables that are used in studies to measure school efficiency, such as parents' education level (Soteriou et al., 1998), pupils from single parent households (Gray et al., 1984), percentage of adults with college education (Ruggiero, 2000), percentage of house owners in the school district (Kang and Green, 2002).

A variety of inputs and outputs can be used in studies on school efficiency measurement depending on the objectives of the studies and the availability of data. This study employs pupils' academic results on entry as input and on exit as output, number of teachers as school resources (input), parents' socio economic status as environmental factors (input), and number of pupils as one of the outputs. The number of classes will be used as a proxy for the number of teachers due to limitation of data. A more detailed description of inputs and outputs used in this study will be given in Chapter 3.

2.4 Review of the Use of DEA in Measuring School Efficiency

The use of DEA in education has a long history and studies using DEA to evaluate the performance of educational institutions have increasingly appeared in recent years. Most of the studies that used DEA to measure school performance (especially recent studies) utilised the VRS model in their methodology (e.g. Waldo, 2007; Ouellette and Vierstraete, 2005; Banker et al., 2004; Mizala et al., 2002; Mante and Brien, 2002; Portela and Thanassoulis, 2001; Mancebon and Molinero, 2000; Mancebon and Bandres, 1999) while some earlier studies utilised the CRS model (e.g. Bradley et al., 2001; Thanassoulis and Dunstan, 1994; Bessent et al., 1982; Charnes et al., 1981; Bessent and Bessent, 1980). There are studies that used both the CRS and VRS models so that comparison of the different results can be made (e.g. Hu, et al., 2009; Kirjavainen and Loikkanent, 1998; Soteriou et al., 1998). This section reviews the inputs and outputs used in studies of school performance to see whether they are appropriate to the methodology that was used (CRS or VRS). At the same time, the possibility of employing HRS model with their choice of inputs and outputs is explored.

One of the earliest applications of DEA in education research was done by Bessent and Bessent (1980) who applied a DEA method to determine the comparative efficiency of elementary schools in an urban school district. The CRS model was used to calculate the efficiency score (the VRS model was not yet introduced). 13 inputs and 2 outputs were used in this study. The inputs are median percentile reading achievement in 1975, median percentile mathematics achievement in 1975, percent Anglo-American pupils, percent pupils not from low income family, percent of average daily attendance, mobility index, number of professional staff per 100 pupils, total per pupil expenditure for instruction, esprit, intimacy, trust, consideration and total individualised instruction index. The two outputs are median percentile reading achievement in 1976 and median percentile mathematics achievement in 1976. The outputs could be proportional to the first two inputs because we can expect those who performed well in 1975 to also perform well in 1976. The rest of the inputs however are not proportional to any of the outputs. Therefore, the relationship between inputs and outputs is selectively proportional where some of the inputs are proportional to the outputs while some are not proportional. The use of the HRS model to calculate the efficiency in this case might give a more realistic result.

Charnes et al. (1981) compared the programme follow through and non-follow through schemes for primary school children in the USA. Inputs in this study are education level of mother, highest occupation of a family member, parental visit index, parental counselling index and number of teachers while the outputs are total reading score, total mathematics score and self-esteem inventory. It seems that there is no proportional relationship between any of the inputs to any of the outputs unless number of pupils is added as one of the outputs so that it is proportional to the number of teachers on the input side. Without the additional output, the VRS model would be more appropriate but with the additional input, the HRS model might give a better result. CRS is clearly inappropriate in this case.

The two studies discussed above used test score as one of the outputs. Test score is bounded by maximum and minimum values. No matter how big the increase or decrease in input value is, the value of output in the form of test score will not exceed its maximum or minimum values. Therefore, the relationship between inputs and test score as output will not be proportional. Studies that use test score as the output cannot utilise the CRS model because it is not appropriate. Other studies that used test score as one of the outputs are, among others, Thanassoulis and Dunstan (1994), Soteriou et al. (1998), Kirjavainen and Loikkanent (1998), Mancebon and Bandres (1999), Mancebon and Molinero (2000), Bradley et al. (2001), Färe et al. (2006), Waldo (2007), and Hu et al. (2009). Most of these studies utilised the VRS model in calculating the efficiency but some used the CRS model, whilst a few of the studies utilised both models.

One study that utilised both models was conducted by Soteriou et al. (1998) who used both the CRS and VRS models to assess the efficiency of secondary schools in Cyprus. Data for this study were taken from the Trend in Mathematics and Science Study (TIMSS) which involved 55 secondary schools randomly selected from all over Cyprus. The inputs are teachers' age, teachers' education, parents' education, pupils' socioeconomic status, school size and the number of books at home, while the output is mathematics score. They did not give any justification for using both models but just used the results from both models to assess the performance of secondary schools in Cyprus and demonstrate how inefficient schools can benefit from their analysis. However, there was no proportional relationship between those inputs and output and therefore, the VRS model is the most appropriate for this study.

Another study that utilised both models is undertaken by Kirjavainen and Loikkanent (1998) who studied efficiency differences among Finnish senior secondary schools. They experimented with four different models where the most complicated model has six inputs and four outputs. The inputs are teaching hours per week, non-teaching hours per week, teachers' experience, education level of teachers, admission level and educational level of pupils' parents. The outputs are number of pupils who passed, number of graduates, score in compulsory subjects, and score in additional subjects. They described the difference between the CRS and VRS models and then discussed the results from both models thoroughly. They concluded that the CRS model's results are better than the one from the VRS model. Based on their choice of inputs and outputs, the CRS model is not appropriate since some of the outputs are test scores. The VRS model is the best model to be utilised in this study.

One example of studies utilising the VRS model was presented in Mancebon and Bandres (1999) who evaluated the efficiency of a sample of Spanish secondary schools, focusing on the theoretical specification of the measurement model and the ex post analysis of the results. They chose the VRS model because they believe it has a structure that is most in agreement with the particular education technology. The DEA model in their study has four inputs and 3 outputs. The inputs are operating expenses per pupil, number of teachers per pupil, socioeconomic factor, and human capital factor, while the outputs are average mark in sciences, average mark in arts, and percentage of passes over course registration. From the inputs and outputs utilised in this study, the VRS model is the most appropriate.

Mancebon and Molinero (2000) also utilised the VRS model to conduct a study to assess the factors that influence schools productive efficiency. They tested both models before retaining only the VRS model in their final model. Their reason for choosing the

VRS model is that the variables they used are measured in percentages and are bounded between 0 and 100. They argued that the VRS model allows only for interpolation within observed data while the CRS model allows for extrapolation beyond the observed values, and there is no guarantee that this target will be bounded by the 100 upper limit. The final model that they used has 3 variables. They are percentage of pupils not eligible for free school meals on the input side and number of pupils who achieved level 4 or more in English SAT, as well as Mathematics SAT on the output side. With their choice of input and outputs, the model that they used is the most appropriate.

Waldo (2007) also used the VRS model to investigate the effect of reform in Sweden's public education in 1991-1993, which introduced a system with private school competition and decentralised the production of public education from central to local government. In this study, the inputs are pupil-teacher ratio, teaching material, parents' educational level, ethnicity, and the share of female pupils. The outputs are pupils' final grades from secondary school, pupils passing all subjects, and pupils progressing to upper secondary school. There was no proportional relationship between the inputs and outputs in this study and therefore the VRS model is appropriate.

One study that utilised the CRS model was undertaken by Bradley et al. (2001) who studied the effect of competition on the efficiency of secondary schools in England. In this study, the inputs are socioeconomic background and staff qualifications while the outputs are attendance rate and examination results. They did not give any justification for using the CRS model but based on the inputs and outputs that they used, the CRS model is not appropriate because there is no proportional relationship between inputs and outputs.

Thanassoulis and Dunstan (1994) employed the CRS model to show how DEA can be used to guide secondary schools to improved performance through role-model identification and target setting in a way that recognizes the multi-outcome nature of the education process and reflects the relative desirability of improving individual outcomes. They used mean verbal reasoning score per pupil on entry and percentage not receiving free school meals as inputs and average GCSE score per pupil and percentage of pupils not unemployed after GCSEs as outputs. Even though they employed the CRS model in the study, they realised that CRS is not easily sustainable when 'scale' relates to the values of the variables after they are normalised as in their choice of inputs and outputs. They argued that if one school has twice the number of pupils of another school and pupils are of similar ability and home background, then if the two schools are both efficient, the first school should produce twice the level of outputs (e.g. total score and number of placement) as the other school. This difficulty will generally be encountered in assessing schools because educational achievement is usually measured on ordinal scales and there is no reason to expect achievements reflected on such scales will be simple multiples of the levels of inputs.

However, they argued that a VRS assumption is not appropriate either especially when a mean value is used. According to them, the same mean value could result from widely differing scores at individual pupil level in two schools. Such schools should not be comparable but the model will find them comparable under a VRS assumption because it will read equal means on input levels as conveying the same scale of operation. In contrast, schools with different mean input levels could have largely comparable distributions of scores at individual pupil level but a VRS model would deem them not comparable. Nevertheless, they decided to use the CRS model by adjusting the data so that they become more compatible with the CRS assumption.

So far, this section has shown some examples of studies that utilised a CRS or VRS model, and whether their choice of inputs and outputs are appropriate with the model. In most of the studies, the relationship between inputs and outputs are not proportional and thus, the VRS model would be more appropriate. However, there are studies that have selective proportionality in their inputs and outputs and the use of the HRS model might be more appropriate and might give a more realistic result.

For example, Ouellette and Vierstraete (2005, 2010) examined the efficiency of Quebec's school boards during a period of severe cutbacks in their finance. Following Banker and Morey (1986), they employed the VRS model with capital constraint to calculate the efficiency score. They used the number of teaching staff, the number of other staff, supplies and material, and energy as inputs, while capital, number of primary pupils, and number of secondary pupils were used as outputs. The number of teaching staff is proportional to the number of pupils because with more staff, schools can take more pupils and the increase in the number of staff is based on the staff-pupil ratio such as 1 staff to 20 pupils. Thus, there exists selective proportionality in the input-output relationship in this case and the HRS model would be more appropriate for this study.

Another example of a DEA study that utilised the VRS model where there is selective proportionality in their input-output choice is Lovell et al. (1994). One of the inputs in this study is total number of staff while one of the outputs is average number of classes taken multiply by the enrolment. The relationship between these input-output is proportional since the increase in the number of staff could lead to a proportional increase in the enrolment. Thus, the HRS model would fit better in this study.

There are many more studies of school efficiency that utilise the number of pupils and teachers as variables but most of them use pupil-teacher ratio as input (e.g. Mante and O'Brien, 2002; Mante, 2001, Mancebon and Molinero, 2000; Mancebon and Bandrés, 1999; McCarty and Yaisawarng, 1993; Ray, 1991). One study use both variables as input (Färe et al. 1988). Other studies that has selective proportionality in their input-output choice can be found in the measurement of university efficiency (e.g. Abbot and Doucouliagos, 2003; Avkiran, 2001; Madden, 1997; Arcelus and Coleman, 1997; Tomkins and Green, 1988).

Not many researchers highlight the inappropriateness of both the CRS and VRS model in measuring the efficiency of schools except Thanassoulis and Dunstan (1994) as have been discussed earlier. Therefore, this study is trying to develop a new method of measuring school efficiency by employing the HRS model as in Podinovski (2004). The

HRS model is more appropriate in the measurement of school efficiency when there is selective proportionality in input-output relationship.

2.5 Change in Efficiency Over Time

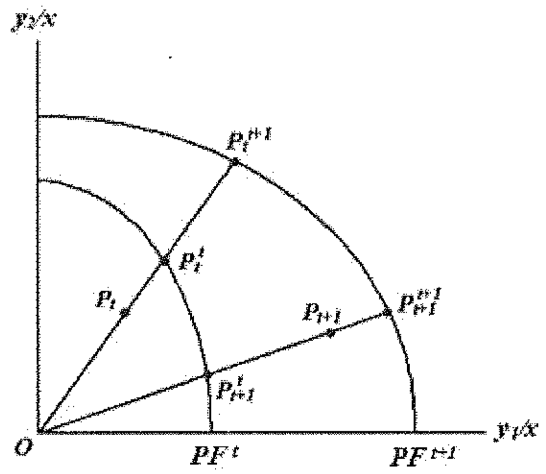
In section 2.2.1 we described measures of the efficiency of a DMU in a specific period of time. This section will elaborate the concept of change in efficiency over time and the Malmquist index as a method of measuring efficiency change over time. Much of the material in this section is based from Johnes and Johnes (2004), Coelli et al. (2005), and Thanassoulis (2001).

2.5.1 Concept

As proposed by Malmquist (1953), the growth in productivity between two different periods can be measured by constructing quantity indices as ratios of distance functions. The output distance function measures how close a particular level of output is to the maximum attainable level of output that could be obtained from the same level of inputs if production is technically efficient. This is the same as the technical efficiency described in section 2.2.1.

Figure 2.4 illustrate the concept of change in efficiency over time. Let us suppose DMU P produces two outputs, y_1 and y_2, by utilising input x. PF^t and PF^{t+1} are the production frontiers for DMU P in two different periods, t and $t+1$ respectively. The position of PF^{t+1}, which is outside PF^t, and not parallel to each other show that improvement in technology has occurred. Production level has changed from P_t in period t to P_{t+1} in period $t+1$. By using the definition given in Equation (2.1), the technical efficiency of the DMU in period t is $TE_t = OP_t/OP_t^t$ while the technical efficiency in period $t+1$ is $TE_{t+1} = OP_{t+1}/OP_{t+1}^{t+1}$. TE_t is the same as output distance function for period t and can be represented by $D_o^t(x_t, y_{1t}, y_{2t})$. Similarly, TE_{t+1} is the same as output distance function for period $t+1$ and can be represented by $D_o^{t+1}(x_{t+1}, y_{1t+1}, y_{2t+1})$.

Figure 2.4: Measuring change in efficiency over time



2.5.2 The Malmquist Index

The Malmquist index was introduced by Caves et al. (1982). They named this index after Malmquist (1953) who proposed constructing quantity indices as ratios of distance functions. It is an index representing total factor productivity (TFP) growth of a decision-making unit (DMU). It reflects progress or regress in efficiency along with progress or regress of the frontier technology over time under the multiple inputs and multiple outputs framework. Since the enhancement by Färe et al. (1994), the Malmquist index has become the standard approach within the nonparametric literature to measure productivity over time.

From section 2.5.1, the change in efficiency over time can be examined in two ways, i.e. by referring to technology in period t or by referring to technology in period $t+1$. By referring to technology in period t, first, the technical efficiency at point P_{t+1} is compared to the maximum that could be achieved with respect to period t technology. This can be denoted as $D_o^t(x_{t+1}, y_{1t+1}, y_{2t+1})$ or OP_{t+1}/OP_{t+1}^t. Then, the technical efficiency at P_t is compared to the maximum that could be achieved with respect to period t technology. This can be denoted as $D_o^t(x_t, y_{1t}, y_{2t})$ or OP_t/OP_t^t (same as *TE* at point P_t). The Malmquist output-oriented productivity index (Malmquist, 1953) with respect to the first period's technology (M_o^t) is then defined as

$$M_o^t = \frac{D_o^t(x_{t+1}, y_{1t+1}, y_{2t+1})}{D_o^t(x_t, y_{1t}, y_{2t})} = \frac{OP_{t+1}/OP_{t+1}^t}{OP_t/OP_t^t}$$

By referring to technology in period $t+1$, first, the technical efficiency at point P_{t+1} is compared to the maximum that could be achieved with respect to period $t+1$ technology. This can be denoted as $D_o^{t+1}(x_{t+1}, y_{1t+1}, y_{2t+1})$ or OP_{t+1}/OP_{t+1}^{t+1}. Then, the technical efficiency at P_t is compared to the maximum that could be achieved with respect to period $t+1$ technology. This can be denoted as $D_o^{t+1}(x_t, y_{1t}, y_{2t})$ or

OP_t/OP_t^{t+1}. The Malmquist output-oriented productivity index with respect to the second period's technology (M_o^{t+1}) is then defined as

$$M_o^{t+1} = \frac{D_o^{t+1}(x_{t+1}, y_{1t+1}, y_{2t+1})}{D_o^{t+1}(x_t, y_{1t}, y_{2t})} = \frac{OP_{t+1}/OP_{t+1}^{t+1}}{OP_t/OP_t^{t+1}}$$

Now there are two measures of change in productivity over two periods of time. The problem is which measures should be used for calculating the change in productivity over the two periods? Färe et al. (1989, 1994) solved this problem by using the Malmquist output-oriented productivity change index (M_o) which is defined as the geometric mean of M_o^t and M_o^{t+1}.

$$M_o = [M_o^t . M_o^{t+1}]^{\frac{1}{2}} = \left[\frac{D_o^t(x_{t+1}, y_{1t+1}, y_{2t+1})}{D_o^t(x_t, y_{1t}, y_{2t})} . \frac{D_o^{t+1}(x_{t+1}, y_{1t+1}, y_{2t+1})}{D_o^{t+1}(x_t, y_{1t}, y_{2t})}\right]^{\frac{1}{2}}$$

Following Färe et al. (1989, 1992), Equation (2.2) is equivalent to:

$$M_o = \frac{D_o^{t+1}(x_{t+1}, y_{1t+1}, y_{2t+1})}{D_o^t(x_t, y_{1t}, y_{2t})} \left[\frac{D_o^t(x_{t+1}, y_{1t+1}, y_{2t+1})}{D_o^{t+1}(x_{t+1}, y_{1t}+1, y_{2t+1})} . \frac{D_o^t(x_t, y_{1t}, y_{2t})}{D_o^{t+1}(x_t, y_{1t}, y_{2t})}\right]^{\frac{1}{2}},$$

where:

Efficiency Change (EC) = $\frac{D_o^{t+1}(x_{t+1}, y_{1t+1}, y_{2t+1})}{D_o^t(x_t, y_{1t}, y_{2t})}$

$$\text{Technical Change (TC)} = \left[\frac{D_o^t(x_{t+1}, y_{1t+1}, y_{2t+1})}{D_o^{t+1}(x_{t+1}, y_{1t} + 1, y_{2t+1})} \cdot \frac{D_o^t(x_t, y_{1t}, y_{2t})}{D_o^{t+1}(x_t, y_{1t}, y_{2t})}\right]^{\frac{1}{2}}$$

Hence, the Malmquist productivity index is the product of the change in relative efficiency that occurred between periods t and $t + 1$, and the change in technology that occurred between periods t and $t + 1$.

The Malmquist index presented in this section is based on CRS. When the underlying technology does not exhibit CRS, the change in productivity may be impacted by changes in scale size. To capture the impact of scale size Färe et al. (1994) proposed a further decomposition of the Malmquist index such that EC = PTEC x SEC where PTEC is Pure Technical Efficiency Change and SEC is Scale Efficiency Change. Thus, when the underlying technology exhibit VRS, the Malmquist index is defined as

$$M_o =$$

$$\frac{D_{o_{vrs}}^{t+1}(x_{t+1}, y_{1t+1}, y_{2t+1})}{D_{o_{vrs}}^{t}(x_t, y_{1t}, y_{2t})} \cdot \frac{SEC_o^{t+1}(x_{t+1}, y_{1t+1}, y_{2t+1})}{SEC_o^{t}(x_t, y_{1t}, y_{2t})} \cdot \left[\frac{D_{o_{crs}}^{t}(x_{t+1}, y_{1t+1}, y_{2t+1})}{D_{o_{crs}}^{t+1}(x_{t+1}, y_{1t}+1, y_{2t+1})} \cdot \frac{D_{o_{crs}}^{t}(x_t, y_{1t}, y_{2t})}{D_{o_{crs}}^{t+1}(x_t, y_{1t}, y_{2t})}\right]^{\frac{1}{2}} \qquad (2.4)$$

However, as demonstrated by Grifell-Tatjé and Lovell (1995), the Malmquist index provides an inaccurate (biased) measure of productivity change in the presence of non-constant returns to scale. Coelli et al. (1998) agreed that a CRS-based Malmquist index could correctly measure productivity change even if the underlying technology exhibits VRS. Following this finding, more studies of the Malmquist index decomposition have been done and many researchers have proposed alternate decompositions of the VRS-based Malmquist index. Among them are Ray and Desli (1997), Simar and Wilson (1998), Zofio and Lovell (1999), Grifell-Tatjé and Lovell (1999) and Balk (2001). A summary of some of these can be found in Balk (2001).

On the other hand, Lambert (1999) argued that the biased result as shown by Grifell-Tatjé and Lovell (1995) is caused by the omission of the scale effect since total factor productivity measure assumes CRS. Lambert insisted that the VRS-based Malmquist index as proposed by Färe et al. (1994) is not biased and is indeed an accurate measure of productivity change if the scale effect is introduced. Grosskopf (2003) also sees nothing 'wrong' with Färe et al.'s (1994) Malmquist index based on empirical VRS technologies as long as users are aware that it does not have an average product interpretation.

This study will follow the VRS-based Malmquist index decomposition as in Färe et al. (1994) but the calculation will be modified to accommodate the use of the HRS DEA model where the VRS-based efficiency score is replaced by the HRS-based efficiency score and the CRS-based efficiency score is replaced by the C-HRS-based efficiency score. This is one of the main contributions of this study because for the first time, the Malmquist index is used with the HRS DEA model. The HRS-based Malmquist index will be described in detail in Chapter 3. Next, a review of previous studies on measuring educational institutions efficiency changes over time by using the Malmquist Index is given.

2.6 Review of the Use of the Malmquist Index in Measuring Educational Institution Efficiency Change Over Time

Among the studies that used the Malmquist index to measure school efficiency are Grosskopf and Moutray (2001), Liu et al. (2004), Färe et al. (2006), Ouellette and Vierstraete (2010), and Barley et al. (2010). In measuring the higher education institution change in efficiency over time, these studies employed the Malmquist index : Johnes et al. (2004), Castano and Cabanda (2007), Hu and Liang (2008), Worthington and Lee (2008), Thanassoulis et al. (2010), and García-Aracil et al. (2009).

From the studies that measure school efficiency as cited in the above paragraph, Grosskopf and Moutray (2001), Liu et al. (2004), and Färe et al. (2006) employed a CRS-based Malmquist index. Grosskopf and Moutray (2001) used DEA type techniques to estimate the indirect distance functions and then used them to construct productivity index over the 1989-94 period. They employed a CRS-based Malmquist index which has been modified to the indirect case as in Färe et al. (1985). Liu et al. (2004) employed a CRS DEA model to evaluate the efficiency of the vocational education institutions in Taiwan. They then used the CRS-based Malmquist index to calculate the efficiency change over time. Färe et al. (2006) used a modified Malmquist index which will allow inputs and proxies for quality of inputs to be accounted for. They employed a CRS-based Malmquist index using output distance function similar to an output-oriented DEA model. They decomposed the productivity change into a quality change component and a productivity change component that does not include quality. In these studies, none has discussed the scale effect and the VRS-based Malmquist index.

The other two studies i.e. Ouellette and Vierstraete (2010) and Barley et al. (2010) employed a VRS-based Malmquist index in calculating the change efficiency over time. Ouellette and Vierstraete (2010) used Malmquist indices with quasi-fixed inputs to measure the efficiency of school districts in the Province of Québec, Canada. They employed both a CRS-based and a VRS-based Malmquist index in calculating the change in efficiency and the results from both methods were compared and described in detail. In using the VRS-based Malmquist index, they acknowledged it might lead to strong bias as shown by Grifell-Tatjé and Lovell (1995). However, they argued that Lambert (1999) has shown that the bias is caused by the omission of the scale effect and to obtain a valid measure, the scale effect must be introduced. That is what they have done to come up with the VRS-based Malmquist index in their study. Barley et al. (2010) employed a VRS-based Malmquist index to come up with the Educational Malmquist Index which is then used to compare the public-private school management in the Basque country. They utilised the decomposition proposed by Ray and Desli (1997).

In measuring the efficiency of higher education institutions, some studies employed a CRS-based Malmquist index (Johnes et al., 2004; Castano and Cabanda, 2007; Thanassoulis et al., 2010) and others employed a VRS-based Malmquist index (Worthington and Lee, 2008; García-Aracil et al., 2009). Johnes et al. (2004) and Thanassoulis et al. (2010) employed both a CRS and a VRS DEA models in calculating efficiency scores but resorted to the CRS-based Malmquist index in calculating efficiency change over time due to the bias introduced in measuring efficiency change using VRS technology. Worthington and Lee (2008) followed Coelli et al. (1998) to decompose the VRS-based Malmquist index into technical efficiency change, technological change, pure technical efficiency change, scale efficiency change, and total factor productivity change. García-Aracil et al. (2009) employed a VRS-based Malmquist index by decomposing the Malmquist index into technical change, pure efficiency change and scale efficiency change as in Simar and Wilson (1998) and Zofio and Lovell (1998).

Even though the number of studies that employed the Malmquist index to measure educational institutions is not that big, most of the studies are very recent and this shows that there is a growing interest in this topic. So far, there is no study in Malaysia that used the Malmquist index to measure educational institutions (as in this study) and only a few similar studies can be found in that region (Liu et al., 2004 (Taiwan); Hu and Liang, 2008 (China); Castano and Cabanda, 2007 (Philippines)).

The issue of the decomposition of the Malmquist index as discussed in the previous section has been addressed in some of the studies where several of the studies resorted to a CRS-based Malmquist index while others resorted to a VRS-based Malmquist index depending on the objectives of their studies. As mentioned in the previous section, this study will follow the VRS-based Malmquist index decomposition as in Färe et al. (1994) but the calculation will be modified to accommodate the use of the HRS DEA model. The modification of the VRS-based Malmquist index to be used with the HRS model is an important contribution of this study. The HRS-based Malmquist index will be described in detail in Chapter 3.

2.7 Non-Parametric Statistical Tests

This study compares the efficiency scores and Malmquist indices of schools in three different categories i.e. school type, state, and location. There are three groups in school type and state categories while location category has two groups. In comparing different groups of DMUs, it is necessary to test for statistically significant differences between them in order to ascertain that the difference did not occur by chance (Cooper et al., 2007). Due to the non-parametric nature of DEA, nonparametric statistical tests are more naturally used with DEA scores (Grosskopf, 1996). Non-parametric tests do not require assumptions about the population distribution function for comparing function of different groups, which is required under the parametric tests (Conover, 1999). Brocket and Golany (1996) suggested the use of non-parametric rank statistics such as the Mann-Whitney test for evaluating the possible differences between two groups of DMUs and the Kruskal-Wallis test for evaluating the differences among more than two groups. They also stressed that other non-parametric methods can be used to investigate a variety of important issues relating to the results of the DEA methods, including inter-temporal analysis and efficiency trends.

The Mann-Whitney test is a non-parametric test for assessing whether two independent samples come from different populations by testing for significant difference between their medians. A significant difference in the medians means they are representing different populations with different median values (Sheskin, 2004). The Mann-Whitney test was proposed initially by Wilcoxon (1945), for equal sample sizes, and extended to arbitrary sample sizes and in other ways by Mann and Whitney (1947). This test is identical to performing an ordinary parametric two-sample *t*-test on the data after ranking over the combined samples. Among the DEA studies that utilised the Mann-Whitney test are Chen and Yeh (2000), Reichmann (2004), Rodriguez-Diaz et al. (2004), Sowlati (2007) and Kantabutra (2009). Chen and Yeh (2000) conducted the test to verify whether two sample banks were drawn from the same productivity change populations. Reichmann (2004) applied the test to look for any significant difference in the efficiencies of different library groups. By employing the Mann-Whitney method, Rodriguez-Diaz et al. (2004) tried to compare the extensive and intensive agriculture in their study of irrigation efficiency in Andalusia. Sowlati (2007) used the test to examine a frontier shift and determine the number of periods to include in an inter-temporal analysis. Kantabutra (2009), in his study of urban rural and size effects on school efficiency in Thailand, examined the effects by using a Mann-Whitney test.

The Kruskal-Wallis one-way analysis of variance by ranks (named after W. Kruskal and W.A. Wallis) is a non-parametric method for testing equality of population medians among groups and is identical to a one-way analysis of variance (ANOVA) with the data replaced by their ranks. It is an extension of the Mann-Whitney test to a design involving three or more independent groups (Sheskin, 2004). A significant result of the Kruskal-Wallis test indicates that at least two of the samples represent populations with different median values (Sheskin, 2004). Many DEA studies employed the Kruskal-

Wallis method in testing for significant difference among groups of DMUs. For example, Nozick et al. (1998) used the Kruskal-Wallis test to examine whether the distribution of passengers per vehicle was different, based on the background condition. Jaforullah and Premachandra (2004) conducted a Kruskal-Wallis test to check for significant difference in mean technical efficiencies from three different models. Van der Meer (2005) used Kruskal-Wallis test to examine significant differences in yearly DEA scores. Kruskal-Wallis and Mann Whitney tests were used by Yang (2006) to assess whether different region or different preferred language of the customers are important factors affecting branch performance. Oliveira et al. (2009) used the Kruskal-Wallis test to investigate whether the homeport can explain some of the variation in the MI.

The Mann-Whitney and Kruskal-Wallis tests discussed so far are used to examine the difference between independent groups of DMUs. For dependent or related groups of DMUs, suitable non-parametric tests are the Wilcoxon matched-pairs signed-rank test and the Friedman two-way analysis of variance ranks test. The Wilcoxon matched-pairs signed-ranks test is a non-parametric statistical hypothesis test involving a design with two dependent samples (Sheskin, 2004). The test is named after F. Wilcoxon who proposed the method. The hypothesis evaluated with the test is whether or not in the underlying populations represented by the samples, the median of the difference scores equals zero. A significant difference indicates a high likelihood that the two samples represent two different populations (Sheskin, 2004). Examples of DEA studies that utilised Wilcoxon matched-pairs signed-rank test are Hollas et al. (2002) who performed the test to inspect the equality of the efficiencies between two different policy periods, Sufian (2009) who employed the test to examine the differences between the mean efficiencies of the traditional DEA and alternative DEA models, and Roh and Choi (2010) who conducted the test to examine the differences in brand efficiency among three brands.

The Friedman two-way analysis of variance ranks test is employed in a hypothesis test involving a design with two or more dependent samples. A significant result from this test indicates a high likelihood that at least two of the samples represent populations with different median values (Sheskin, 2004). In DEA studies, the Friedman two-way analysis of variance ranks test was used among others in Soares and Brazdil (2000) to deduce that there is significant difference in mean correlation of the three different groups they compared, in Haas and Murphy (2003) who examined the equality of the results of four different methods, and in Talluri and Narasimhan (2004) who checked whether the cross-efficiency scores of 23 suppliers are significantly different.

This study will utilise all four statistical tests that have been discussed in this section to test for significant differences in the efficiencies of different types of schools, as well as schools in different states and locations. The details of the implementation procedure of all four tests will be given in Chapter 3.

2.8 Previous Studies on the PPSMI Policy

Since the PPSMI policy was implemented in 2003, a lot of studies of the policy have emerged. The studies looked at various aspects of the policy such as problems and challenges in implementing the policy, as well as the outcome of the policy. On the challenges in implementing the policy, some studies have been carried out to evaluate teachers' competency in English and their readiness to implement the policy. Daud (2004) and Kon (2005) found that teacher readiness is at an intermediate to high level even though some teachers admitted that they lack proficiency in English. They claimed that competency in English for most teachers is just average where teachers are said to generally understand the English language, but lack the oral skills to teach subject matter in English. In terms of preparing the teachers for the change in the medium of instruction, Idris et al. (2007) found that most teachers were satisfied with the training (pre-service or in-service) they had received. However, many teachers felt they still needed more training, especially regarding the use of English to communicate with pupils.

Other than looking at the language problem faced by the teachers, a number of studies discussed the language problems faced by pupils such as pupils' language needs (Chan, 2003), lack of vocabulary and confusion with certain words (Zubir, 2003), and difficulty in understanding non-scientific terms in the scientific context (Samsudin and Ismail, 2004). Following these findings, Idris et al. (2006) discussed the need for understanding pupil problems in using the English language. They have shown that challenges arising from the implementation of the PPSMI policy can be overcome if the school sets up a planned and concrete intervention programme with various strategies directed at teachers and pupils.

One of the important efforts by MOEM to help teachers and pupils in adapting to the new policy is by providing them with courseware (teaching and learning computer applications) to facilitate the teaching and learning process. Surveys on the overall usefulness of courseware found that the majority of teachers agreed that the courseware helped them to teach in English (Peh, 2003; Idris et al., 2006). However, the use of courseware has reduced the interaction between teachers and pupils as revealed by Koh (2006) in his observation of 21 teachers' instructional practices. Teachers were found to be mainly using the click and show approach and depending on the voice-over in the courseware to explain science concepts.

Many studies have also been conducted to evaluate the outcome of the policy. Several studies reveal that pupils with low proficiency in English are in general not performing well in examinations (Surif et al., 2006; Haron et al., 2008). Studies on the effect of the policy to pupils in different locations indicate that after the implementation of the policy, pupils in urban schools did better than those in rural schools (Kiong et al., 2005; Long, 2005; Surif et al., 2006; Hamzah and Abdullah, 2009). Hamzah and Abdullah (2009) also found that the performance of national school type is the most affected when compared to other types of schools. Surprisingly, Nor and Aziz (2009) found that 20.5 percent of the pupils in a fully residential school complained that their mathematics and science grades had deteriorated due to the implementation of the PPSMI policy.

All the studies discussed in this section developed their evaluation methods. Studies on the problems and challenges in implementing the policy were based on the perception of teachers and pupils, as well as observations. Studies of the outcome of the policy were mostly based on the instruments developed to measure pupils' performance or simply based on the results of standardized examination. The data were analysed by means of simple statistics such as frequencies and percentages.

2.9 Gap in the Literature

Based on the literature reviewed in this section, there are three important contributions of this study. First and foremost, this study develops a new method of measuring school efficiency by employing the HRS DEA model. As shown in the previous section, all studies that measure school performance by using DEA usually employed VRS or CRS models and sometimes both models. The use of CRS DEA models requires the assumption of full proportionality between all inputs and outputs but such proportionality cannot always be true because not all inputs and outputs are proportional to each other (e.g. number of teachers and the number of pupils with good grade on exit). The VRS assumption would be more appropriate for the education process. However, the assumptions of VRS under a situation where input such as the number of teachers is proportional to output such as the number of pupils will lead to a lower discrimination of the DEA model and overestimation of the efficiency of units. Thus, this study is intended to fill this gap in the literature by developing a hybrid approach (HRS model) that combines the assumption of CRS with respect to the selected sets of inputs and outputs, while preserving the VRS assumption with respect to the remaining indicators.

The second contribution of this study is the development of an HRS-based Malmquist index to measure the change in efficiency over time. An HRS-based Malmquist index is developed in this study by modifying the VRS-based Malmquist index to accommodate the C-HRS technology. C-HRS is the cone extension of the HRS technology just as CRS is the cone extension of the VRS technology. C-HRS is a technology resulting from the synchronisation of axioms in the CRS technology and the axiom of selective proportionality. Some studies that used Malmquist index utilised CRS technology while some studies utilised VRS technology in calculating the index. This study is the first that utilises HRS and C-HRS technologies in calculating the Malmquist index.

The third contribution of this study is to the PPSMI policy itself where the implications of the policy for the schools performance in mathematics and science subject will be analysed based on efficiency scores and the Malmquist index. This is the first study to utilise DEA and the Malmquist index to measure the schools efficiency concerning the PPSMI policy. Thus, this study contributes to the PPSMI policy by looking at the implications of the policy from a different perspective. This study is hoped to get more understanding of the implications of the policy for the schools performance and thus help MOEM to decide on the future direction of the policy.

2.10 Summary and Conclusion

This chapter introduced the concept of efficiency and the techniques for its measurement. Two popular techniques of efficiency measurement namely the non-parametric DEA and the parametric SFA were compared by looking at their characteristics, as well as analysing the strengths and weaknesses of each method. A more detailed description of DEA, especially the new extension in DEA involving HRS technology was given. Then, a discussion of how to measure school efficiency by using the general efficiency measurement approach is followed by the review of studies that use DEA to measure educational institution efficiency, in particular, school efficiency. The number of studies that employed DEA to measure school efficiency has grown rapidly since the first study by Charnes et al (1978) and is still growing. Most of the studies, especially the recent ones, utilised the VRS model but based on their input-output choice, the HRS model could have been employed in some of the studies.

This chapter continued with the discussion of the concept of efficiency change over time and the method for measuring it i.e. the Malmquist index. Then, the literature on the use of the Malmquist index to measure the educational institutions change in efficiency over time is reviewed. The use of the Malmquist index to measure educational institution over time has become more popular in recent years, which can be seen from the number of new studies employing this methodology. Some studies were found to utilise CRS to calculate the Malmquist index because of the issue of biased estimate if VRS is used. Some studies utilised VRS based on the original decomposition suggested by Färe et al.

(1994), and alternative decomposition by Ray and Desli (1997), Coelli et al. (1998), Simar and Wilson (1998) and Zofio and Lovell (1998).

The non-parametric statistical tests were also reviewed in this chapter since the statistical tests will be used in this study to examine the differences in the efficiencies of different groups of schools. DEA studies that employed four non-parametric statistical tests namely Mann-Whitney, Kruskal-Wallis, Wilcoxon, and Friedman tests were reviewed. Lastly, past studies on the PPSMI policy were reviewed before elaborating on the contributions of the study. There is no study on the PPSMI policy that utilised either DEA or Malmquist index methodologies.

The utilisation of the HRS DEA model and the HRS-based Malmquist index to measure schools efficiency and efficiency change over time is a positive development in the methodology of measuring their performance. The element of selective proportionality can easily be identified in the input-output relationship in the process of education. Thus, HRS technology would result in more realistic efficiency scores and would give a better understanding of the school performance. In Chapter 3, the HRS-based methodology developed to measure school efficiency in implementing the PPSMI policy will be described in detail.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This study develops a novel method of measuring school performance by employing the Hybrid Returns to Scale (HRS) DEA model. It has never been applied to measure school performance before. This study also develops a new HRS-based Malmquist index to measure the change in performance after the implementation of the PPSMI policy. These are described in this chapter. It begins with a description of the CRS, VRS, and HRS DEA models. Then, the HRS-based Malmquist index developed in this study will be described. After that, the conceptual framework of the study and the DEA models developed for this study will be specified. Population and sample as well as data collection procedures will be given next followed by the description of the efficiency scores and the Malmquist index calculation. The statistical tests that are used in this study will be explained before the summary and conclusion of the chapter.

3.2 Data Envelopment Analysis

3.2.1 Concept

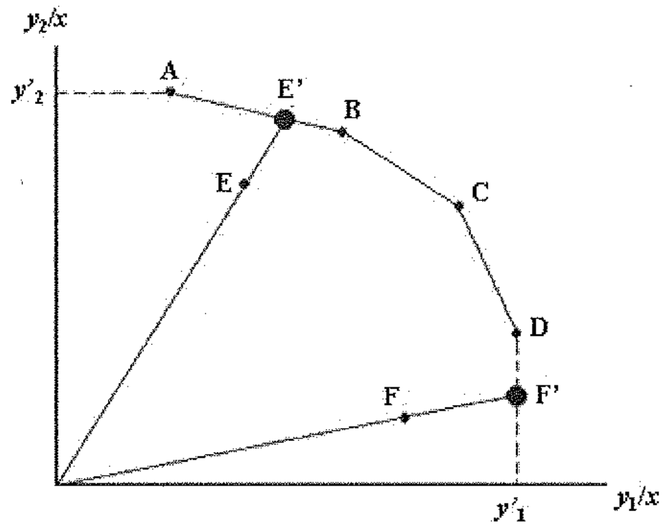
DEA is an approach for evaluating the relative efficiency of a set of homogeneous DMUs which convert multiple inputs into multiple outputs. The term relative efficiency is used because in DEA, a DMU is to be rated as fully efficient on the basis of available evidence if and only if the performances of other DMUs does not show that some of its inputs or outputs can be improved without worsening some of its other inputs or outputs (Cooper et al., 2004). This definition avoids the need for recourse to prices or other assumptions of weights which are supposed to reflect the relative importance of the different inputs or outputs. It also avoids the need for explicitly specifying the formal relations that are supposed to exist between inputs and outputs. This basic kind of efficiency is referred to as "technical efficiency".

DEA estimates technical efficiency by first constructing a production possibility set (PPS) assumed to contain all input-output correspondences which are feasible and then estimating the maximum feasible expansion of the output or contraction of the input levels of the DMUs within the PPS. The estimation of the efficiency of DMUs is conducted using linear programming models.

The DEA models that provide a radial measure of inefficiency require one to choose between an input and an output orientation. The objective of the input-oriented model is to minimise inputs while producing at least the given output levels. On the other hand, the output-oriented model tries to maximise outputs while using no more than the observed amount of any input. The choice between an input-oriented and an output-oriented model can be based upon considerations of which factors are more easily controlled by the DMU. In measuring school performance, output-oriented model is more appropriate since input usage cannot be freely adjusted.

To show the concept of DEA graphically, consider a simple illustration of a set of six DMUs, A, B, C, D, E, and F, with each unit consuming the same amount of an input, x, and producing different amounts of outputs, y_1 and y_2. For a given amount of input, units providing greater amounts of the outputs will be the efficient ones. By plotting y_1/x against y_2/x, as in Figure 3.1, it can be identified that DMUs A, B, C, and D are efficient DMUs since no other units can produce more of both outputs. The piecewise linear boundary, which joins up these DMUs, provide an envelope round the entire data set and can be considered as the efficiency boundary. The data set is enclosed in the envelope by drawing a line from A to y'_2 and D to y'_1. DMUs E and F, however, lie within this envelope and therefore are inefficient. All efficient DMUs received an efficiency score of 1 while DMUs operating below the efficiency boundary receive a score between 0 and 1, with lower efficiency scores indicating greater degree of inefficiency.

Figure 3.1: Graphical Representation of DEA with 1 Input and 2 Outputs



The line drawn from the origin through DMU E can be extended to the boundary at point E', which represents a DMU that is a combination of DMUs A and B and could produce more of both outputs, given the input, than DMU E. Thus, OE/OE' represents the efficiency of DMU E with respect to the efficient boundary. The outputs of DMU E could be proportionally increased by the amount OE'/OE without increasing the input. This is an output-oriented DEA model where outputs are being maximised given the amount of inputs available. An input-oriented measure of technical efficiency could be estimated in the same way but by plotting the ratio of input to each output.

For DMU F, which is also an inefficient DMU, the line drawn from the origin through it can be extended to the boundary at point F'. However, at the same quantity of input, DMU D could produce the same level of y_1 and more of output y_2. Thus, DMU F could also increase its level of y_2 output to be the same as produced by D. This is known as slack. This is observed in the output-oriented model where output could be increased without increasing the input, and in the input-oriented model where input could be reduced without causing a decline in output values. For all technically efficient units, these slack values will be zero.

As mentioned in Chapter 2, the two basic convex DEA models are the constant returns to scale (CRS) and the variable returns to scale (VRS) models. Each of these models has two mutually dual forms: the primal, also referred to as envelopment, and the dual, also referred to as multiplier, forms. In the next sections, description of the envelopment and multiplier form of both the VRS and CRS models will be given. Also, as mentioned in Chapter 2, we will focus on the output-oriented model because it is more suitable in measuring school efficiency where the input cannot be freely adjusted.

3.2.2 The Envelopment VRS Model

The VRS DEA model (also known as the BCC model) was introduced in Banker et al. (1984). To present the model, suppose that we have n DMUs where every DMU$_j$, j =1,2, ..., n, produces the same s outputs in varying amounts, Y_{rj} (r = 1, 2, ..., s), using the same m inputs, X_{ij} (i = 1, 2, ..., m) also in varying amounts. It is assumed that at least one output and at least one input are positive.

The production possibility set is represented as

$$T = \{(X,Y) \mid Y \geq 0 \text{ can be produced from } X \geq 0\}$$

The following properties for the production possibility set, T, are postulated:

Postulate 1. *Convexity.* If $(X_j,Y_j) \in T$, j = 1, ..., n and $\lambda_j \geq 0$ are non-negative scalars such that $\sum_{j=1}^{n} \lambda_j = 1$, then $\left(\sum_{j=1}^{n} \lambda_j X_j,\ \sum_{j=1}^{n} \lambda_j Y_j\right) \in T$.

Postulate 2. *Inefficiency Postulate.* (a) If $(X,Y) \in T$ and $\bar{X} \geq X$, then $(\bar{X}, Y) \in T$. (b) If $(X,Y) \in T$ and $0 \leq \bar{Y} \leq Y$, then $(X, \bar{Y}) \in T$.

Postulate 3. *Minimum Extrapolation.* T is the intersection of all sets $\hat{T}$ satisfying Postulates 1 and 2, and subject to the condition that each of the observed vectors $(X_j, Y_j) \in \hat{T}, j = 1, \ldots, n$.

T is the smallest set consistent with the observed data and the postulated properties of the production possibility set. Postulate 2 is referred to as "Free Disposability" in the economics literature. It indicates that inefficient production is always possible in the form of more inputs, smaller outputs or both. Employing Postulates 2 and 3, it can be deduced that a vector (X, Y) is in the set T if and only if $X \geq \sum_{j=1}^{n} \lambda_j X_j$, and $Y \leq \sum_{j=1}^{n} \lambda_j Y_j$ for some $\lambda_j \geq 0, j = 1, \dots, n$, satisfying the condition that $\sum_{j=1}^{n} \lambda_j = 1$. The procedure developed in this model assigns an efficiency rating of 1 to a DMU if and only if the DMU lies on the efficient production surface.

The efficiency (output-oriented) of a specific DMU_j can be evaluated by the output-oriented envelopment VRS model as follows,

$$
\begin{array}{lll}
\text{maximise} & Z_0 & \\
\text{subject to} & \sum_{j=1}^{n} \lambda_j X_{ij} \leq X_{ij_0}, & \forall i \\
 & \sum_{j=1}^{n} \lambda_j Y_{rj} \geq Z_0 Y_{rj_0}, & \forall r \\
 & \sum_{j=1}^{n} \lambda_j = 1 & \\
 & \lambda_j \geq 0 & \forall j
\end{array}
$$

This output-oriented envelopment model seeks the set of λ values which maximise Z_0 to Z_0^* and identifies a point within the VRS production possibility set whose output levels reflects the highest proportion Z_0^* to which the output levels of DMU_{j0} can be radially expanded without any increment to its input levels. Z_0^* is referred to as *pure technical efficiency*. The efficiency score Z_0 for the efficient unit is 1, while inefficient ones will have a Z_0 value of more than 1. The efficiency of the inefficient units is then calculated by taking $\frac{1}{Z_0}$.

As explained in section 3.2.1, the radial projection $X_0, Z_0^* Y_0$ may not be fully efficient because of the presence of positive residual slacks, so a second stage optimization stage based on the additive model is usually implemented to identify fully efficient and weakly efficient units (Cooper et al., 2007).

3.2.3 The Envelopment CRS Model

The CRS DEA model was introduced in Charnes et al. (1978) and is known as the CCR (Charnes, Cooper, Rhodes) model. Under this assumption, if we scale the input levels of a feasible unit up or down, then another feasible unit is obtained in which the output levels are scaled by the same factor as the input levels.

Suppose, we have *n* DMUs and the production possibility set, *T*, with input possibility set *L*(*Y*) and output possibility set *P*(*X*), as in the VRS DEA model presented in the previous section. However, *T* for the CRS model has one extra property as shown in the following Postulates.

Postulate 1. *Convexity.* If $(X_j, Y_j) \in T, j = 1, \ldots, n$ and $\lambda_j \geq 0$ are nonnegative scalars such that $\sum_{j=1}^{n} \lambda_j = 1$, then $\left(\sum_{j=1}^{n} \lambda_j X_j,\ \sum_{j=1}^{n} \lambda_j Y_j\right) \in T$.

Postulate 2. *Inefficiency Postulate.* (a) If $(X,Y) \in T$ and $\bar{X} \geq X$, then $(\bar{X}, Y) \in T$. (b) If $(X,Y) \in T$ and $0 \leq \bar{Y} \leq Y$, then $(X, \bar{Y}) \in T$.

Postulate 3. *Ray Unboundedness.* If $(X,Y) \in T$ then $(kX,kY) \in T$ for any $k > 0$.

Postulate 4. *Minimum Extrapolation.* T is the intersection of all sets $\hat{T}$ satisfying Postulates 1, 2 and 3, and subject to the condition that each of the observed vectors $(X_j, Y_j) \in \hat{T}, j = 1, \dots, n$.

The extra postulate in this model is Postulate 3, i.e. "ray unboundedness". This postulate enabled us to extrapolate the performance of the most efficient DMUs with efficient scale sizes (for their given input and output mixes) and identify any scale inefficiencies that may be reflected in the level of operations of other DMUs. The difference between this model and the VRS model is that the VRS model evaluates the production inefficiencies at the given level of operations for each DMU only (and not of other DMUs).

As in the previous section, T is characterised as the smallest set satisfying the observed data and the postulated properties. They imply that every (X,Y) of the form $(k\sum_{j=1}^{n}\lambda_j X_j, k\sum_{j=1}^{n}\lambda_j X_j)$ with $k > 0$ and $\lambda_j \geq 0$ is in T. Employing Postulates 2 and 4, we can deduce that a vector $(X,Y) \in T$ if and only if $X \geq k\sum_{j=1}^{n}\lambda_j X_j$, and $Y \leq k\sum_{j=1}^{n}\lambda_j Y_j$ for some $k > 0$ and some λ_j, $j = 1, \dots, n$, satisfying the condition $\lambda_j \geq 0$.

The efficiency (output-oriented) of a specific DMU_j can be evaluated by the output-oriented envelopment CRS model as follows,

$$\begin{aligned} &\text{maximise} && Z_0 \\ &\text{subject to} && \sum_{j=1}^{n} \lambda_j X_{ij} \leq X_{ij_0}, && \forall i \\ & && \sum_{j=1}^{n} \lambda_j Y_{rj} \geq Z_0 Y_{rj_0}, && \forall r \\ & && \lambda_j \geq 0 && \forall j \end{aligned}$$

The difference between this model and the VRS model is that this model does not have the constraint $\sum_{j=1}^{n} \lambda_j = 1$. In an output-oriented model, the envelopment formulation seeks a set of λ values, which maximise Z_0 to Z_0^* and identifies a point within the data set which produces the highest proportion Z_0^* of output levels of DMU j_0 while using input levels which are as low as those of DMUj_0. This point is a composite DMU corresponding to the linear combination of efficient DMUs $\left(\sum_{j=1}^{n} \lambda_j X_{ij}, \sum_{j=1}^{n} \lambda_j Y_{rj}\right)$, with i = 1, ..., m and r = 1, ..., s. Z_0 is termed the *technical efficiency* of DMUj_0. The efficiency score Z_0 for the efficient unit is 1, while inefficient ones will have a Z_0 value of more than 1. The efficiency of the inefficient units is then calculated by taking $\frac{1}{Z_0}$. This model is also solved by using a two-stage procedure similar to the VRS model shown in the previous section.

3.2.4 The Multiplier CRS Model

Based on the basic theory of linear programming, every linear programming problem has another closely related linear program known as its dual. The dual for the envelopment

CRS model is called the multiplier CRS model. In the case of output orientation, the model is given below:

$$\text{minimise} \qquad h_0 = \sum_{i=1}^{m} v_i X_{ij_0}$$

$$\text{subject to} \qquad \sum_{i=1}^{m} v_i X_{ij} - \sum_{r=1}^{s} u_r Y_{rj} \geq 0, \quad j = 1, \ldots, n$$

$$\sum_{r=1}^{s} u_r Y_{rj_0} = 1$$

$$u_{r,} v_i \geq 0, \quad \forall r \; and \; i$$

In this formulation, the output maximisation model minimises the total weighted input in the linearised multiplier form. u_r and v_i are the multipliers or weights for the output and input respectively and treated as variables in the model. The relative efficiency score for DMUj_0 is given by $1/h_0$.

3.2.5 The Multiplier VRS Model

The dual for the envelopment VRS model is called the multiplier VRS model. It includes an additional variable ω_0, which makes it possible for returns to scale (RTS) classification (increasing, constant and decreasing). In the case of output orientation, the multiplier formulation for the VRS model is as follows:

minimise $\quad h_0 = \sum_{i=1}^{m} v_i X_{ij_0} - \omega_0$

subject to $\quad \sum_{i=1}^{m} v_i X_{ij} - \sum_{r=1}^{s} u_r Y_{rj} - \omega_0 \geq 0, \quad j = 1, \dots, n$

$$\sum_{r=1}^{s} u_r Y_{rj_0} = 1$$

$$u_r, v_i > 0, \quad \forall r \; and \; i$$

$$\omega_0 \; free$$

All variables in this model are constrained to be non-negative except for ω_0 which may be positive, negative or zero with consequences that make it possible to use optimal values of this variable to identify RTS. When a DMU is fully efficient and all slacks equal zero, the optimal value of ω_0, i.e. ω_0^* in (3.4), can be used to characterise the situation for RTS. Increasing RTS prevail if and only if $\omega_0^* < 0$ for all optimal solutions. Decreasing RTS prevail if and only if $\omega_0^* > 0$ for all optimal solutions and constant RTS prevail if and only if $\omega_0^* = 0$ for all optimal solutions.

3.2.6 The HRS Model

In the previous models, the input-output relationship is either proportional (CRS) or not proportional (VRS). In many cases however, not all of the inputs and outputs are proportional to each other or not all of the inputs and outputs are not proportional to each other. Variables involving the physical level or the actual amounts might usually have the proportional relationship but variables involving quality of resources or products/services are not normally proportional to each other. For example, in the education sector, the number of teachers is usually proportional to the number of pupils but teachers' qualification is not normally proportional to pupils' quality. In this situation, the use of the CRS model is not valid since the full proportionality cannot be assumed while the use of the VRS model will result in a less discriminating measurement since the VRS model does not represent the true scope of the technology. Motivated by this situation, Podinovski (2004) developed a Hybrid Returns to Scale (HRS) technology based on the assumption that only some of the inputs and outputs exhibit mutual proportionality while the remaining inputs and outputs do not. The HRS technology is partly the CRS technology with respect to inputs and outputs that are proportional to each other, and partly the VRS technology with respect to the remaining inputs and outputs. The HRS technology is generally more discriminating than the VRS technology and in some cases, the CRS technology.

To present formally the HRS model, consider a production technology T with m inputs and s outputs. A vector of inputs, X, and a vector of outputs, Y, represent DMUs in T. I and O represent the sets of all inputs and outputs respectively. If $J = \{1, 2, \dots, n\}$ is the set of observed DMUs, they can be denoted as (X^j, Y^j) and their individual inputs and outputs are X_i^j and Y_r^j respectively where i is the input and r is the output of the observed DMU j. At least one input and one output of each observed DMUj are assumed to be strictly positive. A fundamental concept in the HRS technology is the concept of selective proportionality. Consider the following partition of the input and output sets I and O:

$$I = I^{\mathrm{P}} \cup I^{\mathrm{NP}}, \qquad O = O^{\mathrm{P}} \cup O^{\mathrm{NP}}$$

where the subsets I^{P}, I^{NP}, O^{P}, and O^{NP} are mutually disjoint. In selective proportionality, O^{P} and I^{P} are assumed to be proportional while O^{NP} and I^{NP} are not. Selestive proportionality can be defined in two possible scenarios, expansion and contraction scenarios.

The expansion scenario occurs when the expansion factor α is more than 1. In this scenario, if the inputs from the subset I^{P} increased, the outputs from the subset O^{P} will also increase proportionally. In other word, if the inputs are multiplied by α, the outputs are simultaneously multiplied by α. The remaining inputs and outputs are left unchanged. The formal definition of the resulting DMU (X^{α}, Y^{α}) in the expansion scenario is:

$$X_i^{\alpha} = \begin{cases} \alpha X_i, & if\ i \in I^{\mathrm{P}} \\ X_i, & if\ i \in I^{\mathrm{NP}} \end{cases} \qquad Y_r^{\alpha} = \begin{cases} \alpha Y_r, & if\ r \in O^{\mathrm{P}} \\ Y_r, & if\ r \in O^{\mathrm{NP}} \end{cases} \tag{3.1}$$

The contraction scenario occurs when the contraction factor α is such that, $0 \leq \alpha < 1$. In this scenario, if the inputs from the subset I^{P} decrease the outputs from the subset O^{P} will also decrease proportionally. This is the same as in equation (3.1) where both the inputs and outputs are multiplied by the factor α. However, the reduction of I^{P} might affect the remaining outputs but in an unspecified way. The worst-case scenario is to assume that they would be reduced to zero. The formal definition of the resulting DMU (X^{α}, Y^{α}) in the contraction scenario is:

$$X_i^{\alpha} = \begin{cases} \alpha X_i, & if\ i \in I^{\mathrm{P}} \\ X_i, & if\ i \in I^{\mathrm{NP}} \end{cases} \qquad Y_r^{\alpha} = \begin{cases} \alpha Y_r, & if\ r \in O^{\mathrm{P}} \\ 0, & if\ r \in O^{\mathrm{NP}} \end{cases} \tag{3.2}$$

Based on the selective proportionality concept, the DMU (X^{α}, Y^{α}) should be regarded as feasible for any $\alpha > 1$ in the expansion scenario and for any α in the range $0 \leq \alpha < 1$ in the contraction scenario.

The HRS technology T is defined by the following set of axioms. The technology T is induced by the application of the minimum extrapolation principle (used in Banker et al., 1984) to the axioms:

(A1) *Feasibility of observed data.* The unit $(X^j, Y^j) \in T$ for any $j \in J$.

(A2) *Convexity*. The set T is convex.

(A3) *Free disposability*. $(X, Y) \in T, Y \geq Y' \geq 0$ and $X \leq X'$ implies $(X', Y') \in T$.

(A4) *Selective proportionality*: Let $(X, Y) \in T$. For any $\alpha > 1$, define unit (X^{α}, Y^{α}) as in (3.1). For any α such that $0 \leq \alpha < 1$, define unit (X^{α}, Y^{α}) as in (3.2). Then $(X^{\alpha}, Y^{\alpha}) \in T$.

(A5) *Closedness*: The set T is closed.

In the HRS model, unlike the CRS and VRS models, it has to be stated explicitly that the set of T contains all its limit points. This is done in axiom (A5). The technology defined by this set of axioms will turn into the CRS technology if the sets I^{P} include all inputs and O^{P} include all outputs. Indeed, in this case the unit $(X^{\alpha}, Y^{\alpha}) = (\alpha X, \alpha Y)$ is feasible for any

$\alpha \geq 0$. Likewise, the technology will turn into the VRS technology if no selective proportionality is assumed, where the sets I^{P} and O^{P} are defined as empty sets.

The effect of the contraction scenario as described in equation (3.2) is deliberately assumed to be the worst (reduced to zero) since the extent of the contraction is not known. However, the convexity axiom (A2) would ensure that the drop is in the same proportion α (Podinovski, 2004).

The constructive description of the HRS technology is given by, first, defining the $\bar{X}$ and $\bar{Y}$, the m x n and s x n matrices whose columns are the input and output vectors X^j and Y^j of the observed DMUs. Then, define the matrices $\hat{X}$ and $\hat{Y}$ as follows. The matrices $\hat{X}$ is obtained from $\bar{X}$ by changing to zero all rows $i \in I^{\mathrm{NP}}$. The matrix $\hat{Y}$ is obtained from $\bar{Y}$ by changing to zero every row $r \in O^{\mathrm{NP}}$

Theorem 1 (Podinovski 2004) *Technology T is the set of all nonnegative pairs (X, Y) such that*

$$X = \bar{X}\lambda + \hat{X}\mu - \hat{X}v + d \qquad (3.3)$$

$$Y = \bar{Y}\lambda + \hat{Y}\mu - \bar{Y}v - e \qquad (3.4)$$

$$\sum_{j=1}^{n} \lambda_j = 1 \qquad (3.5)$$

$$\lambda_i \geq v_j \text{ for all } j \in J \qquad (3.6)$$

$$\lambda, \mu, v \in R_+^n, d \in R_+^m, e \in R_+^s \qquad (3.7)$$

The efficiency of DMUj_0 can be obtained using the dual multiplier formulation, as well as the envelopment formulation. However, there is no intuitive interpretation of the HRS model in the multiplier form. Results under the envelopment formulation are easier to interpret and use, since they can be used to identify the radial improvement of inputs and outputs. The envelopment formulation for the output-oriented approach of the HRS model is obtained by taking the reciprocal value of the maximum value z by solving the following program. By converting the equations in (3.3) and (3.4) to more traditional inequalities, the slack vectors d and e are omitted from the program.

$$
\begin{aligned}
\text{maximise} \quad & Z && (3.8)\\
\text{subject to} \quad & \bar{X}\lambda + \hat{X}\mu - \hat{X}\nu \leq X_0 \\
& \bar{Y}\lambda + \hat{Y}\mu - \bar{Y}\nu \geq zY_0 \\
& \sum_{j=1}^{n} \lambda_j = 1 \\
& \lambda_j \geq \nu_j \qquad \forall j \in J \\
& \lambda, \mu, \nu \geq 0 \\
& Z \; free
\end{aligned}
$$

The model in (3.8) evaluate the radial efficiency of DMU j_0 and identify its radial projection on the boundary (X^*, Y^*) equal to (X_o, Z^*Y_o). As in the CRS and VRS models, the radial projection (X^*, Y^*) may not be fully efficient in the Pareto sense. To test for the inefficiency in the Pareto sense, second stage optimisation may be conducted with the aim of maximising the sum of input and output slacks d_i and e_r. DMUj_0 is fully efficient if and only if its radial efficiency is equal to 1 and the sum of slacks S^* is equal zero. The sum of slacks is obtained by the following program:

$$S^* = \max \sum_{i=1}^{m} d_i + \sum_{r=1}^{s} e_r \tag{3.9}$$

subject to

$$\bar{X}\lambda + \hat{X}\mu - \hat{X}\nu + d = X^*$$

$$\bar{Y}\lambda + \hat{Y}\mu - \bar{Y}\nu - e = Y^*$$

$$\sum_{j=1}^{n} \lambda_j = 1$$

$$\lambda_j \geq \nu_j \qquad \forall j \in J$$

$$\lambda, \mu, \nu, d, e \geq 0$$

If DMU j_0 is not fully efficient, model (3.9) identify its efficient target as $(X^* - d^*, Y^* + e^*)$, where d^* and e^* are optimal in model (3.9). The corresponding proofs can be found in Podinovski (2004).

There is one important observation regarding the HRS technology following Theorem 3 in Podinovski (2004): If $I_+^P = I$, the HRS technology is a subset of the CRS technology. If $I_+^P \neq I$, the HRS technology is not a subset of the CRS technology. This observation motivated Podinovski (2009) to extend the HRS model, which is discussed in the next section.

3.2.7 The HRS Model Extension

A further development in the HRS technology was explained briefly in section 2.2.3, Chapter 2. This development was motivated by cases where the technology exhibits both full and selective proportionality, in which case either CRS or HRS might be used to measure the efficiency. The illustration of this situation can be found in Podinovski (2009). It showed that, if $I_+^P \neq I$, the simultaneous assumption of the full and selective proportionality induces hypothetical units beyond the scope of both the CRS and HRS technologies. This indicates a generally larger technology than the simple union of both technologies.

The technology is referred to as the C-HRS technology. It is defined by the same axioms (A1) to (A5) as in the HRS technology plus the additional axiom of full proportionality:

(A6) *Full proportionality.* If $(X, Y) \in T$, then $(\alpha X, \alpha Y) \in T$ for any $\alpha \geq 0$.

The C-HRS technology can be viewed as the minimal technology, which expands the HRS technology by allowing full proportional scaling of the units in the HRS technology. It can be viewed as the cone technology induced by the HRS technology just like the CRS technology as the cone technology induced by the VRS technology. The constructive definition of the C-HRS technology as given by Podinovski (2009) is:

Theorem 2 *Technology C-HRS is the set of all nonnegative pairs* (X, Y) *that satisfy conditions* (3.6), (3.7), (3.8), *and* (3.9).

This theorem states that, except for the normalising equality (3.8), which is removed, the C-HRS technology is described by exactly the same linear conditions as in the HRS technology. This is consistent with the removal of condition (3.8) to obtain the CRS technology as the cone extension of the VRS technology. The C-HRS technology is utilised in this study to calculate the HRS-based Malmquist index based. This is described in the next section.

3.3 The HRS-Based Malmquist Index

The Malmquist index was introduced and described in detail in Chapter 2. This chapter describes HRS-based Malmquist index developed in this study to measure the change in school performance over time. It follows the VRS-based Malmquist index shown in equation (2.4), Chapter 2. In equation (2.4), the index represents a technology with one input, x, and two outputs, y_1 and y_2. To simplify the equation, the VRS-based Malmquist index is rewritten to represent a technology with one input, x, and one output, y. It is defined as

$$\underbrace{M_{j_0}}_{\text{Malmquist Index}} = \underbrace{\frac{D^{t+1}_{o\_vrs}(x_{t+1}, y_{t+1})}{D^{t}_{o\_vrs}(x_t, y_t)}}_{\text{Pure Technical efficiency change}} \cdot \underbrace{\frac{SEC_o^{t+1}(x_{t+1}, y_{t+1})}{SEC_o^{t}(x_t, y_t)}}_{\text{Scale efficiency change}} \cdot \underbrace{\left[\frac{D^{t}_{o\_crs}(x_{t+1}, y_{t+1})}{D^{t+1}_{o\_crs}(x_{t+1}, y_{t+1})} \cdot \frac{D^{t}_{o\_crs}(x_t, y_t)}{D^{t+1}_{o\_crs}(x_t, y_t)}\right]^{\frac{1}{2}}}_{\text{Technical change}}$$

where

$\frac{D_{o\_vrs}^{t+1}}{D_{o\_vrs}^{t}}$ = Efficiency of DMU j_0 computed under the VRS assumption using data of period *t+1* relative to the efficient boundary of period *t*.

$\frac{D_{o\_crs}^{t}}{D_{o\_crs}^{t+1}}$ = Efficiency of DMU j_0 computed under the CRS assumption using data of period *t* relative to the efficient boundary of period *t+1*.

$\frac{SEC_{o}^{t+1}}{SEC_{o}^{t}}$ = Scale Efficiency of DMU j_0 computed using data of period *t+1* relative to the efficient boundary of period *t*.

In the decomposition of Malmquist index under the assumption of the HRS technology, efficiency under the VRS assumption is replaced by efficiency under the HRS assumption. As has been described in the previous section, the C-HRS technology is the cone technology of the HRS technology. Thus, efficiency under the CRS assumption is replaced by efficiency under the C-HRS assumption. The decomposition of the Malmquist index under the HRS assumption is as follows:

$$\underbrace{M_{j_0}}_{\text{Malmquist Index}} = \underbrace{\frac{D_{o\_hrs}^{t+1}(x_{t+1}, y_{t+1})}{D_{o\_hrs}^{t}(x_t, y_t)}}_{\text{Pure Technical efficiency change}} \cdot \underbrace{\frac{SEC_{o}^{t+1}(x_{t+1}, y_{t+1})}{SEC_{o}^{t}(x_t, y_t)}}_{\text{Scale efficiency change}} \cdot \underbrace{\left[\frac{D_{o\_chrs}^{t}(x_{t+1}, y_{t+1})}{D_{o\_chrs}^{t+1}(x_{t+1}, y_{t+1})} \cdot \frac{D_{o\_chrs}^{t}(x_t, y_t)}{D_{o\_chrs}^{t+1}(x_t, y_t)}\right]^{\frac{1}{2}}}_{\text{Technical change}}$$

where

$\frac{D_{o\_hrs}^{t+1}}{D_{o\_hrs}^{t}}$ = Efficiency of DMU j_0 computed under the HRS assumption using data of period *t+1* relative to the efficient boundary of period *t*.

$\frac{D^{t}_{o\_chrs}}{D^{t+1}_{o\_chrs}}$ = Efficiency of DMU j_0 computed under the CRS assumption using data of period t relative to the efficient boundary of period $t+1$.

Definition of SEC is the same as above.

3.4 DEA Models for the Evaluation of School Performance in Mathematics and Science Subjects

This study is trying to evaluate implications of the PPSMI policy for the Malaysian school performance in mathematics and science subjects. The level being measured in this study is upper secondary level, which consists of pupils in form 4 and 5. The output oriented HRS DEA model will be used to measure the school performance, while HRS-based Malmquist index will be used to measure the change in performance over time in particular before and after the implementation of the policy.

The first step when applying DEA is to specify the inputs used and outputs produced by schools. Ideally, any resources used by schools should be included as an input while outputs may include performance and activity measures. However, unavailability of data due to various constraints is limiting the choice of inputs and outputs. Even if data are available, an attempt to incorporate too many inputs and outputs measures might result in several problems. One of them is the problem of multicollinearity when using statistical techniques, where it causes problems in nonparametric techniques such as DEA (Pedraja-Chaparro et al., 1999). Consequently, some important input variables may be omitted but in the context of education, the included inputs are likely to be correlated with the omitted inputs. This will cause biased in statistical studies (Bifulco and Bretschneider, 2001; Johnes, 2004).

One way of choosing variables is by looking at previous empirical evidence as suggested by Chalos and Cherian (1995). As discussed in Chapter 2, there are three minimum aspects to be taken into account when assessing the school performance. They are school related factors, pupils' ability/academic results, and environmental factors (Hanushek, 1986; Thanassoulis, 1996). Based on the literature on the measurement of school performance as presented in Chapter 2, the performance of Malaysian school in implementing the PPSMI policy will be measured by using inputs and outputs reflecting teachers, pupils' academic results and environmental factors. This is discussed further in the next subsections.

3.4.1 Inputs

Teacher is an important resource on the input side and this variable can be measured in many ways such as the number of teachers, the level of experience and the cost of salary. This study will utilise the number of teachers as one of the inputs. This variable was used in many studies that measure school performance (Färe et al., 1988; Lovell et al., 1994; Grosskopf and Moutray, 2001; Maragos and Despotis, 2003; Primont and Domazlicky, 2006; and Alexander et al., 2010). However, data on the number of teachers, although available, is not reliable due to the problem of double counting when calculating the number of teachers of a specific subject. This is because teachers normally teach more than one subjects. To overcome the problem, the number of classes of each mathematics and science subjects will be used as a proxy for the number of teachers. In Malaysia, each class is provided with 1.5 teachers. For example, if a particular school has four mathematics classes, then the school will get six mathematics teachers. This formula is the same for all subjects. Altogether in our study, the school performance is measured based on five subjects namely mathematics, science, physics, chemistry, and biology. These are main mathematics and science subjects in Malaysia.

Pupils' academic results before they enter the upper secondary level will be used as an indicator of their quality on entry. Examples of studies that utilised this variable as input are Bessent and Bessent (1980), Thanassoulis and Dunstan (1994), Portela and Camanho (2009), and Khalili et al. (2010). This variable will be used with the number of pupils with good grades in mathematics and science subjects in SPM examination, which is an indicator of their quality on exit, to measure the value added by schools. The number of pupils with good grades in mathematics and science subjects in PMR examination will be used for this purpose. PMR is taken by pupils at the end of form 3, just before they enter the upper secondary level.

Another variable that will be used as input in this study is the environmental factor in the form of pupils' socioeconomic status (SES). Ruggiero (1996, 1998, and 1999) stressed the importance of including these variables because it can substantially influence the level of output that schools obtain. It is more difficult to teach children with low SES background thus schools with this characteristic might routinely be classified as inefficient. This problem is addressed by the incorporation of environmental variables (Coates and Lamdin, 2002). In this study, the variable to measure pupils' SES is parents' income. Pupils with high parents' income are considered having high SES. Schools with high number of pupils from high SES have an advantage compared to those with many low SES pupils. Examples of studies that used input on parents' socioeconomic status or income are Bessent and Bessent (1980), Smith and Mayston (1987), Sengupta (1990), McCarty and Yaisawarng (1993), Chalos and Cherian (1995), Chalos (1997), and Soteriou et al. (1998).

3.4.2 Outputs

There are two main outputs in this study namely the total number of pupils and the number of pupils with good grade on exit. Although many studies used the total number of pupils as input to education (see Johnes, 2004), there are many cases where the number of pupils (or students/enrolment) is used as proxy for output (Ahn and Seiford, 1993; Avkiran, 2001; Abbott and Doucouliagos, 2003; Ouellette and Vierstraete, 2005, 2010; Millimet and Collier, 2008; Franta and Konečný, 2009). According to Ouellette and Vierstraete (2005, 2010), the total number of pupils must be considered as one of the outputs because schools help to socialise children. The number of teachers is provided based on the number of pupils for this purpose but this contribution has no value if only the number of pupils who passed certain criteria is taken as output. Thus, this study will utilise the number of pupils for each subject as outputs.

The number of pupils with good grade on exit is the most common form of output in school performance measurement (Nesbit and Palardy (2007). Most people use pupils' academic performance as a measure of schools' performance. It is also an important selection mechanism for further education (Hanushek, 1986). Examples of studies that utilised this variable are Bessent and Bessent (1980), Bessent et al. (1982), Färe et al. (1988), Ganley and Cubbin (1992), Chalos and Cherian (1995), Engert (1996), Kirjavainen and Loikkanent (1998), Mancebon and Molinero (2000), Ramanathan (2001), Kiong et al. (2003), Rassouli-Currier (2007), Nesbit and Palardy (2007), Kantabutra (2008), and Morgan (2010). In our study, the number of pupils with good grade (grades A and B) in the five mathematics and science subjects in SPM examination will be used as outputs. SPM is an examination at the end of the upper secondary school level. The next section presents the conceptual framework of this study.

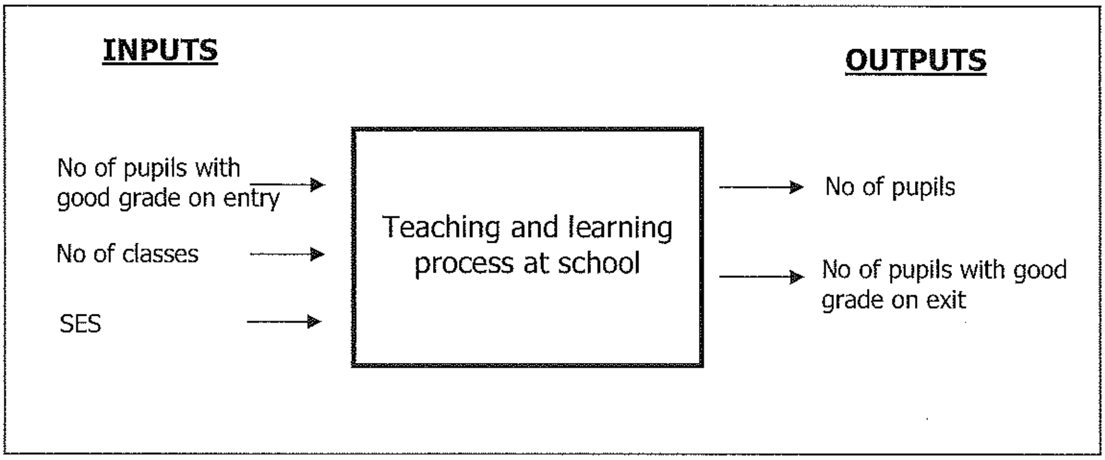
3.4.3 Conceptual Framework

Figure 3.2 presents the conceptual framework underlying the DEA models in this research. Inputs consist of the number of classes, the number of pupils with good grade on entry (grades A and B) and pupil's socio-economic status (SES). Classes in this study refer to the groups of pupils that learn the subjects. Outputs consist of the total number of pupils and the number of pupils with good grade on exit. The process of teaching and learning of mathematics and science utilises and produces these inputs and outputs respectively.

Every pupil is counted towards two outputs: total number of pupils and the number of pupils with good grade on exit. The former represents quantity and the latter quality of the output. On the quantity component, school with many pupils needs more classes and teachers. This can be a burden to the school and must be taken into account when measuring its performance. On the quality component, school that has many pupils with good grade on entry is having an advantage and must also be taken into account when measuring its performance.

A student who performs well, contributes to the efficiency of a school via both the quantity and quality output. The weight of such a student is therefore the sum of two weights attached to the two outputs. If a student is not performing well, they contribute to the efficiency of the school only via one weight attached to quantity. Therefore, a student with good exam results on exit has a higher total weight than a student with low achievement. This higher "value" of good students is achieved without any use of weight restrictions.

Figure 3.2: Conceptual Framework



On the input side, the number of pupils with good grades on entry is divided into two variables, one is for mathematics and the other is for science. The number of classes is divided into five variables, i.e. one for each subject (mathematics, science, physics, chemistry, and biology). Altogether, there will be eight inputs including the SES. On the output side, the total number of pupils and the number of pupils with good grade on exit will be divided into 5 variables each (mathematics, science, physics, chemistry, and biology) thus there will be ten outputs altogether.

Three different models will be developed based on the assumption of the CRS, VRS and HRS to measure overall performance of schools in mathematics and science subjects. All of them are output oriented models. The HRS model is the one that will be used to measure the school performance in mathematics and science, while CRS and VRS models are merely for comparison purpose. The inputs and outputs for all models are as shown in Table 3.1.

Table 3.1: Inputs and Outputs in All Models

INPUTS	OUTPUTS
Mathematics class Science class Physics class Biology class Chemistry class Good mathematics pupils on entry Good science pupils on entry Pupils from high SES group	Mathematics pupils Science pupils Physics pupils Biology pupils Chemistry pupils Good mathematics pupils on exit Good science pupils on exit Good physics pupils on exit Good biology pupils on exit Good chemistry pupils on exit

Some of the inputs are proportional to outputs but some are not. The number of classes is proportional to the number of pupils because classes are formed based on the number of pupils. Every class should have between 30 to 35 pupils. Therefore, an increase in the number of pupils should be followed by an increase in the number of classes proportionately. This means the number of classes and the number of pupils shows CRS relationship.

On the other hand, the number of pupils with good grade on entry is not proportional to the number of pupils with good grade on exit. Although the number of pupils with good grade on exit will be influenced by the number of pupils with good grade on entry, other factors in the teaching and learning process also contribute to pupils' achievement. Hence, an increase in the number of good pupils on entry does not necessarily lead to the same increase in the number of good pupils on exit. As a result, these inputs and outputs show VRS relationship. The number of pupils from high SES group is also not proportionately related to the number of good pupils on exit even though more pupils from high SES are getting good results on exit.

Although some of the inputs and outputs in this study are proportional while some are not, we still assume full proportionality to come up with the CRS model and no proportionality between the inputs and outputs to come up with the VRS model. For the HRS model, which is the main model in this study, we utilise the proportionality of inputs and outputs as explained above. Results from the CRS and VRS models in this study are used to compare with the results from the HRS model. This is to show that the HRS model is always better than the VRS model and in certain cases, is better than the CRS model. All models are shown in Appendix A3.1.

3.5 Population and sample

At first, this study intended to evaluate the performance of all secondary schools in Malaysia. However, the Ministry of Education Malaysia (MOEM) gave the permission to evaluate the performance of schools in three northern states of Malaysia only namely Kedah, Penang, and Perlis due to the difficulty for them to provide the data. Thus, the population for this study consists of all 303 secondary schools from the three states. Out of the 303 schools, only schools that meet the following criteria are selected as samples in this study. The criteria are

- Schools that have pupils taking PMR examination from 2003 - 2006
- Schools that have pupils taking SPM examination from 2005 - 2008

The PMR and SPM examinations results are used as measures of pupils' quality on entry and exit, respectively. The first cohort of pupils under the PPSMI policy took the SPM examination in 2007. The latest year that could be included in this study is 2008 when the second cohort of pupils under the new policy took the SPM examination. For ease of comparison, the two years data before the implementation of the policy are used with the two years data after the policy was implemented, i.e. from 2005 to 2008. Pupils who took the SPM examination in 2005, took the PMR in 2003 when they were in form 3. For those who took the SPM in 2008, they took their PMR in 2006. Therefore, only schools with pupils who took the PMR between 2003 and 2006, and who took SPM between 2005 and 2008 are selected as samples for this study. The performance of schools without these data cannot be calculated and have to be omitted from the sample.

Table 3.2 summarises the number of samples by school type, state and location. Out of 303 upper secondary schools in the three states in 2008, only 237 schools fulfilled the specified criteria. These schools are selected as samples for this study. Out of the 237 schools, 140 are from Kedah, 75 from Penang and 22 from Perlis. By school type, 222 are National, 5 Fully Residential and 10 Religious. In terms of location, 113 are urban schools and 124 are rural schools.

Table 3.2: Number of Samples by School-Types, States, and Locations

School Type	State	Urban	Rural	Total
National	Kedah	46	87	133
	Penang	53	17	70
	Perlis	6	13	19
	Total	105	117	222
Fully Residential	Kedah	1	2	3
	Penang	1	0	1
	Perlis	1	0	1
	Total	3	2	5
Religious	Kedah	1	3	4
	Penang	2	2	4
	Perlis	2	0	2
	Total	5	5	10

3.6 Data Collection

Data collection started with an application to conduct research in Malaysia to Economic Planning Unit (EPU), Prime Minister's Department Malaysia. This is the department that manages the application and gives permission to all researchers from outside Malaysia to conduct research in Malaysia. Permission to conduct the research was granted by EPU on April 2008. With the permission, data for this study were obtained from Malaysian Examination Syndicate (MES), Educational Planning and Research Division (EPRD) and School Division (SD).

Data on examination results for the selected schools are taken from MES, which is a division under the MOEM in charge of handling public national examinations in Malaysia. Two main examinations where the results are used in this study are Lower Secondary Assessment (PMR) and Malaysia Certificate of Examination (SPM). SPM is a major national examination at the end of form 5 and is equivalent to GCSE in England. PMR is a national examination at the end of form 3.

Data on the number of pupils and teachers are taken from EPRD, which is in charge of an application known as Education Management Information System (EMIS). EMIS is an official application under the MOEM collecting all information regarding schools, teachers and pupils in all government schools. Data in EMIS are updated thrice a year, i.e. 31 January, 30 June and 31 October. However, only data on 30 June is published in the ministry's official statistical book. In this study, data on the number of mathematics and science pupils as well as the number of mathematics and science teachers are as of 30 June of each year. Data on pupils' SES was taken from School Division.

3.7 Data Analysis

3.7.1 Calculation of Efficiency Scores and the Malmquist Index

The calculation of efficiency scores of each school is explained in Appendix A3.2. Since no DEA software is readily available to be used with the HRS model, a mathematical programming software known as LINGO is used to solve the model. LINGO allows us to build models that extract information directly from databases and spreadsheets. Similarly, LINGO can output solution information right into a database or spreadsheet.

Before LINGO was used to solve the HRS model, we first use LINGO to solve the CRS and VRS models. Results from LINGO for the VRS and CRS models were compared with the results from the DEA software such as Warwick DEA and DEA Solver to ensure accuracy and consistency of the LINGO programming that is developed for this study. After that, the programming was extended for the HRS model. Appendices A3.3, A3.4 and A3.5 show the LINGO programming for the HRS, VRS and CRS models respectively. LINGO was also used to calculate the efficiency under the C-HRS model. The efficiency scores from the HRS and C-HRS scores were then used to calculate the Malmquist index using the equation (3.17).

3.7.2 Infeasibility Problem in Calculating Malmquist Index

One crucial issue in calculating the Malmquist index is the problem of infeasibility. Infeasibility in such calculation may arise when attempting to express future production levels intertemporal as convex combinations of production sets drawn from a current period (Bjurek, 1996). Tone (2004) pointed out that the oriented VRS models suffer from the problem of infeasible solution in the super-efficiency (intertemporal) score estimation. Super-efficiency estimation refers to the estimation of efficiency across different periods of time. This is not a rare case, since the Malmquist model deals with data sets over time that display large variations in magnitude and hence the super-efficiency model suffers from many infeasible solutions.

Briec and Kerstens (2009) conclude that there is no easy solution in general apart from reporting any eventual infeasibility. In a many circumstances, the problem of infeasibilities cannot be avoided irrespective of the estimation method used for technology. Reporting the infeasibilities when computing productivity indices and indicators could then be one of the options. However, only a few empirical studies explicitly report the prevalence of infeasibilities in the Malmquist productivity index. Among them are Chitkara (1999) and Mukherjee et al. (2001).

If there are schools that suffer from infeasibility problem in this study, they will be excluded when analysing the implications of the PPSMI policy for the schools performance since both the efficiency score and the Malmquist index are needed to analyse the schools performance. The list of schools with feasibility problem will then be reported in Chapter 4.

3.7.3 Statistical Tests

As discussed in Chapter 2, four nonparametric statistical will be used to examine the difference in the performance of schools in different groups. The four tests are Mann-Whitney U Test, Kruskal-Wallis Test, Wilcoxon Signed Ranks Test, and Friedman's Two-

Way Analysis of Variance. This section will describe the implementation procedure of the four tests. All descriptions are drawn from Sheskin (2004).

The Mann-Whitney U Test is used to evaluate a hypothesis that two independent samples represent two populations with different median value. It is employed with ordinal data involving a design with two independent samples. The null hypothesis in this test is that the median of the population Group 1 represents equals the median of the population Group 2 represents. The alternative hypothesis is that the median of the population Group 1 represents does not equal the median of the population Group 2 represents. In this study, The Mann-Whitney U Test will be used to examine the difference in the performance of schools in two different locations, i.e. rural and urban. The assumption of this test is satisfied in this case because location data are of ordinal type and the scores from schools in different locations are independent from each other.

The Kruskal-Wallis Test is used to evaluate the hypothesis that in a set of two or more independent samples, at least two of the samples represent populations with different median values. It is employed with ordinal data involving a design with two or more independent samples. This test is an extension of the Mann-Whitney U Test. The null hypothesis is this test is that the median of the population each group represents are equal. The alternative hypothesis is that there is a difference between at least two of the population medians. In this study, the Kruskal-Wallis Test will be used to examine the difference in the performance of schools in different states and of different types. There are three states and three school-types in this study. The data are of ordinal type and the scores from schools in different states and school-types are independent from each other.

The Wilcoxon Signed Ranks Test is used to evaluate a hypothesis that two dependent samples represent two different populations. It is employed with ordinal data involving a design with two dependent samples. The null hypothesis in this test is that the median of differences between two different groups equals zero. The alternative hypothesis is that the median of differences between two different groups does not equal zero. This test will be used to examine the difference in the school performance when measured by using two different models (HRS and VRS, HRS and CRS). This test will also be used to evaluate the pairwise differences among the efficiency scores in different years. The data are of ordinal type but the scores from different models and from different years are dependent since they come from the same schools.

The Friedman's Two-Way Analysis of Variance is used to evaluate a hypothesis that in a set of two or more dependent samples, at least two of the samples represent populations with different median values. It is employed with ordinal data involving a design with two or more dependent samples. The null hypothesis in this test is that the median of the population each group represents are equal. The alternative hypothesis is that there is a difference between at least two of the population medians. This test is used to examine the difference in the school performance in different years and the difference in the Malmquist index across different periods. The data are of ordinal type but the scores across different years and periods are dependent since they come from the same schools.

The SPSS software will be used to compute all the tests at the 0.05 level of significance. If the level of significance is less than 0.05, the null hypothesis will be rejected and the alternative hypothesis will be accepted. For the Mann-Whitney and Wilcoxon Signed Ranks Test, the two groups being tested will be concluded as significantly different if the level of significance is less than 0.05. Otherwise, the null hypothesis will be accepted and the conclusion will be there is no significant difference between the two groups being tested. For the Kruskal-Wallis Test and Friedman's Two-Way Analysis of Variance, if the level of significance is less than 0.05, the conclusion will be there is a significant difference between at least two of the population medians. This will be followed by conducting pairwise comparison to find the difference between each group. The pairwise comparison for the Kruskal-Wallis Test is conducted using the Mann-Whitney U Test and for the Friedman's Two-Way Analysis of Variance, the pairwise comparison will be conducted using the Wilcoxon Signed Ranks Test. If none of the tests gives significant results, then the level of significance will be increased to 0.1.

3.8 Summary

This chapter described in detail the DEA methodology, especially the CRS, VRS and HRS models that will be used to assess the school efficiency in this study. This is followed by the introduction of the HRS-based Malmquist index as an extension to the Malmquist index described in Chapter 2. The HRS-based Malmquist index is developed to measure the change in school performance over time by utilising the HRS model efficiency scores. Then, a more specific model developed specifically to measure the Malaysian upper secondary school performance in mathematics and science subjects was described. The inputs and outputs chosen for the DEA models in this study were explained in detail.

The number of schools and the criteria for choosing them were also given in this chapter. Out of 303 schools in the population of this study, 237 were selected based the specified criteria. Then the procedure of data collection including the sources of data was described. Altogether, there were four sets of data from year 2005 to 2008.

Lastly in this chapter, the procedure of calculating the efficiency scores and analysing the data were described. The efficiency scores were calculated by using a programming software known as LINGO. Results from the programming were tested and compared with results from ready-made software such as Warwick DEA and DEA Solver to ensure that the programming is reliable and accurate. Then, the final section of this chapter explained the statistical procedure that was used to examine the difference in the performance of schools in different groups.

CHAPTER 4

EMPIRICAL ANALYSIS

4.1 Introduction

This chapter applies the methodology outlined in Chapter 3 to secondary schools in three northern States of Malaysia namely Kedah, Penang and Perlis. The schools comprise three different types namely the national, fully residential, and religious types. They are located in either urban or rural locations. A series of data from 2005 to 2008 are used in this study. The first cohort of pupils under the English in the Teaching of Mathematics and Science (PPSMI) policy took the Malaysian Certificate of Education (SPM) examination in 2007. The latest year that could be included in this study is 2008 when the second cohort of pupils under the new policy took the SPM examination. For ease of comparison, 2 years data before the implementation of the policy are used with the two years data after the policy was implemented.

The number of schools in the three states in 2008 was 303 but only 237 are selected for this study because they satisfied the data requirements (refer to Chapter 3 for a detailed description of the data). Of these schools, 16 caused the infeasibility problem when calculating the Malmquist index. The problem of infeasibility and the ways to deal with it were discussed in Chapter 3. Schools with an infeasibility problem are excluded from the analysis as both efficiency score and Malmquist index are needed to analyse the school's performance. The number of excluded schools is relatively small compared to the total number of schools in this study. The list of schools with the infeasibility problem is given in Appendix A4.2. The final number of schools assessed in this study is 221. The following table summarises the number of schools by state, type, and location.

Table 4.1: Number of Schools by School-Types, States, and Locations

State	School-type	Urban	Rural	Total
Kedah	National	43	79	122
	Fully Residential	1	2	3
	Religious	1	2	3
	Total	45	83	128
Penang	National	51	16	67
	Fully Residential	1	0	1
	Religious	2	1	3
	Total	54	18	71
Perlis	National	6	13	19
	Fully Residential	1	0	1
	Religious	2	0	2
	Total	9	13	22
National Total		100	108	208
Fully Residential Total		3	2	5
Religious Total		5	3	8
Grand Total		108	114	221

All 221 schools are used in the analysis of school performance by school-type. However, when analysing school performance by state and location, only the national school-type (208 altogether) is used. This is because pupils in the national school-type come from the nearby area but pupils in the fully residential and religious school-types are selected from all over the country and state. Therefore, location does not affect the performance of the fully residential and religious school-types. The performance is analysed in terms of the overall school performance, performance by school-type, performance by state and performance by location. In each category, the performance is analysed by means of the efficiency score, the Malmquist index and statistical tests. Although the policy is a national one, it is important to analyse the performance of schools in different groups (school-type, state and location) because each group contains pupils from different backgrounds. Thus, if the analysis shows that the performance is significantly different, we would be able to conclude that certain a group benefited or was adversely affected by the policy.

The efficiency score is used as a measure of school performance in one particular period. The efficiency score is calculated by using the Hybrid Returns to Scale (HRS) DEA model. The associated Variable Returns to Scale (VRS) and the Constant Returns to Scale (CRS) models are used as a comparison. Ten inputs and eight outputs are used in each model. The efficiency score is calculated for years from 2005 to 2008. The efficiency scores in 2005 and 2006 are the efficiencies when Bahasa Melayu is used in the process of teaching and learning mathematics and science subjects. On the other hand, the efficiency scores in 2007 and 2008 are the efficiencies when English is used in the teaching and learning process. A detailed description of the DEA models, inputs and outputs, and interpretation of the efficiency scores, was given in Chapters 2 and 3.

In calculating the performance of a particular school, the pupils in that school are assumed to be the same between entry and exit year. For example, if one pupil enters the school in 2006, he or she is assumed to be there until exit year in 2008. Although there was some dropout, the figure was small and considered as insignificant. Furthermore, this scenario happens almost equally in all schools and therefore is ignored in this study.

The Malmquist index is used to measure the change in performance over time and the methodology has been explained in detail in Chapter 3. It consists of an efficiency change and a technical change. The efficiency change can be further decomposed into a pure technical efficiency change and a scale efficiency change. In this study, the Malmquist index is calculated based on the efficiency scores from the HRS model. If the value of the Malmquist index and any of its components is more than 1, this denotes a progress in the performance, while values less than 1 denote deterioration in the performance. The Malmquist index equal to 1 means the performance has not changed.

In this chapter, the Malmquist index is used to calculate the changes in performance over time based on year on year productivity changes. The Malmquist index is used to calculate the productivity changes in three different periods namely 2005-2006, 2006-2007, and 2007-2008. The first period (2005-2006) represents the time before the implementation of the policy. The second period (2006-2007), represents the time before and after the implementation of the policy. The third period (2007-2008) represents the time after the implementation of the policy.

Statistical tests are used to look for significant differences in the performance of schools in different categories and in the change in performance over time (before and after the implementation of the policy). The statistical tests used in this chapter were described in Chapter 2 and described in Chapter 3. This chapter will focus only on presenting the results. A more detailed discussion of the results, especially regarding the implications of the policy for school performance will be presented in Chapter 6.

4.2 Comparison of the HRS, VRS and CRS models

The efficiency scores generated from the three models in each year (2005 to 2008) are given in Appendix A4.1. Most of the efficiency scores under the HRS model are lower than the scores under the VRS model and the CRS model although some scores are the same. None of the scores under the VRS model is lower than under the HRS model while a few scores under the CRS model are lower than under the HRS model. Table 4.2 shows the descriptive statistics of the efficiency scores of different models from 2005 to 2008. In each year, the HRS model has the lowest minimum and means score followed by the CRS model and the VRS model. In general, the HRS model is more discriminating than the CRS and VRS models. This result is in line with Podinovski (2004). A statistical test is conducted to determine whether the difference in the efficiency scores is significant in the statistical sense.

The efficiency scores from the HRS model are tested for significant difference from the CRS and VRS models by using the Wilcoxon Signed Ranks Test. The null hypothesis is the median of differences between the efficiency score distributions equal 0. The alternative hypothesis is the median of differences between the efficiency score distributions does not equal 0. The test results are given in Appendix A4.3. It shows that all differences are significant beyond the 0.05 level. Hence, the null hypothesis (of each test) is rejected and the alternative hypothesis that there is a significant difference in the median of differences between the efficiency scores under the HRS and VRS (or CRS) models is accepted. Since the mean efficiency scores of the HRS model is lower than the CRS and VRS models, it can be concluded statistically that the HRS model is significantly more discriminating than the VRS and CRS models. The above tests have shown that the HRS model developed in this study resulted in a better estimate of the school efficiencies.

Table 4.2: Descriptive Statistics of Efficiency Scores of Different DEA Models

Year	Model	N	Minimum	Maximum	Mean
2005	HRS	221	.59	1.00	.9016
	VRS	221	.62	1.00	.9475
	CRS	221	.62	1.00	.9345
2006	HRS	221	.50	1.00	.9134
	VRS	221	.64	1.00	.9551
	CRS	221	.53	1.00	.9352
2007	HRS	221	.57	1.00	.9105
	VRS	221	.61	1.00	.9570
	CRS	221	.61	1.00	.9399
2008	HRS	221	.58	1.00	.8929
	VRS	221	.60	1.00	.9527
	CRS	221	.60	1.00	.9392

In the next sections, the efficiency score and the Malmquist index of schools from the HRS models are analysed by four different categories, namely the overall, type, state, and location. The efficiency scores and the Malmquist indices of schools in different categories are tested for significant differences. A significant difference in the efficiency scores represents a significant difference in school performance in one particular year and a significant difference in the Malmquist indices represents a significant difference in the change in performance over time.

Box-plots are used to show the distributions of efficiency scores and the Malmquist indices. With box-plots, it is easier to observe the spread and the difference in the distributions. Box-plots show the median, upper and lower quartiles as well as minimum and maximum data values. Box-plots also give some indication of the data's symmetry and skewness.

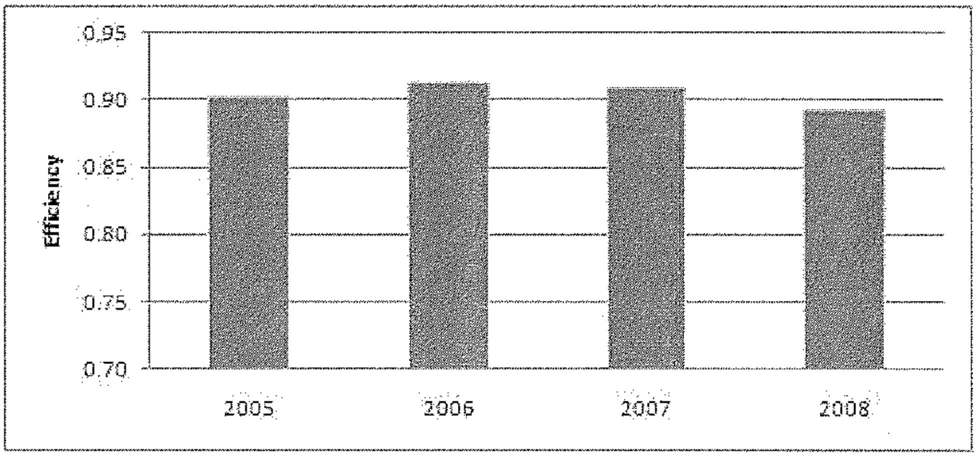
4.3 Overall School Performance in Mathematics and Science Subjects

4.3.1 Analysis of Efficiency Scores for Overall School Performance

The average efficiency scores in each year are used to assess the overall school performance. Figure 4.1 shows the average efficiency scores from 2005 to 2008. The highest average efficiency score was recorded in 2006, just before the implementation of the policy but started to drop after the policy was implemented in 2007. It indicates that in 2008 the gap in performance of the most and the least efficient schools has increased.

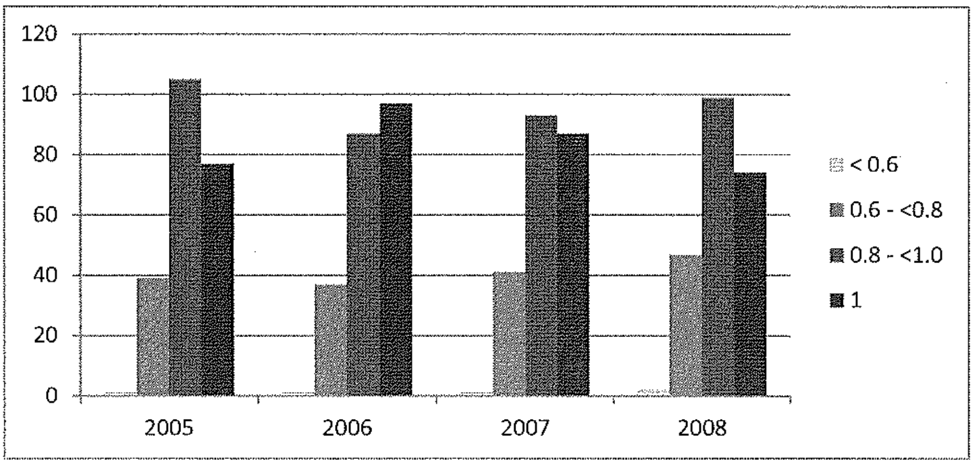
To get a clearer picture of the trend in efficiency scores, they were grouped into four different categories i.e. fully efficient (efficiency = 1.0), $0.8 \leq$ efficiency < 1.0, $0.6 \leq$ efficiency < 0.8, and efficiency < 0.6). Figure 4.2 shows the number of schools by the four efficiency categories. Before the implementation of the policy, the number of fully efficient schools was on the rise and the number of schools in the second and third categories (efficiency between 0.6 and 0.99) was decreasing. The trend was reversed when the policy was implemented in 2007 where the number of fully efficient schools started to decrease and the number of schools in the other groups started to increase. The number of schools with an efficiency of less than 0.6 also increased. This situation demonstrates that the distance between schools and the new efficient boundary after the policy was implemented increased and hence the average efficiency is lower as shown in Figure 4.1.

Figure 4.1: Average Efficiency Scores



The increase in the distance between schools and the new efficient boundary could be the result of an upward shift in the efficient boundary or a decrease in school efficiency. If the new boundary had shifted upward, it would indicate that the performance of schools that formed the boundary had increased while a lower average efficiency score would show that the performance of the inefficient schools had not increased as much as the fully efficient schools and hence become less efficient with regard to the new efficient boundary. This situation will be analysed further in section 4.3.3 using the Malmquist index. Statistical tests are conducted to determine whether the differences in the efficiency scores in different years are significant in the statistical sense. The results of the tests are discussed in the next section.

Figure 4.2: Number of Schools by Efficiency Categories

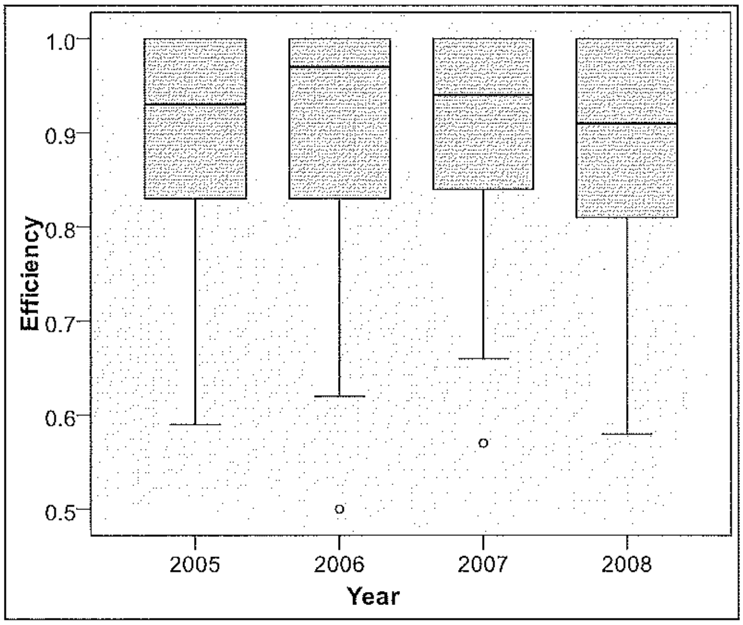


4.3.2 Statistical Test for the Difference in Efficiency Scores Over Time

The distributions of the efficiency scores in each year are shown in Figure 4.3. Friedman's Two-Way Analysis of Variance by Ranks is used to test for significant differences between them. The null hypothesis is that the distributions of efficiency scores in 2005, 2006, 2007, and 2008 are the same and the alternative hypothesis is that there is a significant difference between them.

The test result as given in Appendix A4.4(1) shows that there was a significant difference beyond the 0.05 level in the distributions of the efficiency scores in different years. Thus, the null hypothesis is rejected. Then, Wilcoxon Signed Ranks Tests are conducted to evaluate the pairwise differences among the efficiency scores in different years. The following pairs of years are used: 2005/2006, 2005/2007, 2005/2008, 2006/2007, 2006/2008, and 2007/2008. The results as given in Appendix A4.4(2) show that only two pairs were significantly different beyond the 0.05 level. The two pairs are 2006/2008 and 2007/2008. Since the median efficiency score in 2008 was lower than the median efficiency scores in 2006 and 2007, it can be concluded that the schools efficiency in 2008 was significantly lower than their efficiencies in 2006 and 2007. Even though the efficiency in 2008 was the lowest, it might be due to a higher efficient boundary and not a decrease in school efficiency itself. This will be analysed in the next section by using the Malmquist index.

Figure 4.3: Distributions of Efficiency Scores



4.3.3 Analysis of the Malmquist Index for Overall School Performance

The change in performance over time is measured by the Malmquist index. The average Malmquist index and its decompositions are presented in Table 4.3. On average, the Malmquist index increased by 1.79 percent. The increase is contributed by the large increase in the third period (2007-2008) with an increment of 6.37 percent. The value of the Malmquist index attributed mostly to the technical change where it had changed from a decrease of 3.13 percent in the first period (2005-2006) to an increase of 6.97 percent in the third period. The efficiency change was on a downward slide over the period of the study with a change from an increase by 1.92 percent in the first period to a decrease by 0.57 percent in the third period. This is due to the decrease in the scale efficiency change by 1.13 percent. The pure technical efficiency change on the other hand increased by 1.21 percent over the period of the study.

Table 4.3: Malmquist Index and its Decomposition

	2005-2006	2006-2007	2007-2008	Average
Pure Technical Efficiency Change (1)	1.0190	1.0116	1.0057	1.0121
Scale Efficiency Change (2)	1.0002	0.9982	0.9887	0.9957
Efficiency Change (3) = (1)x(2)	1.0192	1.0097	0.9943	1.0078
Technical change (4)	0.9687	0.9916	1.0697	1.0100
Malmquist Index (5) = (3)x(4)	0.9873	1.0013	1.0637	1.0179

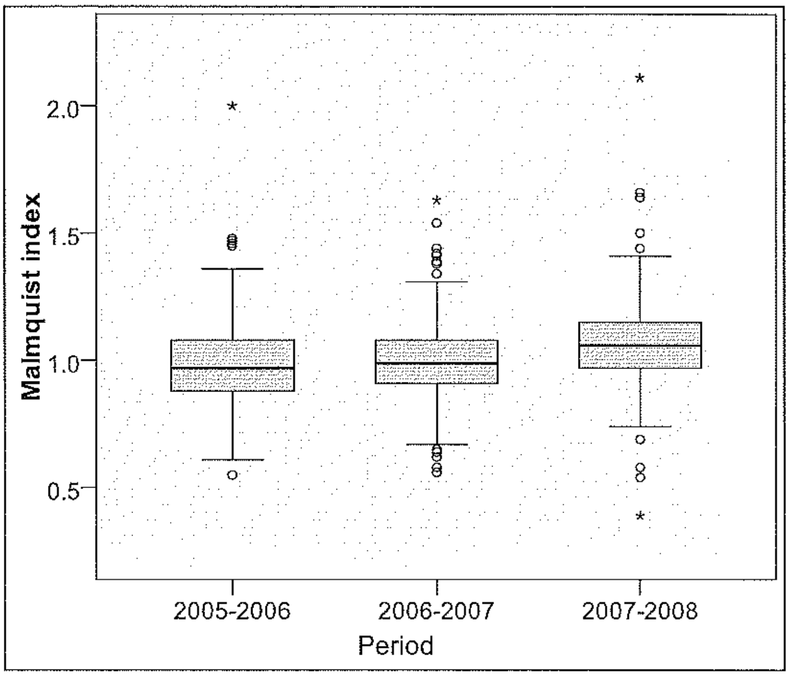
Although the mean efficiency score for 2008 was the lowest among the four years being studied as shown in Figure 4.1, the schools performance in 2008 actually increased when compared to their performance in 2007. The large increase in the technical change shows that the overall school performance increased considerably and the new efficient boundary is much higher than in 2007.

A lower average efficiency score in 2008 is reflected in the decrease of the efficiency change component, which shows that the performance of the inefficient schools regressed, stagnated, or did not progress as much as the fully efficient schools. This situation leads to a bigger gap between the performance of fully efficient schools and inefficient schools and lower mean efficiency scores. In general, it can be concluded that the overall school performance progressed in the third period, but the difference in the performances of fully efficient schools and inefficient schools grew bigger. The progress is tested for statistical significance and the results are given in the next section.

4.3.4 Statistical Test for the Difference in the Malmquist Index

The distributions of the Malmquist index in different periods are tested for significant difference. Figure 4.4 shows the distribution of the Malmquist index in the three different periods. Friedman's Two-Way Analysis of Variance by Ranks is used to test for significant difference across different periods. If there is significant difference, Wilcoxon Signed Ranks Test will be conducted to examine the pairwise differences between different periods. The null hypothesis is that the distributions of the Malmquist index in the three periods (2005-2006, 2006-2007, and 2007-2008) are the same. The alternative hypothesis is that the distributions of the Malmquist index in the three periods are not the same. The tests results are given in Appendix A4.4(3). The test shows that the distributions of the Malmquist index in the three periods were significantly different beyond the 0.05 level.

Figure 4.4: Distributions of Malmquist Indices



Post hoc tests are conducted to examine the pairwise differences between the Malmquist indices of national schools in different periods by using the Wilcoxon Signed Ranks Test. The null hypothesis is the median of differences between the distributions of the Malmquist indices in the first and second periods equals 0 (and two similar tests for the first and third periods and the second and third periods). The alternative hypothesis is that the median of differences between the distributions of the Malmquist indices in the first and second periods does not equal 0. The results of the tests in Appendix A4.4(4) show that there are significant differences between the first and third periods, as well as the second and third periods. Based on the median of the

Malmquist indices distributions (Figure 4.3), the performance in the third period has increased significantly as compared to the second and first periods. In the previous section, it was concluded that the overall school performance progressed in the third period. This section confirms that the progress was statistically significant.

4.3.5 Summary of Overall School Performance in Mathematics and Science Subjects

The average efficiency score in 2008, i.e. two years after the implementation of the policy, shows that variation in school performance was significantly bigger than in the years before that. This resulted from the decrease in the number of fully efficient schools and the increase in the number of inefficient schools. This indicates that on average, the distance between schools and the efficient boundary was greater, which means more schools were less efficient when compared to the fully efficient ones.

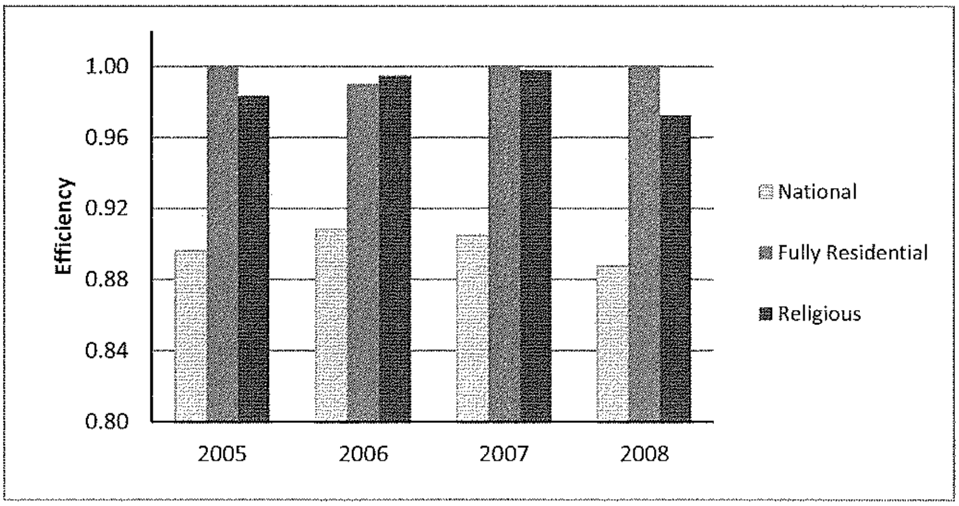
Analysis by using the Malmquist index shows that the lower average efficiency in 2008 was due to the higher efficient boundary, which was caused by the increase in the performance of fully efficient schools. On the other hand, the inefficient schools have not progressed as much as the fully efficient schools, thus creating a bigger gap between them and resulting in the lower average efficiency score in 2008. These circumstances show that the PPSMI policy might have benefited some schools (the fully efficient schools) but might have adversely affected the performance of other schools (the inefficient schools). The question is why the performance had not change significantly in 2007 as compared to the change in performance in 2008. This question and other factors related to the change in performance in 2008 will be discussed in more detail in Chapter 6. The next sections will analyse whether the policy may have benefited or adversely affected the performance of certain types of school or schools in certain locations only.

4.4 Performance in Mathematics and Science Subjects by School-Types

4.4.1 Analysis of Efficiency Scores by School-Types

The fully residential school-type is expected to be the best performer since its pupils were selected among the best pupils from all over the country. Pupils in the religious school-type are also able pupils who were selected from the all over the state. However, the requirements to attend the religious school-type are not as high as to attend the fully residential school-type. Logically, the fully residential school-type would be the best performer followed by the religious school-type and the national school-type.

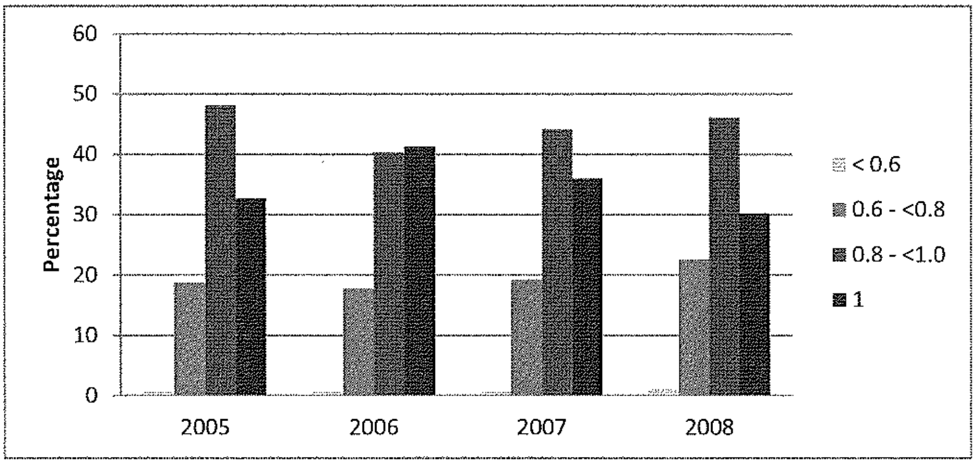
Figure 4.5: Average Efficiency Scores by School-Types



The efficiency scores confirm that the fully residential type is the most efficient among the three school-types followed by the religious and national school-types. Figure 4.5 shows the average efficiency scores by school-type from 2005 to 2008. The average efficiency scores of the religious and national school-types had increased in 2006. When the policy was implemented in 2007, their average efficiencies did not change much but in 2008, their efficiencies started to decrease considerably. The fully residential school-type remains fully efficient throughout the study except in 2006 where the average efficiency was slightly below 1. The gap between the average efficiency of the fully residential school-type and the other school-types has widened after the implementation of the policy.

Figure 4.6 shows the percentage of the national school-type by the four efficiency categories from 2005 to 2008. The percentage of the national school-type was the highest in the second category (efficiency between 0.8 – 0.99) throughout the study period except in 2006. Before the policy was implemented, the percentage of fully efficient schools was increasing while for other categories, the percentages were decreasing. It was the other way round after the policy was implemented: the percentage of fully efficient schools started to decrease and the percentages for other categories started to increase. This indicates that there was a bigger gap in the efficiency of the fully efficient and the inefficient national school after the PPSMI policy was implemented.

Figure 4.6: Percentage of National Schools by Efficiency Categories



The fully residential school-type on the other hand was fully efficient in each year except in 2006 where one of the schools recorded an efficiency score of less than 1 (Figure 4.7). The efficiency of the inefficient school was actually almost equal to 1. It seems that the efficiency of the fully residential school-type was not affected by the policy since all fully residential schools in this study remained fully efficient after the implementation of the policy.

Figure 4.7: Percentage of Fully Residential Schools by Efficiency Categories

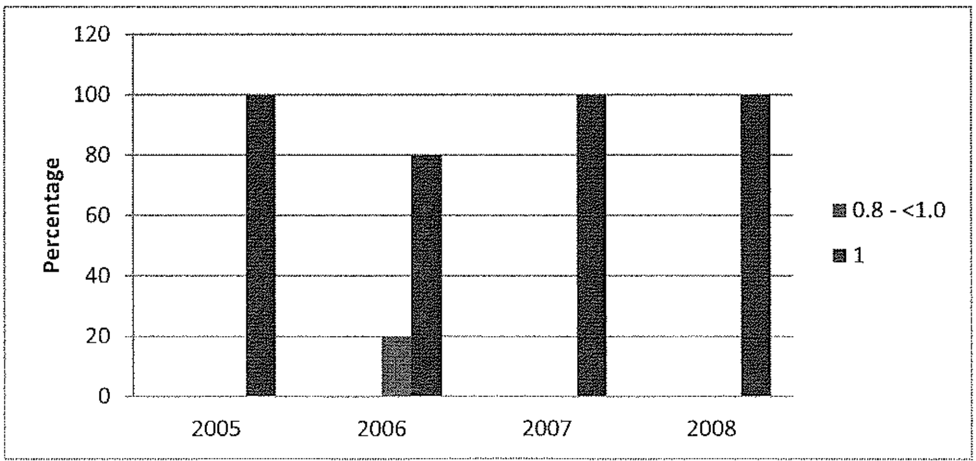
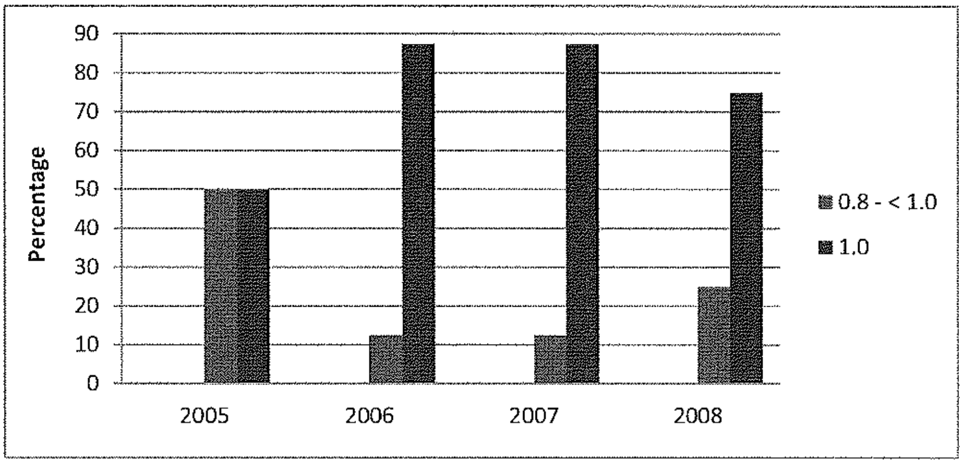


Figure 4.8 shows the percentage of the religious school-type by the efficiency category. All religious schools were in the top two categories. The percentage of the fully efficient religious school-type increased in 2006 and remained the same in 2007 when the policy was implemented. However, the percentage dropped slightly in 2008.

Figure 4.8: Percentage of Religious Schools by Efficiency Categories



Among the three school-types, the national school-type has shown a lower efficiency immediately after the implementation of the policy. The efficiency of the religious school-type was almost the same in the first year of the policy implementation but it was lower in the second year. The fully residential school-type remained fully efficient after the policy was implemented. The efficiencies are tested for significant difference and the results are given in the next section. Analysis by the Malmquist index in section 4.4.3 will show whether the performance of each school-type has progressed, regressed, or remained the same since the implementation of the policy.

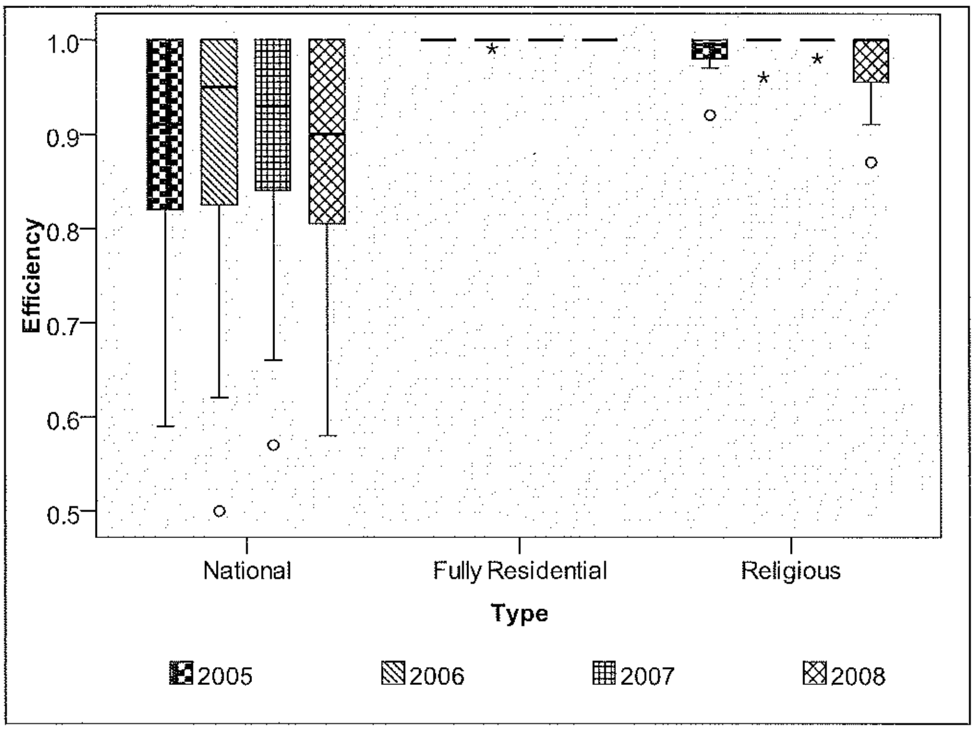
4.4.2 Statistical Test for the Difference in Efficiency Scores of Different School-Types

Statistical tests are conducted to test for significant difference in the efficiency of different school-types. The differences are tested in two ways, i.e. the difference in the efficiency of different school-types in each year and the difference in the efficiency of each school-type in different years. A significant difference in the efficiency can be concluded if there is a significant difference in the distribution of efficiency scores of different school-type. A significant difference in the schools efficiency after the implementation of the policy shows that they might have been affected by the policy.

Figure 4.9 shows the box-plots of the distributions of efficiency scores by school-type from 2005 to 2008. A Kruskal-Wallis Test is used to examine the differences in the distributions of the efficiency scores of different school-types. The null hypothesis is that the distribution of the efficiency scores in 2005 is the same across the national, fully residential and religious school-types (and 3 similar tests for 2006, 2007, and 2008). The alternative hypothesis is that the distribution of the efficiency scores is different across the national, fully residential and religious school-types.

The results of the Kruskal-Wallis tests are given in Appendix A4.5(1). The tests show that throughout the study period, the distribution of the efficiency scores was significantly different beyond the 0.05 level across the national, fully residential and religious school-types. Based on the median, the school-type with the highest efficiency was the fully residential followed by the religious and national school-types. This result is already expected due to the quality of pupils attending each type of school.

Figure 4.9: Distribution of Efficiency Scores by School-Types and Year



Post hoc tests are conducted to evaluate pairwise differences among the three school-types. The Mann Whitney U Test is used to examine the differences in the distributions of the efficiency scores between the national and fully residential school-types, the national and religious school-types, and the fully residential and religious school-types. The tests results are given in Appendix A4.5(2). The results indicate a significant difference beyond the 0.05 level between the fully residential and national school-types in all four years. The difference was more significant in 2008 (p=0.008). Tests on the national and religious school-types reveal that there were significant differences beyond the 0.05 level between their distributions of efficiency scores throughout the study period.

The distributions of efficiency scores of the fully residential and religious school-types on the other hand, had no significant difference beyond the 0.05 level throughout the study period. These tests confirm that the efficiency of the fully residential and religious school-types was significantly higher than the efficiency of the national school-type throughout the study period. The difference in the efficiency of the fully residential and national school-types was more significant in 2008, 2 years after the implementation of the policy, due to the lower efficiency of the national school-type. For the fully residential and religious school-types, there was no significant difference between their efficiencies throughout the study period (before and after the implementation of the policy) even though the efficiency of the fully residential school-type was higher than the religious school-type.

To test for significant difference in the efficiency of each school-type in different years, Friedman's Two-Way Analysis of Variance by Ranks is used. The null hypothesis is that the distributions of efficiency scores of the national school-type in 2005, 2006, 2007, and 2008 are the same (and two similar tests for the fully residential and religious school-type). The alternative hypothesis is that the distributions of efficiency scores are not the same. If there is significant difference in the distributions of the efficiency scores, a Wilcoxon Signed Ranks Test will be conducted to find the pairwise differences between different years.

The results of the tests are given in Appendix A4.5(3). For the national school-type, there was a significant difference beyond the 0.05 level in the distributions of the efficiency scores in different years. There were no significant differences in the distributions of the efficiency scores in different years for the fully residential and religious school-types. Thus, a Wilcoxon Signed Ranks test is conducted to examine the pairwise differences in the distributions of the efficiency scores of the national school-type in different years. The null hypothesis is that the median of differences between the efficiency distributions in 2005 and 2006 equals 0 (and 5 similar tests between 2005-2007, 2005-2008, 2006-2007, 2006-2008, and 2007-2008). The alternative hypothesis is that the median of differences between the efficiency distributions does not equal 0. The tests results in Appendix A4.5(4) show that the efficiency scores of the national school-type in 2008 were significantly different beyond the 0.05 level from its efficiency scores in 2007 and 2006. Based on the median, we can conclude that the efficiency of the national school-type in 2008 was significantly lower than its efficiencies in 2007 and 2006. There was no significant difference in the efficiency scores of the fully residential and religious school-types in any of the tests.

These tests confirm that the efficiency of the national school-type in 2008 was significantly lower than that of the other school-types and of its own efficiencies in the previous years. As discussed in section 4.3.2, the lower efficiency in 2008 might be the result of a higher efficiency boundary and not a decrease in school performance. This will be analysed by the Malmquist index in the next section.

4.4.3 Analysis of the Malmquist Index by School-Types

The Malmquist index of schools by type and its decomposition from 2006 and 2008 is shown in Table 4.4. The analysis is based on the year on year productivity changes. Throughout the study period, the Malmquist indices of the national and religious school-types were increasing whereas for the fully residential school-type it was decreasing. On average, the Malmquist index of the national school-type increased by 1.92 percent while for the religious school-type it increased by 3.06 percent. For the fully residential schools, on average it decreased by 4.06 percent. The change in the Malmquist index of each school-type is attributed mostly to the change in the technical change.

Before the implementation of the policy, the Malmquist indices of all school-types indicated a regression in performance. In the second period (performance in 2007 compared to performance in 2006), the national school-type showed some progress but the fully residential and religious school-types still indicated regression in performance. In the third period (performance in 2008 compared to performance in 2007), the national school-type continued to have a progression in performance while the performance of the religious school-type started to progress substantially but the performance of the fully residential schools continued to regress.

The Malmquist index for the national school-type changed from a regression of 1.33 percent in 2006 to a progress of 6.57 percent in 2008. The change in the Malmquist index is attributed mostly to technical change where it had regressed by 3.19 percent in 2006 but progressed by 7.04 percent in 2008. The efficiency change was decreasing: in 2006 it progressed by 2.03 percent whereas in 2008 it regressed by 0.44 percent. The progress in 2006 is attributed to the pure technical efficiency change but the regression in 2008 is attributed to the scale efficiency change.

Table 4.4: Malmquist Index by School-Types

School-type	Year	Pure Technical Efficiency Change (1)	Scale Efficiency Change (2)	Efficiency Change (3) = (1) x (2)	Technical change (4)	Malmquist Index (5) = (3) x (4)
National	2006	1.0203	1.0000	1.0203	0.9681	0.9877
	2007	1.0123	0.9980	1.0103	0.9926	1.0028
	2008	1.0077	0.9880	0.9956	1.0704	1.0657
	Average	1.0134	0.9953	1.0087	1.0104	1.0192
Fully Residential	2006	0.9981	0.9997	0.9978	0.9592	0.9571
	2007	1.0020	1.0000	1.0020	0.9776	0.9796
	2008	1.0003	1.0000	1.0003	0.9412	0.9415
	Average	1.0001	0.9999	1.0000	0.9594	0.9594
Religious	2006	1.0092	1.0050	1.0143	0.9915	1.0056
	2007	1.0077	1.0007	1.0083	0.9835	0.9917
	2008	0.9729	0.9992	0.9721	1.1223	1.0910
	Average	0.9966	1.0016	0.9982	1.0324	1.0306

The performance of the religious school-type did not change much in 2006 and 2007 where it progressed by only 0.56 percent in 2006 and regressed by only 0.83 percent in 2007. However, in 2008 its performance progressed by 9.10 percent. The sudden progress in the performance of the religious school-type is also attributed to the drastic upward shift in the efficient boundary. Similar to the trend of the national school-type, the efficiency change was on a downward trend: in 2006 it progressed by 1.43 percent whereas in 2008 it regressed by 2.79 percent. The regression in the efficiency change is attributed to the regression in the pure technical efficiency score. The trend for the fully residential school-type was completely different from the other school-types. The performance regressed throughout the whole period of the study. The regression is attributed mostly to the technical change since the pure technical efficiency change and the scale efficiency change were very close to 1 in all periods and therefore had no effect on the Malmquist index.

In general, the Malmquist index in the third period indicates that the performances of the national and religious school-types progressed and the performance of the fully residential school-type regressed. This is attributed mostly to the shift in the efficiency boundary where the efficient boundary of the national and religious school-types shifted upward and the efficiency boundary of the fully residential school-type shifted downward. Although as shown in section 4.4.1 and 4.4.2, the efficiency of the fully residential school-type was better than the other school-types, the Malmquist index shows that the performance of the fully efficient national and religious school-types increased while the performance of the fully efficient fully residential school-type decreased. This could be associated with the increase in the efficient boundary of the national and religious school-types and the decrease in the efficient boundary of the fully residential school-type. A more detailed discussion on the performance on each school-type will be given in Chapter 5.

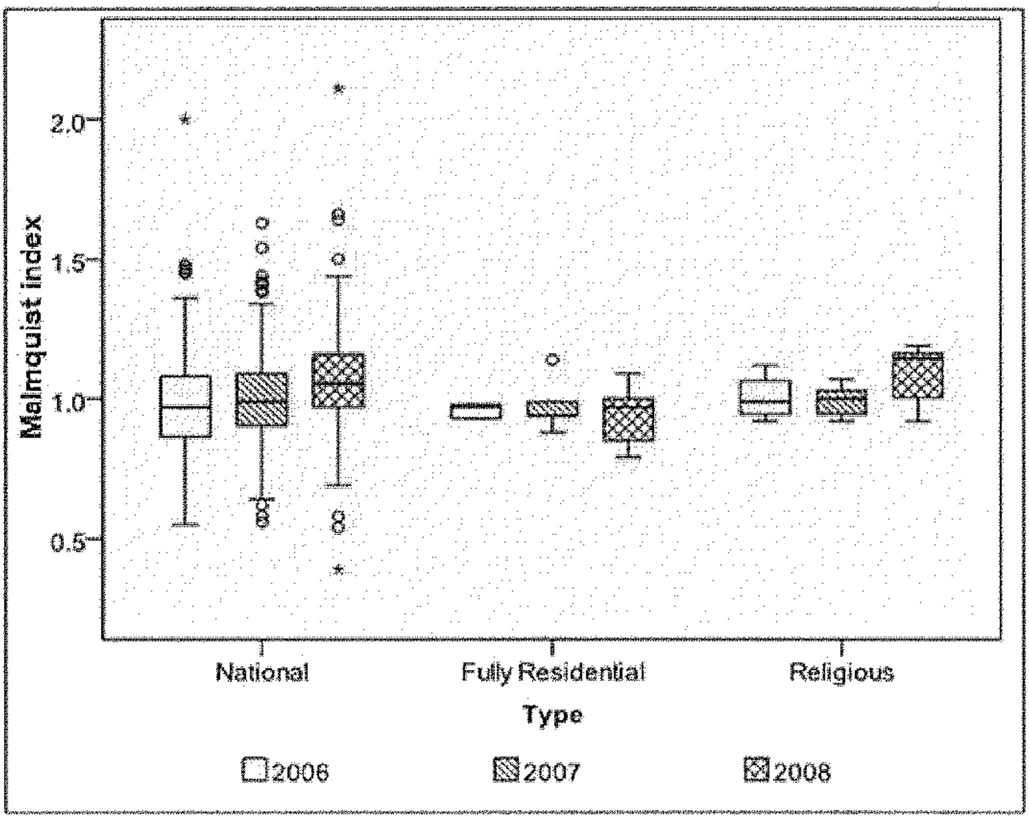
Section 4.4.2 has shown that the efficiency of the national school-type in 2008 was significantly lower than the efficiency of other types of schools and also lower than its own efficiencies in 2007 and 2006. This is caused by the increase in the efficiency of fully efficient schools, which shifted the efficiency boundary upward. On the other hand, the efficiency of the inefficient schools had decreased with regard to the new efficiency boundary. This created a bigger gap between the efficient and inefficient schools. It is interesting to know why there were drastic efficiency changes of the national and religious school-types in 2008, i.e. two years after the full implementation of the policy, and why there was a big shift in the efficiency boundary. This will be discussed in more detailed in Chapter 6. In the next section, statistical tests are conducted to examine any significant difference in the change in performance across school-types and over time.

4.4.4 Statistical Test for the Difference in the Malmquist Index of Different School-Types

The distributions of the Malmquist index of each school-type are tested for significant difference to see whether the Malmquist indices of each school-type are significantly different from each other and over time. Figure 4.10 shows the distribution of the Malmquist indices by school-type in three different periods. Friedman's Two-Way Analysis of Variance by Ranks is used to test for significant difference over time while the Kruskal-Wallis Test is used to examine the significant difference in the Malmquist indices of different school-types. If there is a significant difference over time, a Wilcoxon Signed Ranks Test will be conducted to examine the pairwise differences between different periods. A Mann-Whitney Test will be conducted to examine the pairwise differences between different types of schools.

For Friedman's Two-Way Analysis of Variance by Ranks, the null hypothesis is that the distributions of the Malmquist index of the national school-type in the three periods (2005-2006, 2006-2007, and 2007-2008) are the same (and two more similar tests for the fully residential and the religious schools). The alternative hypothesis is that the distributions of the Malmquist index of the national schools in the three periods are not the same. The tests results are given in Appendix A4.5(5). The test shows that the distributions of the Malmquist indices of the national school-type in the three periods were significantly different beyond the 0.05 level. For the fully residential and religious school-types, there was no significant difference in the distributions of their Malmquist index in the three periods.

Figure 4.10: Distributions of Malmquist Indices by School-Types



Post hoc tests are conducted to examine the pairwise differences between the Malmquist indices of national schools in different periods by using the Wilcoxon Signed Ranks Test. The null hypothesis is that the median of differences between the distributions of the Malmquist indices in the first and second periods equals 0 (and two similar tests for the first and third periods and the second and third periods). The alternative hypothesis is that the median of differences between the distributions of the Malmquist index in the first and second periods does not equal 0. The results of the tests in Appendix A4.5(6) show that there were significant differences between the first and third periods, as well as between the second and third period. Based on the median of the Malmquist index distributions (Figure 4.10), the performance of the national school-type increased significantly in the third period as compared to the first and second periods.

Secondly, the Malmquist index distributions of different school-types are tested for significant difference from each other in the three periods of study by using a Kruskal-Wallis test. The null hypothesis is that the distribution of the Malmquist index in the 2005-2006 period is the same across the national, fully residential, and religious school-types (and two similar tests for 2006-2007 and 2007-2008 periods). The alternative hypothesis is that the distribution of the Malmquist index is not the same across the national, fully residential, and religious school-types. The results of the tests are given in Appendix A4.5(7). The tests show that the differences in the distributions of the Malmquist index of different school-types were not significant in all periods of the study. It is clear from Figure 4.10 that in 2008, the Malmquist index of the religious school-type is higher than the Malmquist index of the fully residential school-type. However, the difference cannot be shown to be statistically significant because the numbers of the fully residential and religious school-types in this study are too small (5 and 8 respectively). Krejcie and Morgan (1970) and Roscoe (1975) state that the use of statistical analyses with samples less than 10 is not recommended. Gay and Diehl (1992) recommended at least 30 subjects per group for experimental research. Nevertheless, those schools are the only schools available for this study and there was no choice but to proceed with what was available for this study. These tests confirm the finding in section 4.4.3 that the performance of the national school-type in the third period (2007-2008) was significantly higher than its performance in the other two periods.

4.4.5 Summary of Performance in Mathematics and Science Subjects by School-Types

The average efficiency scores show that the efficiency of the national school-type is significantly lower than the efficiencies of the fully residential and religious school-types throughout the study period. The difference is more significant after the implementation of the policy. The efficiency of the national school-type in 2008 was also significantly lower than its efficiencies in 2007 and 2006. For the fully residential and religious school-types, there is no significant difference between their efficiencies or in their efficiencies before and after the implementation of the policy.

The Malmquist index shows that the performances of the national and religious school-types have progressed significantly but the performance of the fully residential school-type has regressed in the second year of the implementation of the policy. The change in performance is attributed mostly to the technical change. The insignificant difference between the Malmquist indices of different school-types might be due to the small number of the fully residential and religious school-types in this study even though the Malmquist index of the fully residential school-type is apparently lower than the Malmquist indices of the national and religious school-types.

Surprisingly, the findings in this section indicate that the fully residential school-type was adversely affected by the policy. Although the efficiency scores of the fully residential school-type were the highest throughout the study period, the Malmquist index shows that its performance regressed. For the national school-type, the lower average efficiency score after the implementation of the policy indicates a bigger gap between the performance of fully efficient and inefficient national schools. It shows that some national schools might have benefited much from the policy while others might have not benefited as much or might have been adversely affected by it. In the next two sections, the performance of the national school-type will be analysed in terms of state and location to see whether schools in certain states and locations benefited or were negatively affected by the policy.

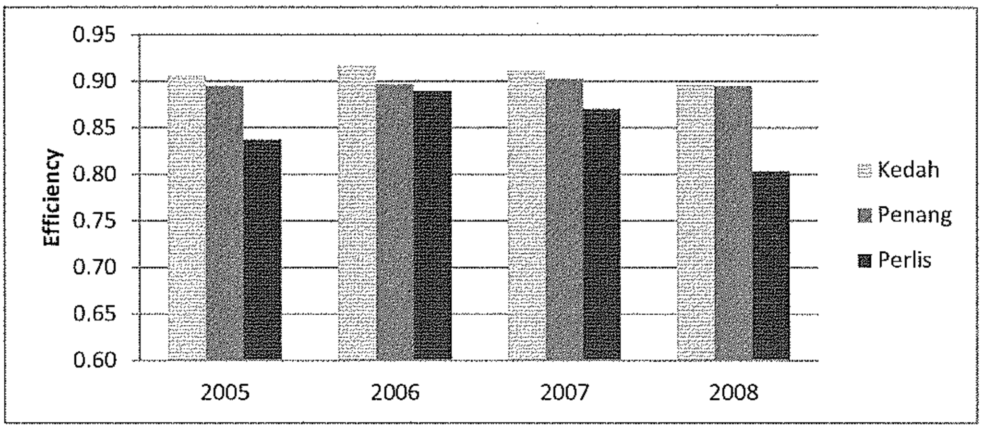
4.5 Performance in Mathematics and Science Subjects by States

4.5.1 Analysis of Efficiency Scores by States

Among the three states, Penang is the most developed and has more schools in urban locations. Thus, we expect the efficiency of schools in Penang to be better than the efficiency of schools in Kedah and Perlis. However, it appears from the efficiency scores that the efficiency of schools in Kedah is the best followed by schools in

Penang and Perlis. Figure 4.11 shows the average efficiency scores in the three different states from 2005 to 2008.

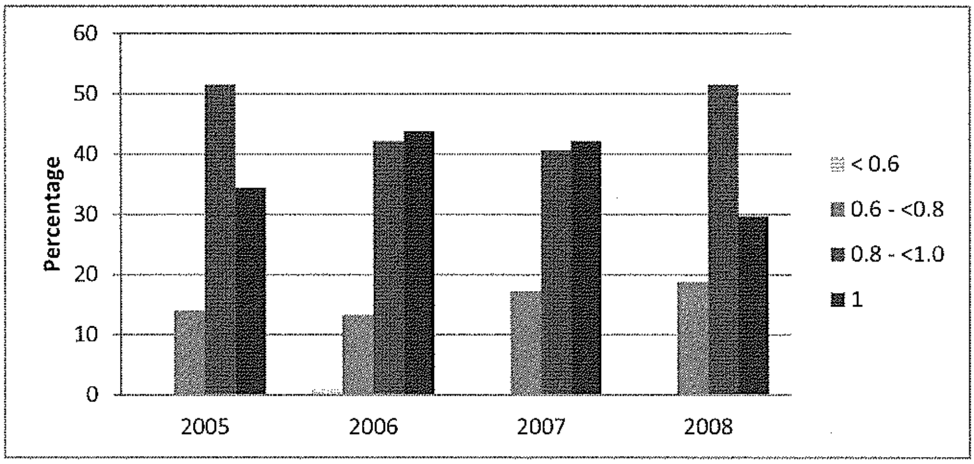
Figure 4.11: Average Efficiency Scores by States



Before the implementation of the policy, the average school efficiencies in all states had increased but after it was implemented in 2007, the average efficiency of schools in Kedah and Perlis started to decrease. Then in 2008, the average efficiencies of schools in all states decreased with schools in Perlis decreasing the most. These results indicate that the gap in the efficiency of fully efficient and inefficient schools in Perlis has grown bigger after the implementation of the PPSMI policy.

The four categories of efficiency are analysed as in the earlier sections. Figure 4.12 shows the percentage of schools by the four efficiency categories in Kedah. The percentage of fully efficient schools was on the rise in 2006 before the implementation of the policy but it started to decrease after the policy was implemented where most of the schools are in the second category (efficiency between 0.8 and 1.0). Even though the average efficiencies in 2008 and 2007 did not differ much, the percentage of fully efficient schools dropped substantially as shown in Figure 4.12. This indicates that more schools became less efficient after the implementation of the policy.

Figure 4.12: Percentage of Schools by Efficiency Categories in Kedah



In Penang, the percentage of fully efficient schools decreased in the first year of the policy implementation (Figure 4.13). In the second year, the percentage of fully efficient schools increased while the percentages of other categories were about the same as in 2006. However, the efficiency of some schools went down to below 0.6. It shows that the efficiency of many schools in Penang increased after the policy was implemented although a few schools became less efficient with regard to the new efficient boundary.

Figure 4.13: Percentage of Schools by Efficiency Categories in Penang

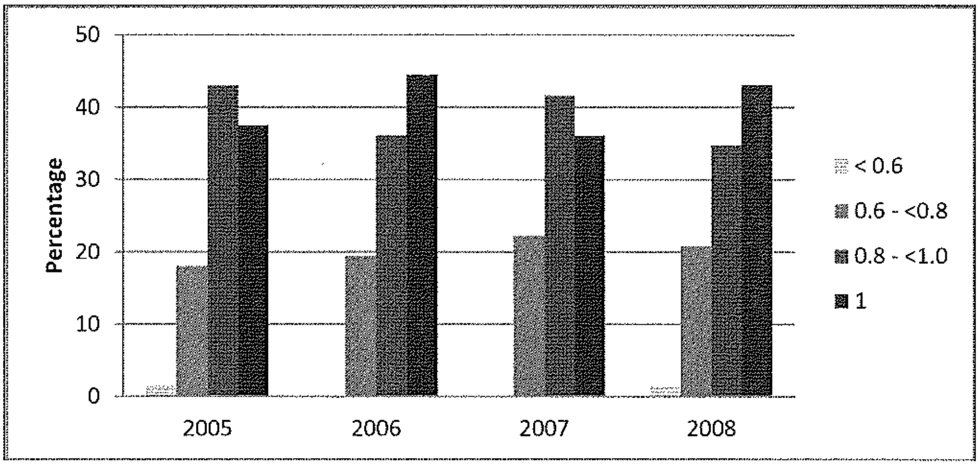
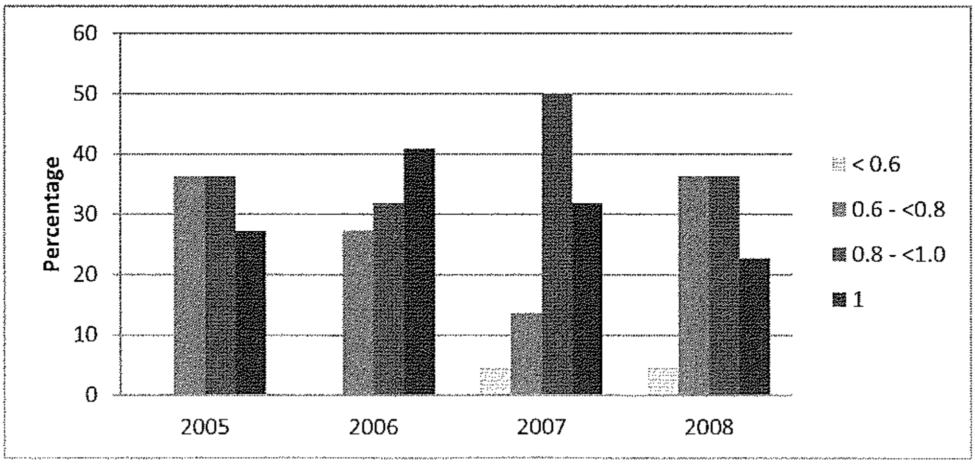


Figure 4.14 shows the percentage of schools by the four efficiency categories in Perlis. It shows that the percentage of fully efficient schools increased in 2006 but after the implementation of the policy, the percentage dropped considerably. The percentage of schools in the second category also dropped while the percentage of schools in the third category increased. The spread of the efficiencies is bigger after the policy was implemented, where a few schools registered an efficiency score of less than 0.6.

Figure 4.14: Percentage of Schools by Efficiency Categories in Perlis



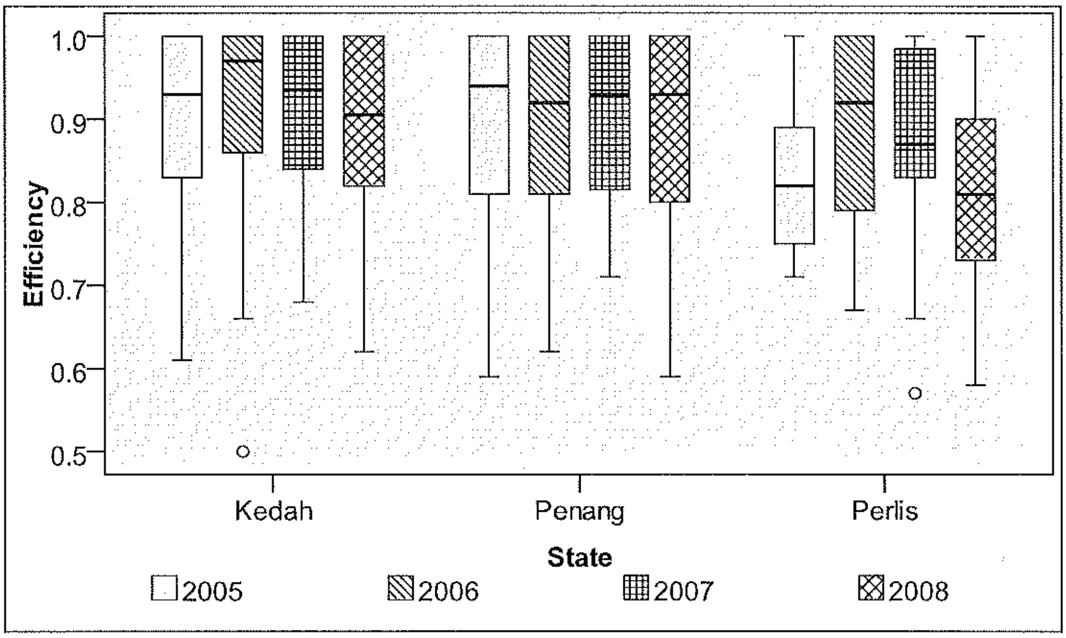
In summary, the average efficiency scores show that the efficiency of schools in Kedah was the highest followed by schools in Penang and Perlis throughout the period of this study. The efficiencies of schools in Kedah and Perlis decreased after the implementation of the policy with schools in Perlis affected the most. In Penang, although the percentage of fully efficient schools increased, the spread of efficiencies was bigger because there were schools with efficiency of less than 0.6. This suggests that while many schools in Penang become more efficient after the implementation of the policy, there are some that become less efficient with regards to the new efficient boundary. The efficiency of schools across different states and the efficiency of schools in each state in different years are tested for significant difference in the next section.

4.5.2 Statistical Test for the Difference in Efficiency Scores of Different States

As in the earlier section, significant differences in efficiencies across the states and years are tested by conducting statistical tests to examine the difference in the distributions of the efficiency scores. Figure 4.15 shows the box-plots of the distributions of the school efficiency scores from 2005 to 2008. A Kruskal Wallis Test is used to examine the difference in the distributions of efficiency scores of schools in Kedah, Penang and Perlis. The null hypothesis is that the distributions of efficiency scores in 2005 are the same across Kedah, Penang, and Perlis (and 3 similar tests for 2006, 2007, and 2008). The alternative hypothesis is that the distributions of efficiency scores are not the same across Kedah, Penang, and Perlis. If there is a significant difference in the distributions of the efficiency scores, a Mann Whitney Test will be conducted as a post hoc test to find the pairwise differences among different states.

The tests results in Appendix A4.6(1) show that there were significant differences beyond the 0.05 level in the distributions of the efficiency scores across different states in 2005 and 2008. Post hoc tests are conducted to evaluate pairwise differences among the three States in 2005 and 2008 by using a Mann-Whitney Test. The null hypothesis is that the distributions of efficiency scores in Kedah and Penang in 2005 are the same (and one similar test in 2008, plus four similar tests between Kedah and Perlis, and Penang and Perlis in 2005 and 2008). The alternative hypothesis is that the distributions of efficiency scores in the two states are not the same.

Figure 4.15: Distribution of Efficiency Scores by States (2005-2008)



Results from the Mann Whitney Tests in Appendix A4.6(2) show that the distributions of efficiency scores between Kedah and Perlis as well as between Penang and Perlis in 2005 and 2008 were significantly different beyond the 0.05 level. However, there was no significant difference in the distributions of the efficiency scores of schools in Kedah and Penang. Based on these results and the median of the efficiency scores (Figure 4.15), it can be concluded that the efficiencies of schools in Kedah and Penang in 2005 and 2008 were significantly higher than the efficiency of schools in Perlis.

To test for significant difference in the efficiency of each state in different years, Friedman's Two-Way Analysis of Variance by Ranks is used. The null hypothesis is that the distributions of efficiency scores of schools in Kedah in 2005, 2006, 2007, and 2008 are the same (and two similar tests for schools in Penang and Perlis). The alternative hypothesis is that the distributions of efficiency scores are not the same. If there is significant difference in the distributions of the efficiency scores, a Wilcoxon Signed Ranks Test will be conducted as a post hoc test to find the pairwise differences between different years.

The results of the tests are given in Appendix A4.6(3). There were no significant differences in the distributions of efficiency scores of schools in Kedah and Penang in different years. For schools in Perlis, there was a significant difference at the 0.10 level. Thus, a post hoc test is conducted to examine the pairwise differences in the distributions of the efficiency scores of schools in Perlis in different years. The null hypothesis is that the median of differences between the efficiency distributions in 2005 and 2006 equals 0 (and 5 similar tests between 2005-2007, 2005-2008, 2006-2007, 2006-2008, and 2007-2008). The alternative hypothesis is that the median of differences between the efficiency distributions does not equal 0. Results from the Wilcoxon Signed Ranks test in Appendix A4.6(4) show that the efficiency of schools in Perlis in 2008 was significantly different beyond 0.05 level from their efficiencies in 2007 and 2006. Based on the median, it can be concluded that the efficiency of schools in Perlis in 2008 was significantly lower than their efficiencies in 2007 and 2006.

As a summary, the efficiency of schools in Kedah and Penang was significantly better than the efficiency of schools in Perlis in 2008, but before that, there was no significant difference between their efficiencies. In terms of the efficiency in different years, schools in Perlis have shown a significantly lower efficiency in 2008, two years after the policy was implemented. The differences in the efficiency of schools in Kedah and Penang before and after the implementation of the policy were not significant. These will be discussed further in Chapter 5. In the next section, the change in performance over time will analysed by using the Malmquist index.

4.5.3 Analysis of the Malmquist Index by States

The Malmquist index of schools by states and its decomposition were analysed in three different periods i.e. 2005-2006, 2006-2007, and 2007-2008 and are shown in Table 4.5. In general, the Malmquist indices of all states have increased. Average increment throughout the study period for Kedah is 1.34 percent, for Penang 2.55 percent and for Perlis 3.32 percent. All states registered a large increase in the Malmquist index in the third period due to the increase in the technical change. On average, the efficiency change in all states increased by 0.25 percent to 1.25 percent. This increase is attributed to the increase in the pure technical efficiency change. The scale efficiency change, on the other hand, decreased.

In Kedah, the Malmquist index before the implementation of the policy had decreased by 1.59 percent (first period). After the policy was implemented in 2007, it increased by 0.2 percent before continuing to increase by 5.33 percent in the third period. This is attributed to the technical change, which had changed from a regression of 3.27 percent and 0.85 percent in the first and second periods respectively to a progress of 5.71 percent in the third period.

Table 4.5: Malmquist Indices by States

State	Year	Pure Technical Efficiency Change (1)	Scale Efficiency Change (2)	Efficiency Change (3) = (1) x (2)	Boundary Shift (4)	Malmquist Index (5) = (3) x (4)
Kedah	2006	1.0182	0.9992	1.0173	0.9673	0.9841
	2007	1.0067	1.0038	1.0105	0.9915	1.0020
	2008	1.0061	0.9904	0.9965	1.0571	1.0533
	Average	1.0103	0.9978	1.0081	1.0053	1.0134
Penang	2006	1.0096	1.0017	1.0113	0.9814	0.9924
	2007	1.0207	0.9908	1.0114	0.9783	0.9894
	2008	1.0292	0.9832	1.0120	1.0819	1.0948
	Average	1.0198	0.9919	1.0115	1.0138	1.0255
Perlis	2006	1.0716	0.9991	1.0707	0.9261	0.9915
	2007	1.0182	0.9864	1.0044	1.0502	1.0548
	2008	0.9419	0.9898	0.9323	1.1157	1.0402
	Average	1.0106	0.9918	1.0025	1.0307	1.0332

The efficiency change is more stable: it progressed by 1.73 percent in the first period and 1.05 percent in the second period and it regressed by only 0.35 percent in the third period. This is attributed to the decrease in the scale efficiency change. The pure technical efficiency change increased by an average of 1.03 percent throughout the study period. The increases in both the technical change and pure technical efficiency change shows that the performance of both fully efficient and inefficient schools in Kedah increased. However, the increase in the performance of fully efficient schools in 2008 was more than the increase in the performance of inefficient schools, thus resulting in lower average efficiency scores as shown in Figure 4.11.

Schools in Penang registered a decrease of 0.76 percent in the Malmquist index in the first period. It continued to decrease by 1.06 percent in the second period but had a large increase of 9.48 percent in the third period. Again, this is attributed to the technical change, which regressed by 1.86 percent in the first period and 2.17 percent in the second period but progressed by 8.19 percent in the third period. The efficiency change progressed between 1.13 percent and 1.20 percent throughout the study. This progress is attributed to the improvement in the pure technical efficiency. In the third period, the increase in the technical change was more than the increase in the pure technical efficiency change but both increases were more than what had been achieved by schools in Kedah. Thus, the mean efficiency score as shown in Figure 4.11 was lower than the previous period but the decrease was not as much as the decrease recorded by schools in Kedah.

In Perlis, the Malmquist index increased substantially after the implementation of the policy: in the second period it increased by 5.48 percent and in the third period by 4.02 percent. This is attributed to the large improvement in technical change, which progressed by 5.02 percent and 11.57 percent in the second and third periods respectively. In contrast, the efficiency change was on a downward slide: in the first period it progressed by 7.07 percent but in the second period the progress was only

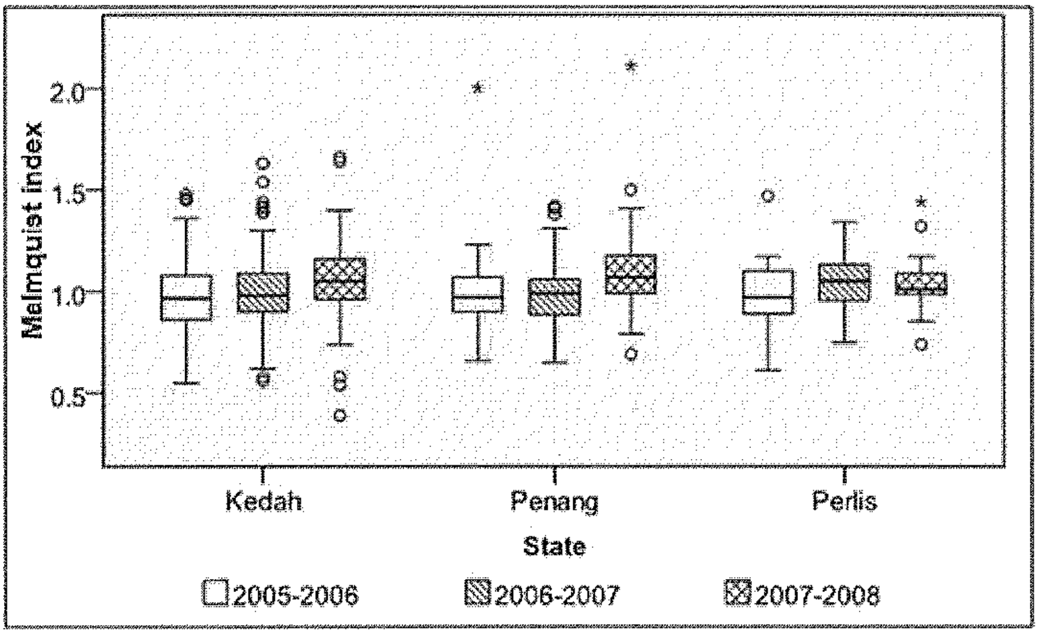
0.44 percent and in the third period it regressed by 6.77 percent. This is attributed to the pure technical efficiency change, which had the same trend. The scale efficiency change also regressed but by less than 2 percent. In the third period, the increase in the technical change and the decrease in the pure technical efficiency change indicate a big difference between the performances of fully efficient and inefficient schools, which is reflected in the lower efficiency mean as shown in Figure 4.11.

In summary, the Malmquist indices of schools in Kedah, Penang, and Perlis have shown that in the third period the efficient boundary shifted upward, which means the performance of fully efficient schools increased. At the same time, the performance of inefficient schools in Kedah and Penang also increased though not as high as the increase in performance of fully efficient schools. This resulted in a small decrease in the mean efficiency scores as discussed in section 4.5.1. However, the performance of the efficient schools in Perlis increased considerably resulting in a bigger gap between the performances of the efficient and inefficient schools and a lower mean efficiency score. This analysis shows that the performance of schools in all three states increased in 2008, two years after the implementation of the PPSMI policy. In the next section, the differences in the Malmquist indices of different states and in different periods are tested for statistical significance.

4.5.4 Statistical Test for the Difference in Malmquist Indices of Different States

The distributions of the Malmquist index in different states are tested for significant difference to see whether the average Malmquist index in each state are significantly different over time and from each other. Friedman's Two-Way Analysis of Variance by Ranks is used to test for significant difference over time while Kruskal-Wallis Test is used to examine the significant difference in the Malmquist index of different school-types. If there is a significant difference over time, a Wilcoxon Signed Ranks Test will be conducted to examine the pairwise differences between different periods. A Mann-Whitney Test will be conducted to examine the pairwise differences between different types of schools. Figure 4.16 shows the distributions of the Malmquist index by state in three different periods.

Figure 4.16: Distributions of Malmquist Indices by States



For Friedman's Two-Way Analysis of Variance by Ranks, the null hypothesis is that the distributions of the Malmquist index of schools in Kedah in the three periods (2005-2006, 2006-2007, and 2007-2008) are the same (and two more similar tests for Penang and Perlis). The alternative hypothesis is that the distributions of the

Malmquist index of schools in Kedah in the three periods are not the same. The tests results are given in Appendix A4.5(5). The tests show that the distributions of the Malmquist indices of schools in Kedah and Penang in the three periods were significantly different beyond the 0.05 level but there was no significant difference in the distribution of the Malmquist index of schools in Perlis.

Post hoc tests are conducted to examine the pairwise differences between the Malmquist indices of schools in Kedah and Penang in different periods by using a Wilcoxon Signed Ranks Test. The null hypothesis is that the median of differences between the distributions of the Malmquist index in periods 2005/2006 and 2006/2007 for schools in Kedah equals 0 (and two similar tests for periods 2005/2006-2007/2008 and 2006/2007-2007/2008 plus three similar tests for schools in Penang). The alternative hypothesis is that the median of differences between the distributions of the Malmquist index in the first and second periods does not equal 0. The results of the tests in Appendix A4.6(6) show that there were significant differences between periods 2005-2006 and 2007-2008, as well as 2006-2007 and 2007-2008. Based on the median of the Malmquist index distributions (Figure 4.16), the performances of schools in Kedah and Penang increased significantly in the third period as compared to the first and second periods.

Then, the Malmquist index distributions of different school-types are tested for significant difference from each other in the three periods of study by using a Kruskal-Wallis test. The null hypothesis is that the distributions of the Malmquist index in the first period are the same across Kedah, Penang, and Perlis (and two other similar tests for the second and third periods). The alternative hypothesis is that the distributions of the Malmquist index are not the same across Kedah, Penang, and Perlis. The results of the tests are given in Appendix A4.6(7). The tests show that the differences in the distributions of the Malmquist index of schools in different states were not significant in all periods.

4.5.5 Summary of Performance in Mathematics and Science Subjects by States

The average efficiency scores show that the efficiency of schools in Kedah is the highest followed by schools in Penang and Perlis throughout the period of study. The statistical tests show that the efficiencies of schools in Kedah and Penang were significantly better than the efficiency of schools in Perlis after the implementation of the policy. There was no significant difference between the efficiencies of schools in Kedah and Penang throughout the study period.

In terms of the efficiency of schools in each state, schools in Perlis have shown a significantly lower efficiency since the implementation of the policy. Schools in Kedah and Penang did not show any significant difference in their efficiencies before and after the implementation of the PPSMI policy. The spread of efficiencies for schools in Perlis and Penang was bigger after the policy was implemented with the efficiency of some schools being less than 0.6.

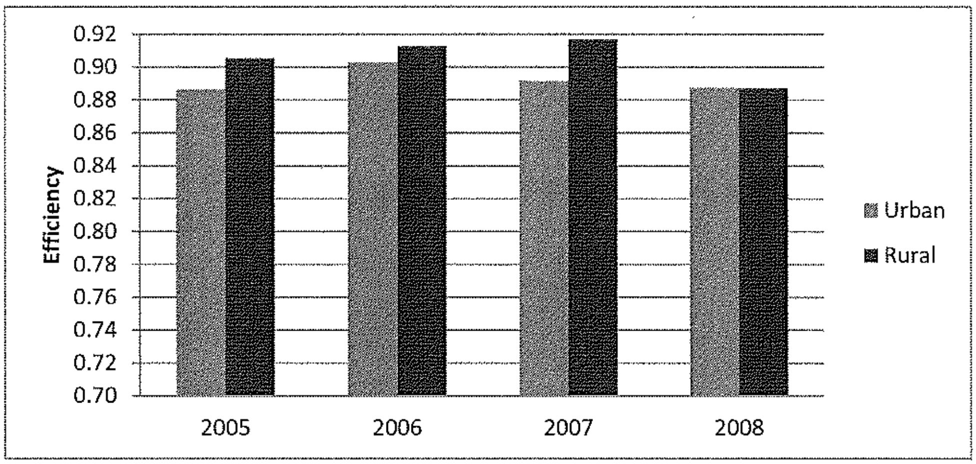
The Malmquist indices of schools in Kedah and Penang in period 2007-2008 were significantly higher than in periods 2006-2007 and 2005-2006. In Perlis, there was no significant difference between the Malmquist indices in different periods. It can be concluded that the performance of schools in Penang and Kedah in 2008 progressed significantly from their performances in 2007 and 2006. Although the performance of schools in Perlis also progressed in 2008 as measured by the Malmquist index, the difference was not statistically significant. A more detailed discussion on these results will be given in Chapter 6.

4.6 Performance in Mathematics and Science Subjects by Locations

4.6.1 Analysis of Efficiency Scores by Locations

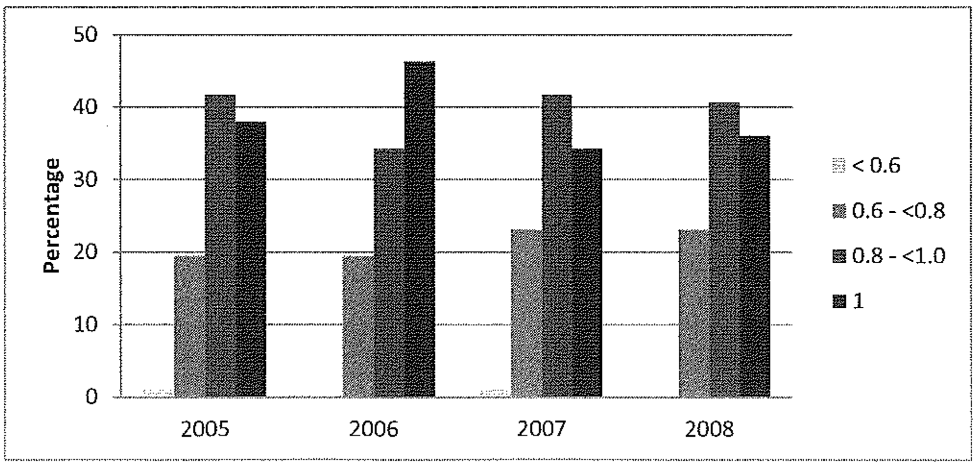
In Malaysia, many studies suggest that urban schools performed better than rural schools (Swetz, Langgulung et al. 1983; Kiong, Yong et al. 2005; Long 2005; Surif, Ibrahim et al. 2006; Hamzah and Abdullah 2009). However, the average efficiency scores calculated in this study as shown in Figure 4.17 reveals that schools in rural locations were more efficient than schools in urban locations especially before the implementation of the PPSMI policy. The average efficiency for both locations increased slightly in 2006, before the implementation of the policy. After the implementation of the policy in 2007, the average efficiency of urban schools started to decrease but the average efficiency of rural schools was not affected. However, in 2008, both locations showed a decrease in the average efficiency scores with the efficiency of rural schools decreasing more than the urban schools.

Figure 4.17: Average Efficiency Scores by Locations



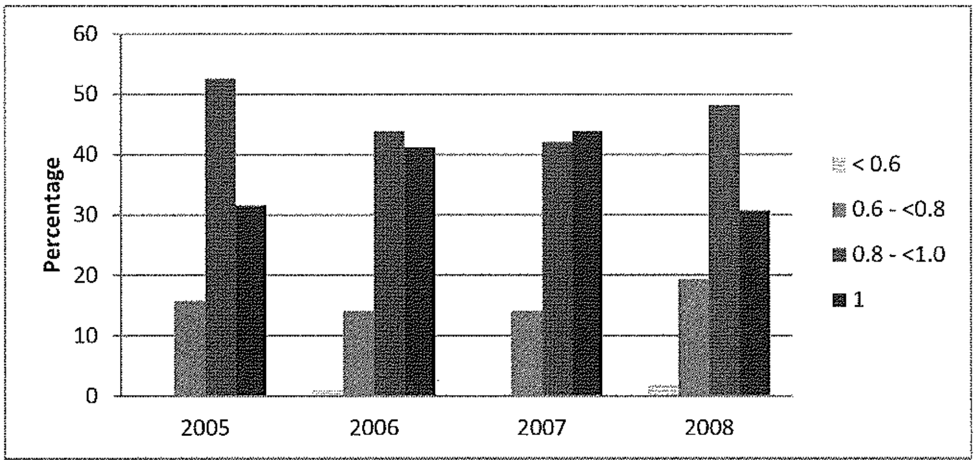
Analysis by the four categories of efficiency for schools in urban locations is shown in Figure 4.18. It shows that the percentage of fully efficient schools decreased after the implementation of the policy in 2007 but increased again a little in 2008. The percentages of schools in the second and third categories in 2007 and 2008 were more than in 2006. This means more schools in urban locations have become less efficient since the implementation of the policy.

Figure 4.18: Average Efficiency Scores of Urban Schools



The percentage of fully efficient rural schools in the four efficiency categories is shown in Figure 4.19. The percentage of fully efficient schools increased a little after the policy was implemented in 2007 but decreased a lot in 2008. More schools were in the second and third categories and a small percentage even registered an efficiency score of less than 0.6. The lower percentage of fully efficient schools and the bigger efficiency spread show that the variation in performance of rural schools increased after the implementation of the PPSMI policy. The decrease in the percentage of efficient rural schools is much more than the decrease in the percentage of efficient urban schools.

Figure 4.19: Average Efficiency Scores of Rural Schools



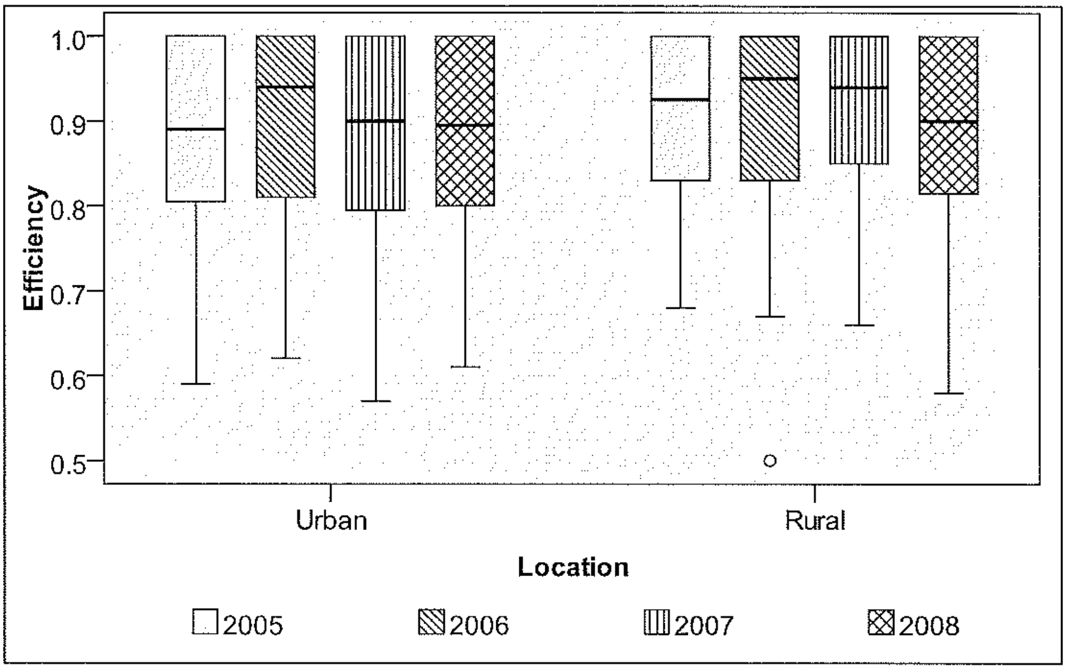
In summary, the implementation of the PPSMI policy affected the efficiency of schools in both locations but rural schools were more affected than urban schools. Before the policy was implemented, the average efficiency of rural schools was higher than urban schools but in 2008, the average efficiencies of schools in both locations were about the same. Statistical tests are conducted to test for significant difference in the efficiency of urban and rural schools before and after the implementation of the policy. The results are given in the next section.

4.6.2 Statistical Test for the Difference in Efficiency Scores of Different Locations

Statistical tests are used to test for significant difference in the distributions of school efficiency in different locations and to test for significant difference in the distributions of school efficiency of each location in different years. Figure 4.20 shows the box-plot of the school efficiency distributions of urban and rural locations from 2005 to 2008. A Mann-Whitney Test is used to examine the difference in the distributions of efficiency scores of schools in urban and rural locations each year. The null hypothesis is that the distributions of efficiency scores in urban and rural locations in 2005 are the same (and three similar tests for 2006, 2007, and 2008). The alternative hypothesis is that the distributions of efficiency scores are not the same. The results from the Mann-Whitney U test are shown in Appendix A4.7(1). It shows that there was no significant difference beyond the 0.05 level between the distributions of efficiency scores of urban and rural schools in each year.

To test for significant difference in the performance of each location in different years, Friedman's Two-Way Analysis of Variance by Ranks is used. The null hypothesis is that the distributions of efficiency scores of urban schools in 2005, 2006, 2007 and 2008 are the same (and one similar test for rural schools). The alternative hypothesis is that the distributions of efficiency scores are not the same. If there is a significant difference in the distributions of the efficiency scores, a Wilcoxon Signed Ranks Test will be conducted as a post hoc test to find the pairwise differences between different years.

Figure 4.20: Distributions of Efficiency Scores by Locations (2005-2008)



The results of the tests are given in Appendix A4.7(2). There was no significant difference in the distributions of efficiency scores of urban schools in different years. For rural schools, there was a significant difference at the 0.10 level. Thus, a post hoc test is conducted to examine the pairwise differences in the distributions of the efficiency scores of rural schools different years. The null hypothesis is that the median of differences between the efficiency distributions in 2005 and 2006 equals 0 (and 5 similar tests between 2005-2007, 2005-2008, 2006-2007, 2006-2008, and 2007-2008). The alternative hypothesis is that the median of differences between the efficiency distributions does not equal 0. Results from the Wilcoxon Signed Ranks test in Appendix A4.7(3) show that the efficiency of rural schools in 2008 was significantly different beyond the 0.05 level from their efficiencies in 2007 and 2006. Based on the median, it can be concluded that the efficiency of rural schools in 2008 was significantly lower than their efficiencies in 2007 and 2006. For urban schools, there was no significant difference in their efficiency before and after the implementation of the policy.

In summary, the statistical tests conducted in this section confirmed that there was no significant difference in the efficiency of schools in urban and rural locations throughout the study period. The tests also confirm that the efficiency of rural schools was significantly lower in 2008, two years after the implementation of the policy. There was no significant difference in the efficiency of urban schools before and after the implementation of the PPSMI policy.

4.6.3 Analysis of the Malmquist Index by Locations

The Malmquist indices of schools in different locations and their decomposition in three different periods (2005-2006, 2006-2007, and 2007-2008) are shown in Table 4.6. In general, the Malmquist indices of schools in both locations were increasing. On average, the Malmquist indices of urban and rural schools increased by 2.84 percent and 1.06 percent respectively throughout the study period. Both locations recorded the biggest increase in 2008 when their Malmquist indices increased by 8.23 percent and 5.04 percent respectively. The increase is attributed mostly to the improvement in the technical change.

On average, efficiency change for both locations has improved: in urban locations it has improved by 1.50 percent and in rural locations by 0.61 percent. The improvement is attributed to the progress in the pure technical efficiency change: in urban locations it progressed by 1.86 percent and in rural locations by 0.87 percent. The scale efficiency change on the other hand regressed by 0.52 percent in urban locations and by 0.41 percent in rural locations.

Table 4.6: Malmquist indices by Locations

Location	Year	Pure Technical Efficiency Change (1)	Scale Efficiency Change (2)	Efficiency Change (3) = (1) x (2)	Technical change (4)	Malmquist Index (5) = (3) x (4)
Urban	2006	1.0281	0.9980	1.0260	0.9749	1.0003
	2007	1.0029	0.9988	1.0017	1.0006	1.0023
	2008	1.0247	0.9876	1.0120	1.0694	1.0823
	Average	1.0186	0.9948	1.0132	1.0150	1.0284
Rural	2006	1.0131	1.0018	1.0149	0.9618	0.9761
	2007	1.0209	0.9974	1.0182	0.9852	1.0031
	2008	0.9920	0.9884	0.9805	1.0713	1.0504
	Average	1.0087	0.9959	1.0045	1.0061	1.0106

One important finding in 2008 is that the pure technical efficiency change increased by 2.47 percent in urban locations but decreased by 0.80 percent in rural locations. The scale efficiency change decreased in both locations in 2008 i.e by 0.52 percent in urban locations and 1.16 percent in rural locations. These led to an increase in the efficiency change in urban locations by 1.32 percent and a decrease by 1.95 percent in rural locations. This indicates that the performance of urban schools progressed but the performance of rural schools regressed in the second year of the implementation of the policy.

In summary, the Malmquist index shows that the performance of schools in urban and rural locations progressed in the third period (2007-2008). The progress is attributed mainly to the increase in the technical change. However, the efficiency change indicates that the performance of urban schools progressed while the performance of rural schools regressed in the second year of the implementation of PPSMI policy.

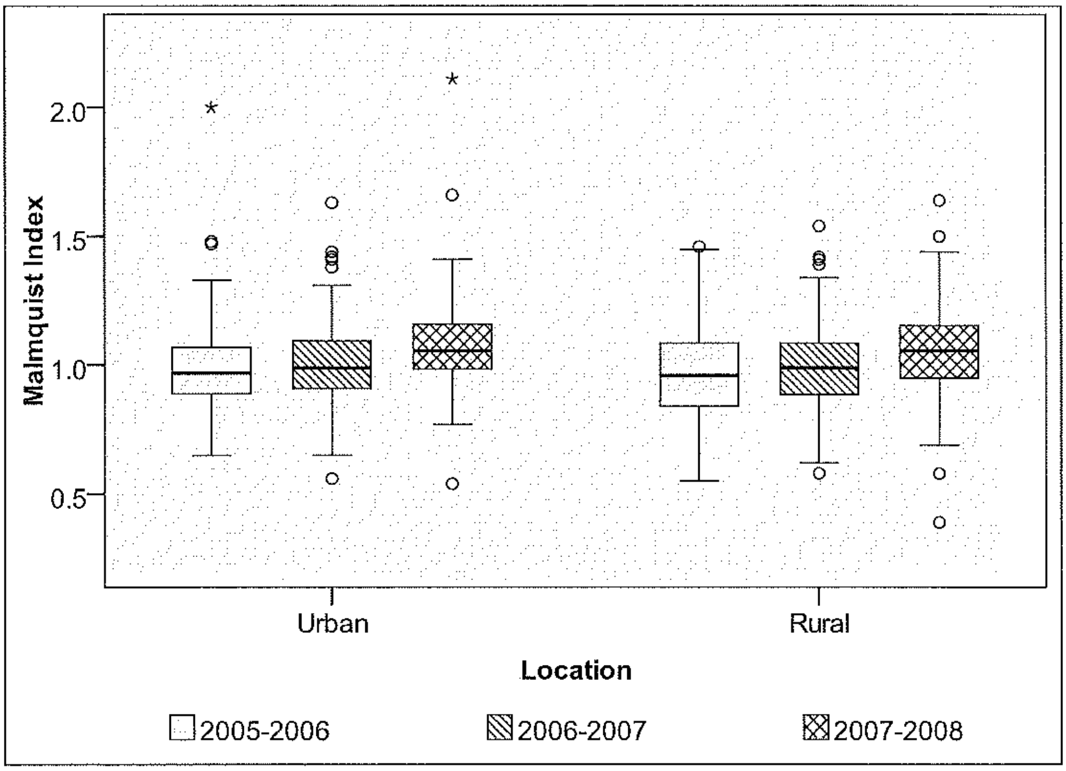
4.6.4 Statistical Test for the Difference in the Malmquist Indices of Different Locations

The distributions of the Malmquist index in different states are tested for significant difference to see whether the average Malmquist indices in each location are significantly different over time and from each other. Friedman's Two-Way Analysis of Variance by Ranks is used to test for significant difference over time while a Mann-Whitney U Test is used to examine the significant difference in the Malmquist index of schools in different locations. If there is significant difference over time, a Wilcoxon Signed Ranks Test will be conducted to examine the pairwise differences between different periods. Figure 4.21 shows the distributions of the Malmquist index by location in three different periods.

For Friedman's Two-Way Analysis of Variance by Ranks, the null hypothesis is that the distributions of the Malmquist index of urban schools in the three periods (2005-2006, 2006-2007, and 2007-2008) are the same (and one similar test for rural schools).

The alternative hypothesis is that the distributions of the Malmquist index of urban schools in the three periods are not the same. The tests results are given in Appendix A4.7(4). The tests show that the distributions of the Malmquist indices of schools in both locations in the three periods were significantly different beyond the 0.05 level.

Figure 4.21: Distributions of Malmquist Indices by Locations



Post hoc tests are conducted to examine the pairwise differences between the Malmquist indices in different periods by using a Wilcoxon Signed Ranks Test. The null hypothesis is that the median of differences between the distributions of the Malmquist indices in periods 2005/2006 and 2006/2007 equals 0 (and 2 similar tests for periods 2005/2006-2007/2008 and 2006/2007-2007/2008 plus three similar tests for rural schools). The alternative hypothesis is that the median of differences between the distributions of the Malmquist indices in the first and second periods does not equal 0. The results of the tests in Appendix A4.7(5) show that, for urban schools, there were significant differences between the first and third periods, as well as the second and third periods, while for rural schools, there was significant difference between the first and third periods. Based on the median of the Malmquist index distributions in Figure 4.21, the performances of schools in both locations progressed significantly in the third period as compared to the first period. The performance of urban schools also progressed significantly compared to their performance in the second period.

Then, the Malmquist index distributions of schools in different locations are tested for significant difference from each other in the three periods of study by using a Mann-Whitney U Test. The null hypothesis is that the distributions of the Malmquist index in the period 2005-2006 is the same in both locations (and two other similar tests for periods 2006-2007 and 2007-2008). The alternative hypothesis is that the distributions of the Malmquist index in urban and rural locations are not the same for the given period. The results of the tests are given in Appendix A4.7(6). The tests show that the difference in the distributions of the Malmquist index of different locations was not significant in all periods.

In general, the Malmquist indices of schools in both locations were significantly higher after the second year of the implementation of the PPSMI policy. This means the performances of schools in both locations progressed significantly in 2008 as compared to their performance in 2007. However, the efficiency change indicates that the performance of urban schools progressed while the performance of rural schools regressed after the implementation of the PPSMI policy. This will be discussed further in Chapter 5 and 6.

4.6.5 Summary of Performance in Mathematics and Science by Locations

The average efficiency scores of urban and rural locations show that the efficiency of rural schools was higher than urban schools before the implementation of the PPSMI policy. After the policy was implemented, the efficiencies of schools in both locations decreased with the efficiency of rural schools decreasing more than the efficiency of urban schools. In 2008, their average efficiency scores were about the same but the percentage of fully efficient rural schools is lower than that of urban schools. However, the statistical tests confirmed that there was no significant difference in the efficiency of schools in urban and rural locations throughout the study period. The tests also confirmed that the efficiency of rural schools was significantly lower after the implementation of the policy but there was no significant difference in the efficiency of urban schools before and after the implementation of the PPSMI policy.

The Malmquist index of schools in urban and rural locations shows that their performance progressed after the second year of the implementation of the policy. The progress is attributed mainly to the increase in the technical change. The efficiency change however indicates that the performance of urban schools progressed while the performance of rural schools regressed after the implementation of the PPSMI policy. The statistical tests show that the Malmquist indices of schools in both locations were significantly higher after the implementation of the PPSMI policy, which means the performance of schools in both locations, progressed significantly in the third period (2007-2008). Nevertheless, there was no significant difference between the Malmquist indices of schools in urban and rural locations.

4.7 Summary and Conclusion

This chapter presented the empirical analysis of this study. The efficiency scores under the assumption of the CRS, VRS, and HRS DEA models were computed and compared. The HRS model was found to be significantly the most discriminating among the three models. Analysis of the efficiency scores shows that the overall school efficiency was lower after the implementation of the policy. The fully residential school-type was the most efficient followed by the religious and national school-types while schools in Kedah had the highest efficiency scores followed by schools in Penang and Perlis. The efficiency of both urban and rural schools decreased after the implementation of the policy but the efficiency of rural schools decreased more than the decrease in the efficiency of urban schools.

Analysis by the Malmquist Index shows that in 2008, 2 years after the implementation of the policy, the overall school performance progressed significantly. The performances of the national and religious school-types progressed but the performance of the fully residential school-type regressed. The performance of schools in all three states i.e. Penang, Kedah and Perlis also progressed but the variation in performance of schools in Perlis has grown much bigger. The performance of schools in urban and rural locations also progressed significantly. The progression in performance is attributed mainly to the increase in the technical change. The efficiency change, on the other hand, shows that the performance of rural schools regressed. The increase in the technical change and the decrease in the efficiency change reflect an increase in the performance of efficient schools, which shifted the efficiency boundary upward, and a decrease in the performance of inefficient schools, which created a bigger gap between their performances and a lower average of efficiency scores after the policy was implemented.

In general, the implementation of the PPSMI policy benefited most of the schools in the second of the policy implementation, as shown by the increase in the Malmquist index in 2008. However, the performance of some schools increased much higher than other schools thus created a bigger variation in the performances of schools in different locations and in schools of different types. The policy seems to have benefited the religious and national schools especially those located in urban areas. On the other hand, the fully residential schools seem to have been negatively affected by the policy although their efficiency was the highest among the three types of schools in this study. A more detailed analysis of the implications of the PPSMI policy for school performance will be presented in the Chapter 6.

CHAPTER 5

FURTHER ANALYSIS BY MALMQUIST INDEX

5.1 Introduction

In the previous chapter, the Malmquist index was computed to reflect how productivity (value added) changes year on year basis. This chapter analyses the Malmquist index by using 2005 as the base year. The computation of the Malmquist index is done by progressively pairing the base year with 2006, 2007 and 2008 to capture the impact of the PPMSI policy as it was rolled out. This analysis reflects differences between Malay and English as the media of instruction especially when the base year (2005 – two years before the implementation of the policy) is paired with 2008 (two years after the implementation of the policy).

5.2 Analysis of the Malmquist Index for Overall School Performance

The average Malmquist index and its decompositions are presented in Table 5.1. It shows that the Malmquist index decreased by 1.27 percent in 2006, 5.8 percent in 2007 and 2.49 percent in 2008. The decrease in the Malmquist index attributed mostly to the decrease in the technical change. The efficiency change was on a downward slide over the period of the study with a change from an increase by 1.92 percent in 2006 to a decrease by 0.37 percent in 2008. This is due to the decrease in both scale efficiency change and pure technical efficiency change.

This result shows that, when compared to the performance in 2005, the schools performance decreased noticeably in 2007, i.e. immediately after the implementation of the policy. Their performance in 2008 was also lower than their performance in 2005 but it was not as bad as in 2007. This means, the schools performance might have been adversely affected when the PPSMI policy was first implemented in 2007 but their performance started to improve in 2008.

Table 5.1: Malmquist Index and its Decomposition

	2005-2006	2005-2007	2005-2008
Pure Technical Efficiency Change (1)	1.0190	1.0073	0.9992
Scale Efficiency Change (2)	1.0002	0.9979	0.9971
Efficiency Change (3) = (1)x(2)	1.0192	1.0051	0.9963
Technical change (4)	0.9687	0.9372	0.9751
Malmquist Index (5) = (3)x(4)	0.9873	0.9420	0.9715

5.3 Analysis of the Malmquist Index by State

The Malmquist indices of schools by states and its decomposition were analysed by using 2005 as the base year and are shown in Table 5.2. In general, the Malmquist indices of all states have decreased. Perlis recorded the highest decrease followed by Penang and Kedah. The decrease in the Malmquist index of all states was the highest in 2007 and attributed mostly to the decrease in the boundary shift (technical change). The performance of schools in Perlis was affected the most with the decrease in the Malmquist index by 11.83 percent. This is followed by schools in Penang with a decrease of 4.42 percent and schools in Kedah with a decrease by 3.01 percent. In 2008, the performance of schools in all three states was still lower than their performance in 2005 but the regression in performance was not as much as in 2007. This result indicates that schools in all states might have been negatively affected by the PPSMI policy when it was first implemented in 2007 but their performance started to progress in the second year of the policy implementation. Among schools in the three states, schools in Perlis were affected the most followed by schools in Penang and Kedah.

Table 5.2: Malmquist Indices by State

State	Year	Pure Technical Efficiency Change (1)	Scale Efficiency Change (2)	Efficiency Change (3) = (1) x (2)	Boundary Shift (4)	Malmquist Index (5) = (3) x (4)
Kedah	2006	1.0182	0.9992	1.0174	0.9673	0.9841
	2007	1.0096	1.0017	1.0113	0.9591	0.9699
	2008	1.0056	1.0018	1.0074	0.9814	0.9887
Penang	2006	1.0291	0.9888	1.0176	0.9721	0.9892
	2007	1.0171	0.9988	1.0159	0.9408	0.9558
	2008	1.0097	0.9879	0.9975	0.9694	0.9670
Perlis	2006	1.0716	0.9991	1.0706	0.9261	0.9915
	2007	0.9549	0.9911	0.9464	0.9316	0.8817
	2008	0.9256	1.0006	0.9261	0.9887	0.9156

5.4 Analysis of the Malmquist Index by Location

The Malmquist indices of schools in different locations and their decomposition were computed by using 2005 as the base year and the result is shown in Table 5.3. In general, the Malmquist indices of schools in both locations decreased after the implementation of the PPSMI policy. In 2007, the Malmquist index of schools in rural location decreased drastically by 7.04 percent while the Malmquist index of schools in urban location decreased by 4.46 percent. In 2008, the Malmquist index of schools in both locations was better than their Malmquist index in 2007.

It shows that the performance of schools in both locations regressed after the policy was implemented. However, the regression in performance of schools in both locations in the second year of the policy implementation was not as much as in the first year of the policy implementation. On the whole, the regression in performance attributed mostly to the decrease in the boundary shift and the performance of schools in urban location was better than the performance of schools in rural location.

Table 5.3: Malmquist Indices by Location

Location	Year	Pure Technical Efficiency Change (1)	Scale Efficiency Change (2)	Efficiency Change (3) = (1) x (2)	Boundary Shift (4)	Malmquist Index (5) = (3) x (4)
Urban	2006	1.0281	0.9980	1.0260	0.9749	1.0003
	2007	1.0121	0.9969	1.0090	0.9469	0.9554
	2008	0.9993	1.0076	1.0069	0.9794	0.9862
Rural	2006	1.0131	1.0018	1.0149	0.9618	0.9762
	2007	1.0027	0.9988	1.0016	0.9281	0.9296
	2008	0.9915	0.9993	0.9908	0.9711	0.9622

5.5 Summary and Conclusion

In this chapter, school performance was assessed by using 2005 as the base year and by progressively pairing the base year with 2006, 2007 and 2008 to capture the impact of the PPSMI policy as it was rolled out. Analysis on the overall schools performance shows that their performance regressed significantly in 2007 i.e. immediately after the implementation of the policy. In 2008, the schools performance was still lower than their performance in 2005 but better than their performance in 2007. This finding shows that the schools performance might have been adversely affected by the policy although they started to improve in the second year of the policy implementation.

Analysis by states shows that the performance of schools in all states depreciated after the implementation of the policy with the performance of schools in Perlis depreciated the most followed by schools in Penang and Kedah. However, the schools performance in all states started to get better in 2008. Analysis by location shows that the performance of schools in both locations regressed substantially after the policy was implemented in 2007 but their performance started to improve in 2008. This study also found that the performance of schools in urban location was better than the performance of schools in rural location.

Findings from this chapter show that, in general schools performance regressed after the implementation of the policy where the regression in performance was obvious in 2007. Nevertheless the schools performance started to get better in 2008 although it is still lower than their performance before the policy was implemented. In Chapter 4, it was shown that the schools performance progressed significantly in 2008. The different in findings from this chapter and the previous chapter is due to the method of calculating the Malmquist index where in this chapter, 2005 is used as the base year while in the previous chapter the base year changes year on year basis. In actual fact, results in this chapter do not contradict results in the previous chapter because they both show that the schools performance in 2008 was better than their performance in 2007. On the whole, it can be concluded that the schools performance declined immediately after the policy was implemented but their performance started to improve in the second year of the policy implementation.

CHAPTER 6

POLICY IMPLICATIONS

6.1 Introduction

The Ministry of Education Malaysia (MOEM) undertook various programmes and strategies to facilitate the change in the medium of instruction under the English in the Teaching of Mathematics and Science (PPSMI) policy. These include English courses for science and mathematics teachers, development and dissemination of the new curriculum, delivery of teaching and learning courseware (computer application to assist teaching and learning process), textbooks, reading materials, and Information and Communication Technology (ICT) equipments, monitoring and guidance, and giving special incentive for teachers (Educational Planning and Research Division, 2008b). The English Language Training Centre has been given the responsibility for developing and conducting an English language enhancement programme known as English for the Teaching of Mathematics and Science (ETeMS). These are part of the initial package that was design to ensure that the implementation of the policy is smooth and pupils' performance in mathematics and science subjects would not be affected.

ETeMS is regarded as an urgent interim measure, besides several other support mechanisms to ensure that mathematics and science teachers have the basic capacity to use English as the medium of instruction (Zin, 2003). This is complementary to other on-going professional development courses for pre-service and in-service teachers involved in the PPSMI policy. A large portion of an allocation was used for the ETeMS training, developing teaching courseware, monetary incentives and provision of new teaching and learning materials such as laptops, LCD projectors and textbooks. The Education Minister disclosed that the cost of implementing the PPSMI policy since it was introduced in 2003 was about RM 5 billion (Loh, 2009).

However, while this study is being carried out, the MOEM announced that the Government has decided to reverse the PPSMI policy and revert to the use of Bahasa Melayu in the national schools, and Chinese and Tamil in the vernacular schools from 2012 (Dom, 2010). The main reason for the decision as stated by the Education Minister is the command of Malaysian pupils in science and mathematics subjects have been on a steady decline as shown by the MOEM records and the Trend in Mathematics and Science Study (TIMSS) 2007. A new policy with the objective to dignify Bahasa Melayu as the national language while raising the standard of English among Malaysian will replace PPSMI (School Management Division, 2010).

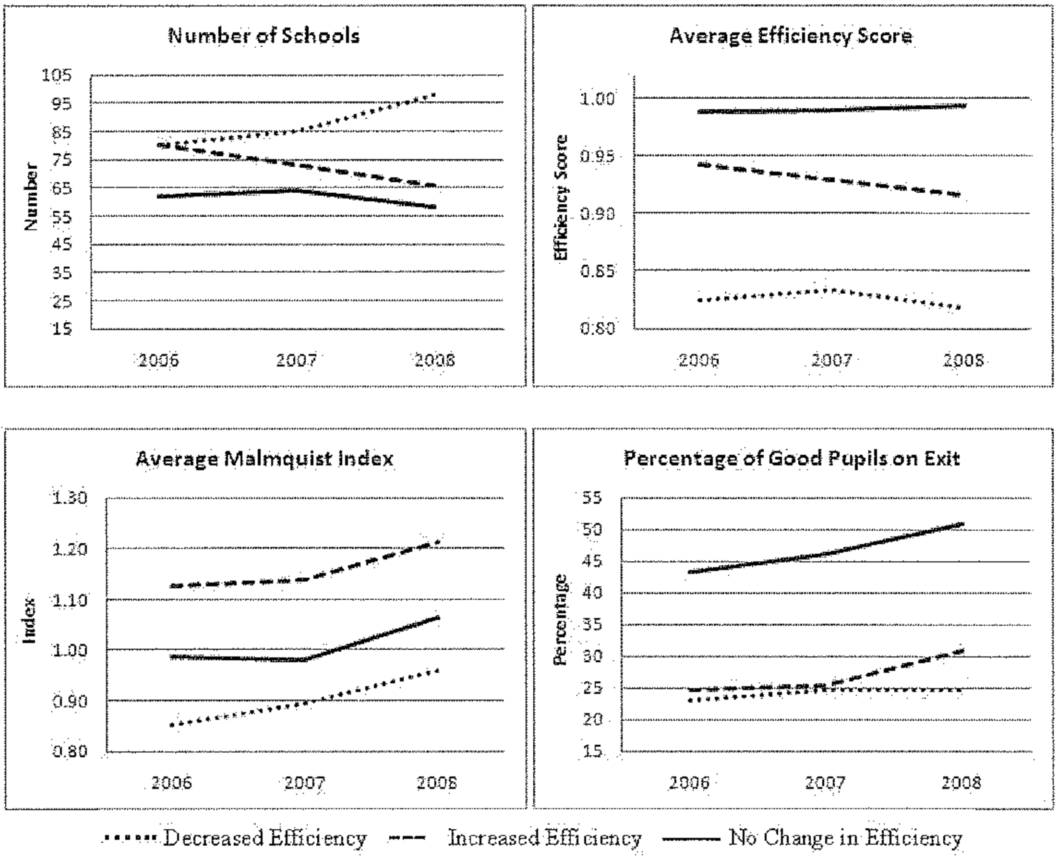
This chapter will discuss the research findings in terms of the implications of the PPSMI policy for the performance of secondary schools in mathematics and science subjects. The findings from Chapter 4 and Chapter 5 will be elaborated and discussed based on overall school performance, performance by school-type, performance by state, and performance by location. The findings will be correlated with findings from other studies to get more understanding on the implications of the policy for the school performance. This study will come up with recommendations regarding the implementation of the PPSMI policy.

6.2 Implications for Overall School Performance

As has been presented in Chapter 4, in 2008 (two years after the implementation of the PPSMI policy), the overall school efficiency in mathematics and science subjects was significantly lower than in 2007 and 2006. This can be seen from the lower number of the fully efficient schools and the higher number of the inefficient schools. This indicates that the average distance between schools and the efficient boundary had increased. The Malmquist index showed that the increase in the average distance between schools and the efficient boundary was due to the increase in the efficient boundary itself where the performance of the fully efficient schools that formed the boundary had progressed considerably and pushed the efficient boundary higher. The inefficient schools on the other hand, had either regressed, stagnated, or did not progress as much as the fully efficient schools, thus became less efficient with respect to the new efficient boundary. Therefore, the average efficiency in 2008 was significantly lower than in 2007 and 2006 as shown in section 4.2.2.

To see a clearer picture on the schools performance before and after the implementation of the policy, they are divided into three groups as presented in Figure 6.1. The three groups are (i) schools that had higher efficiency score as compared to the previous year (increased efficiency), (ii) schools that had lower efficiency score as compared to the previous year (decreased efficiency), and (iii) schools that had no change in efficiency score as compared to the previous year (no change in efficiency). The Malmquist index in this Figure is based on year on year productivity changes.

Figure 6.1: Overall School Performance



The number of schools in the decreased efficiency group increased immediately after the policy was implemented in 2007. The number continued to increase considerably in 2008. The opposite situation happened to the other two groups where the number of schools in both groups decreased in 2008. The average efficiency scores for both the increased efficiency and decreased efficiency groups also decreased in 2008. In contrast, the Malmquist index for all groups had increased. The percentages of pupils with good grade on exit for the increased efficiency group and the group with no change in efficiency also increased but not for the decreased efficiency group. In 2008, the gap between the percentages of pupils with good grade on exit of the increased efficiency and decreased efficiency groups was bigger.

Analysis by year on year basis as shown in Chapter 4 shows that the Malmquist index and the percentages of pupils with good grade had increased in 2008. Analysis by using 2005 as the base year as shown in Chapter 5 also shows that the schools performance in 2008 was better than their performance in 2007. These indicate that the overall school performance had increased in 2008 as compared to 2007 and the efficient boundary in 2008 was higher than in 2007. However, the increase in the number of schools in the decreased efficiency group and the decrease in average efficiency scores show that more schools became less efficient due to the higher efficient boundary. This situation demonstrates that some schools might have benefited much from the implementation of the policy thus their performance progressed significantly. Other schools might have also benefited from the policy but their progress was not as much as the progress of the fully efficient schools thus decreasing their efficiency with regard to the new efficient boundary. The bigger gap between the percentages of pupils with good grade on exit of the increased efficiency and decreased efficiency groups indicates that the difference between the fully efficient and less efficient schools has widened.

The drastic increase of efficient boundary in 2008, i.e. two years after the policy was implemented, might be associated with certain factors. In 2007, the examination was taken by the first batch of pupils who learned the subjects in English. At that time, most of the teachers and pupils were still adapting to the new policy thus many of them did not fully used English in the teaching and learning process. A study by Educational

Planning and Research Division (2005) shows that both teachers and students were not confident in using English as a medium of instruction in the classroom and there were teachers who did not use English at all. Schools Inspectorate (2005, 2006) also presented the same finding where teachers were not proficient in English and they had to mix Bahasa Melayu and English language in the teaching and learning process. They also found that students interact in English neither with teachers nor with their friends. Analyses on the results of diagnostic tests for Science and Mathematics done by Malaysian Examination Syndicate (2005, 2006) show that 60 to 75 percent students could not express ideas in English while 50 to 60 percent could not understand the teaching and learning process in English and could not understand the questions in English.

In the second year of the policy implementation, teachers and pupils were becoming more confident to use English in the teaching and learning process. Beginning 2005, the MOEM carried out several intervention programmes to enhance English proficiency among the students and improve the PPSMI policy implementation. These programmes include diagnostic tests for Science and Mathematics, remedial classes for students, English orientation programmes for form one students, activity-based programmes in English, periodic on-site training for teachers, English proficiency assessment for all teachers and the Early Literacy Through English (ELiTE) for Year One students (Goh and Chapman, 2008). Although the average efficiency seems to have dropped considerably in 2008, this is actually due to the drastic increase in the technical change, which created a greater distance between the inefficient schools and the efficient boundary, therefore reducing the average efficiency. These efforts might have started to show results thus contributing to the significant increase in the efficient boundary in 2008.

Other than efforts by the MOEM as the central agency, one important factor that could also contribute to the success of schools in implementing the policy is the initiatives by the schools themselves. For example, Idris et al (2006) did a case study on the effective implementation of the PPSMI policy in one secondary school. They found many good practices in the school that could be replicated by others. Examples of the good initiatives by the school are effective implementation of the policy, parents and teachers work closely to ensure remedial classes are well attended, pupils are encouraged to keep notebooks for mathematics and science glossaries, and the school maintains a notice board where new mathematics and science content is featured every week to create interest in the subject.

The increase in the performance of some schools that contributed to the increase in efficient boundary (especially in the urban location) could also be associated with the quality of pupils and teachers that they have. Some schools have many pupils from the high socio-economic background, as well as many well-qualified and competent English-speaking teachers. These schools might thrive under the new policy independently of the initiatives or the new materials provided by the MOEM as mentioned earlier. These factors could contribute to the significant progression in performance of the fully efficient schools that formed the efficient boundary. However, the bigger gap between the fully efficient and inefficient schools shows that some schools were having difficulty to adapt to the new policy. According to Educational

Planning and Research Division (2005) and Schools Inspectorate (2005, 2006) schools were having difficulty to implement the new policy due to the inability of their teachers and pupils to use English effectively.

Although the progress in schools performance could be associated with the efforts by the MOEM, schools, and teachers as well as pupils' ability, some people see the drastic increase in performance as questionable because many studies showed that teachers and pupils were having problems in the process of teaching and learning in English. The training given to the teachers and the facilities provided to assist teachers and pupils in the teaching and learning process were shown not to be that effective. Despite all these, school performance still increased significantly in 2008 and this has made people to ask whether the increase was genuine or the passing mark has been lowered to show that the policy is not affecting the performance in mathematics and science subjects. The basis for this claim is, in 2009 the MOEM was suppose to make an important decision whether to carry on with the PPSMI policy or revert to the use of Bahasa Melayu as the medium of instruction. Therefore, the sudden increase in the number of good quality students could be the result of the standard setting in examination where the passing marks was lowered to show that the performance in mathematics and science subject is not affected by the policy. However, this claim was denied by the MOEM (Malaysian Parliament, 2009).

In summary, the implications of the PPSMI policy for overall schools performance are a sudden increase in performance of some schools as shown by the drastic increase in the technical change (higher efficient boundary) and an increase in variation of schools performance where the gap between fully efficient and inefficient schools has widened. A bigger gap between fully efficient and inefficient schools shows that the policy might be very beneficial to schools that can cope with policy which lead to much better performance as compared to other schools. This finding is different from other PPSMI studies, which show that the schools performance on the whole dropped after the policy was implemented (Haron et al., 2008; Nor and Aziz, 2009; Surif et al., 2006).

However, it cannot be concluded with certainty that the change in performance is directly related to the policy because other factors such as teachers, facilities, programmes, or other policies could also contribute to the school performance. Since no data was available to relate other factors to the school performance, this study can only conclude that the school performance might have benefited or adversely affected by the policy. The type and location of school that benefited or adversely affected by the policy are discussed in the next sections.

6.3 Implications for the Performance of Different School-Type

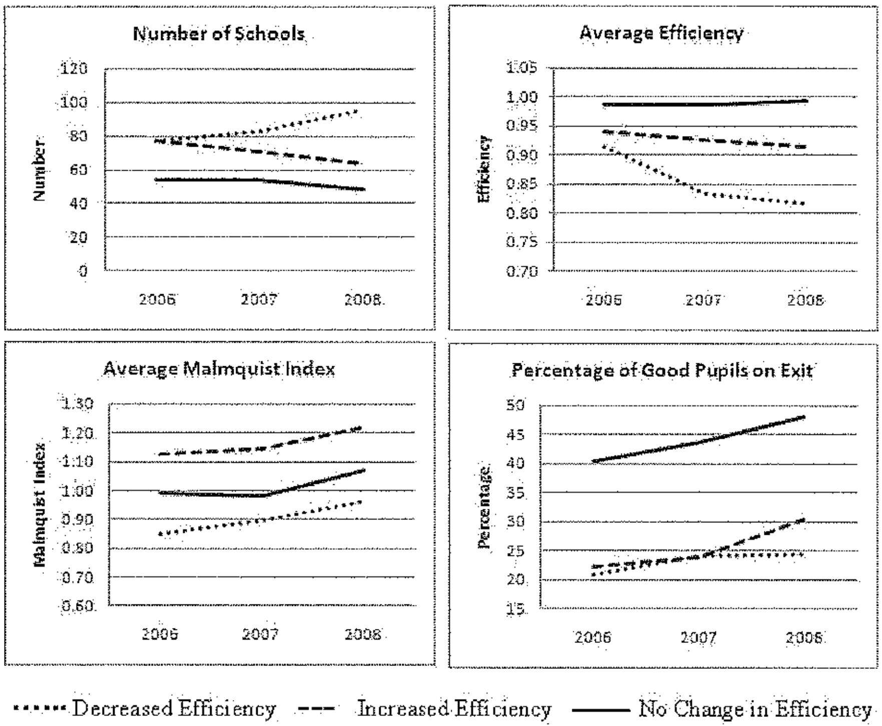
Throughout the period of this study, the average efficiency score shows that the fully residential is the most efficient school-type. The efficiency of the fully residential school-type was significantly better than the efficiency of the national school-type but there was no significant difference between the efficiencies of the fully residential and religious school-type. The efficiency of the national school-type was also significantly lower than the efficiency of the religious school-type. However, in terms of the change in performance over time (from 2007 to 2008), the national and religious school-types have shown a drastic progress in the performance but the fully residential school-type has shown a regress in the performance.

6.3.1 Implications for the Performance of the National School-type

The efficiency of the national school-type is similar to the overall school efficiency since the national school-type formed the majority of the samples in this study. The average efficiency of the national school-type in 2008 was significantly lower than in 2007 and 2006 due to the higher efficient boundary. It indicates that some schools performed much better in 2008 and pushed the efficient boundary higher but other schools were less efficient with respect to the new efficient boundary thus pulling the average efficiency down. Analysis on the three groups of schools as in the earlier section is presented in Figure 6.2. The Malmquist index in this Figure is based on the year on year productivity changes.

The number of schools in the decreased efficiency group increased in 2007 and 2008 while the number of schools in the increased efficiency group and the group that had no change in efficiency had decreased. The average efficiency for both the decreased efficiency and increased efficiency groups had decreased, which explain why the average efficiency in 2008 was significantly lower than in 2007 and 2006. The percentages of pupils with good grade on exit in the increased efficiency schools and those with no change in efficiency were on the rise. The gap between the percentages of pupils with good grade on exit of the increased efficiency and decreased efficiency groups was bigger in 2008. This can be associated with the drastic increase in the Malmquist index and the decrease in average efficiency score where the efficient schools had pushed the efficient boundary upward but the distance between the inefficient schools and the new efficient boundary became greater thus contributed to the lower average efficiency score.

Figure 6.2: Performance of the National School-Type



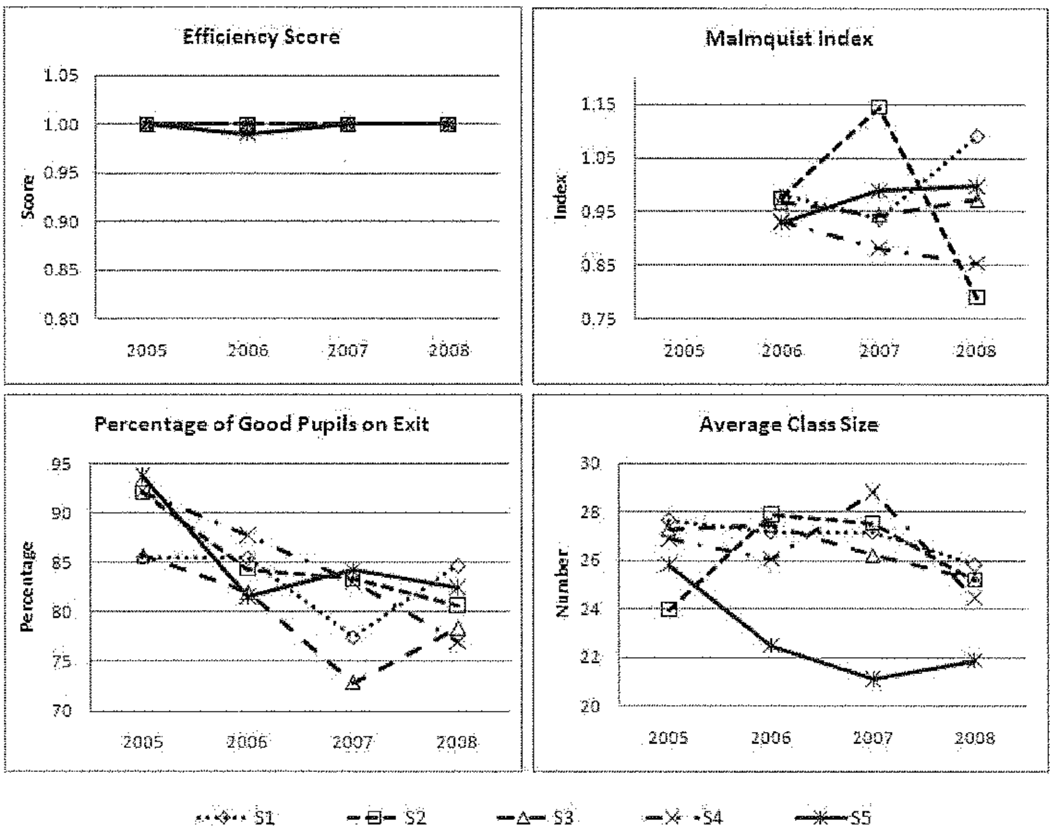
As in the progress of the overall schools discussed earlier, the progress of the fully efficient national schools that shifted the efficient boundary upward could also be associated with the efforts by the MOEM, the efforts by the schools themselves, and the high quality teachers and pupils that the school have. In general, although the efficiency of the national school-type was significantly lower than other types of schools, its performance has actually progressed significantly when compared to their performance in 2007. This finding contradicts with the finding of other studies which show that the national school-type performance was worse than the performances of other school-types after the implementation of the policy (Hamzah and Abdullah, 2009; Long, 2005). This finding indicates that the national schools might have benefited from the policy although there are some that might have been adversely affected by the policy.

6.3.2 Implications for the Performance of the Fully Residential School-Type

The trend of the fully residential school-type is completely different from the other school-types. All fully residential schools were fully efficient throughout the study period except for one school in 2006. However, the Malmquist index shows that the performance of the fully residential school-type regressed throughout the period of study. The regress attributed mostly to the technical change since the value of the efficiency change was very close to 1 in all periods and therefore did not affect the Malmquist index. The performance of the fully residential schools was analysed individually since there were only five of them. The analysis is shown in Figure 6.3.

Figure 6.3 shows the efficiency scores, the Malmquist index, the percentage of good quality pupils on exit, and the average class size of all fully residential schools. In general, the percentage of good quality pupils on exit was decreasing throughout the study period. Although the percentage is still better than those of the other school-types are, the decrease in the percentage of good quality pupils on exit resulted in a lower efficient boundary and contributed to the decrease in the Malmquist index. The Malmquist index in this Figure is based on the year on year productivity changes.

Figure 6.3: Performance of the Fully Residential School-Type



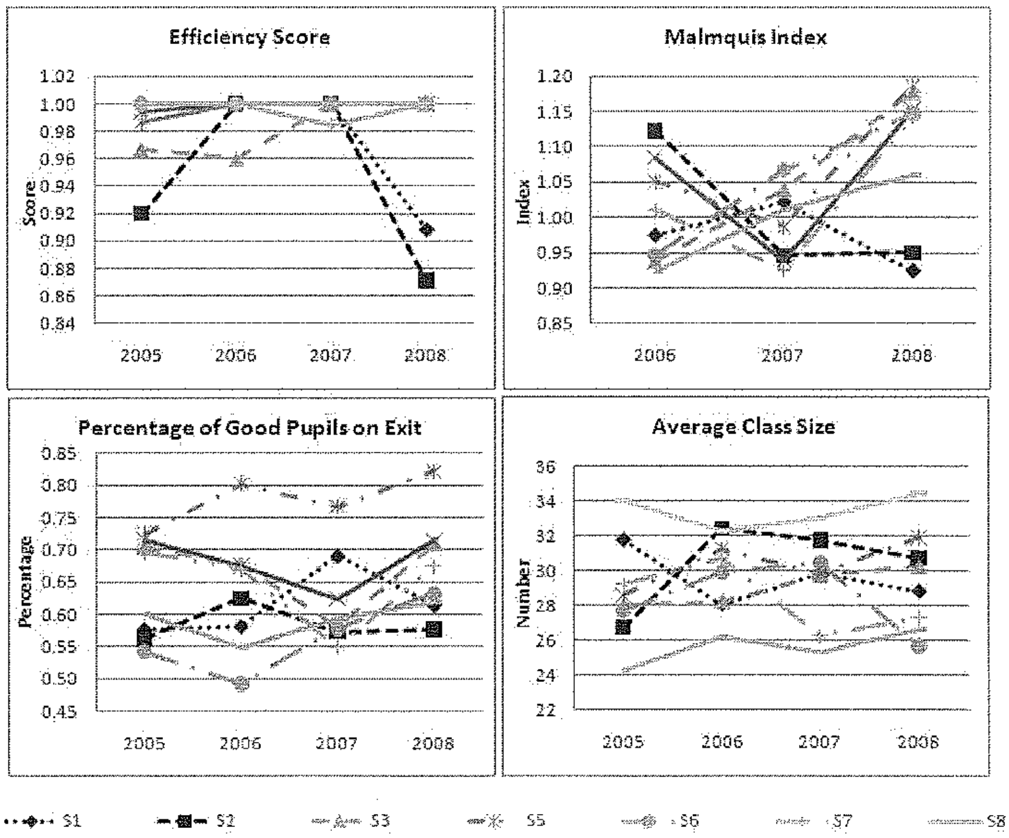
One school that is quite different from the others is S2 where in 2007 its performance progressed by almost 15 percent but in 2008, its performance regressed by more than 20 percent. The increase in the Malmquist index of S2 in 2007 could be associated with the increase in the percentage of pupils with good grade and the high average class size as compared to other schools. However, in 2008 both the percentage of pupils with good grade on exit and the average class size of S2 decreased considerably resulting in the regression of its performance. S5 is the school that was not fully efficient in 2006. This could be explained by the sharp decrease in both the percentage of pupils with good grade on exit and the average class size. Although the percentage of pupils with good grade increased after that, the average class size continued to drop further resulting in the regression of performance as shown by the Malmquist index.

It can be concluded that the performance of the fully residential schools regressed after the implementation of the policy even though all of them remained fully efficient. This could be the result of the decrease in the percentage of good quality pupils on exit. The regress in performance of the fully residential school-type is surprising because it is considered as the best school-type among all secondary school-types in Malaysia. Pupils in the fully residential schools are very good but are not necessarily proficient in English although they achieved grade A in English at the PMR level. Findings in Nor and Aziz (2009) could be used to explain the regress in performance of the fully residential schools. Nor and Aziz (2009) undertook a research to determine if the pupils performance in a fully residential school had improved or deteriorated as a consequences of the PPSMI policy. They concluded that only 36.4 percent of the pupils in their sample found it easier to understand the mathematical and science concepts in English and very few pupils felt that their mathematics and science grades had improved as a result of learning the subjects in English. They also said that 20.5 percent of the pupils complained that their performance deteriorated because of the PPSMI policy. This is consistent with the regression in performance of the fully residential schools as shown in this study.

6.3.3 Implications for the Performance of the Religious School-Type

The trend in performance of the religious school-type was the same with the national school-type where the performance, as shown by the Malmquist index, increased in 2008 when compared to their performance in 2007. However, the variation in performance has also increased as shown by the lower average efficiency among religious school-type. Since there were only eight religious schools in this study, the results of each school were analysed individually in order to get more understanding on the implications of the policy for their performance. Statistics on the individual school performance is given in Figure 6.4. The Malmquist index in this Figure is based on the year on year productivity changes.

Figure 6.4: Performance of the Religious School-Type



It seems that, after the implementation of the policy, two schools i.e. S1 and S2 contributed to the lower average efficiency scores. The Malmquist indices of these schools were less than 1. This could be associated with the percentages of pupils with good grade on exit and average class size. While the percentage of pupils with good grade on exit was on the rise for other schools, theirs have either decreased or stagnated and were among the lowest. At the same time, their average class size had also decreased. The decrease in the percentages of pupils with good grade in the two schools could be associated with the teachers, pupils, or the schools themselves but no conclusion could be made regarding the cause of the decrease since this study was not design to do that.

These results show that six religious schools in this study showed a better performance and two schools showed a lower performance after the implementation of the PPSMI policy. It can be implied that most religious schools benefited from the PPSMI policy although a few were adversely affected by the policy. The results from this study could not be compared with other studies since there is no study that specifically measures the implications of PPSMI policy for the performance of the religious school-type.

6.3.4 Summary of Implications for the Performance of Different School-Types

The efficiency of the national school-type in 2008 was significantly lower than its efficiencies in 2007 and 2006 but the Malmquist index shows that its performance progressed significantly in 2008 when compared to their performance in 2007. These indicate that some schools had a drastic increase in performance and contributed to the increase in the Malmquist index but at the same time, other schools did not progress as much as the fully efficient schools and contributed to the lower average efficiency scores. This finding shows in general that national schools might have benefited from the policy although there are some that might have been adversely affected by the policy.

All fully residential schools were fully efficient throughout the study period except for one school in 2006 but the Malmquist index shows that the performance of the fully residential school-type regressed throughout the study period. The percentage of pupils with good grade on exit of the fully residential school-type was the highest compared to other school-types and this could be the reason why they were fully efficient. However, the percentage decreased after the policy was implemented and this lead to the lower Malmquist index. In general, we can conclude that the performance of the fully residential school-type regressed after the implementation of the policy. The regress is unexpected considering the quality of its pupils.

The trend in performance of the religious school-type is the same with the national school-type where the performance of most of the religious school type progressed after the implementation of the policy. Out of the eight religious schools in this study, six showed a better performance and only two schools showed a lower performance after the policy was implemented. It can be implied that most of the religious schools benefited from the policy even though some were negatively affected.

6.4 Implications for the Performance of Schools in Different States

Penang is the most developed state and has more schools in urban location as compared to Kedah and Perlis. Many studies in Malaysia showed that schools in urban location perform better than schools in rural location (Hamzah and Abdullah, 2009; Surif et al., 2006; Kiong et al., 2005; Long, 2005; Swetz et al., 1983). It can be associated with factors like schools' facilities, parents' education, and socio-economic status. Thus, we can expect the performance of schools in Penang to be higher than the performance of schools in Kedah and Perlis. The examination results normally reflect this ranking.

In terms of efficiency scores as shown in Figure 4.11 in Chapter 4, schools in Kedah had the highest average efficiency scores followed by the efficiencies of schools in Penang and Perlis. This is more obvious before the implementation of the policy. This could be the result of value-added phenomenon where schools in Kedah produced better outputs (such as pupils with good grade on exit) with respect to their inputs (such as pupils with good grade on entry) as compared to schools in Penang.

The efficiencies of schools in all states were lower after the implementation of the policy with schools in Perlis and Kedah registered a significantly lower efficiency. The efficiencies of schools in Kedah and Penang were significantly higher than the efficiency of schools in Perlis after the implementation of the policy but there was no significant difference between the efficiencies of schools in Kedah and Penang throughout the study period.

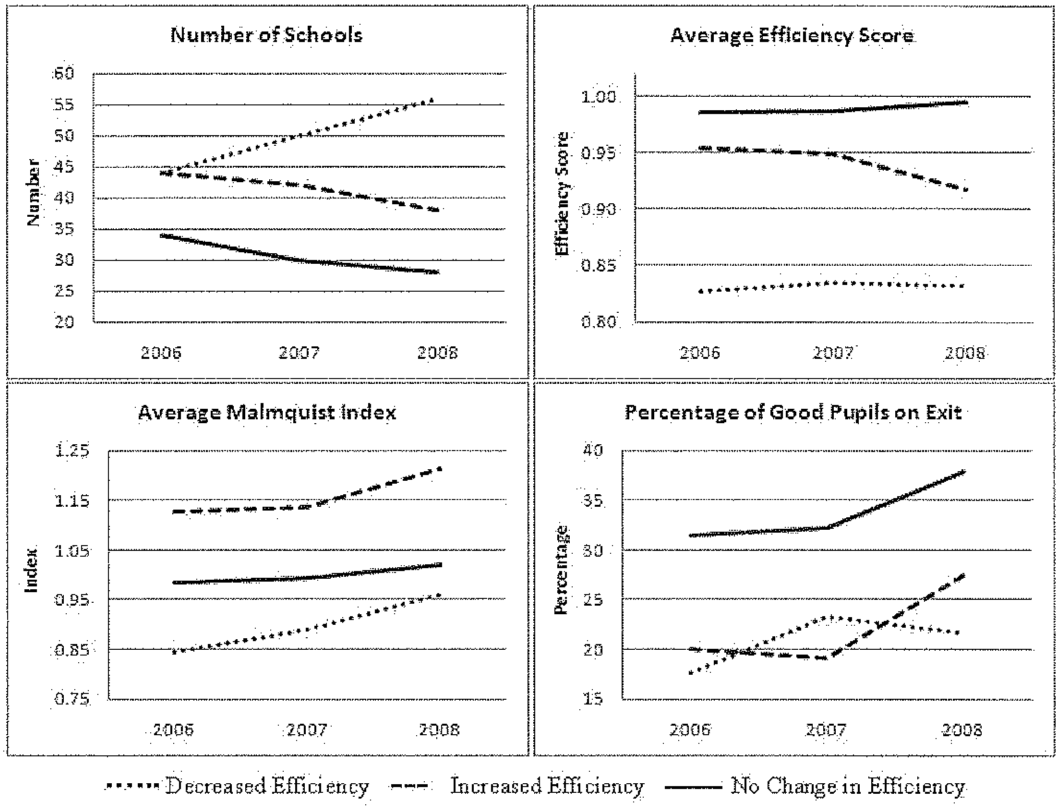
Analyses based on both year on year productivity changes and 2005 as the base year show that the schools performance in 2008 was better than their performance in 2007. The progress was significant for schools in Kedah and Penang but was not significant for schools in Perlis. A more detailed analysis based on the three different groups as in the previous sections is given in the following subsections. The Malmquist index in this analysis is based on the year on year productivity changes.

6.4.1 Implications for the Performance of Schools in Kedah

The average efficiency score of schools in Kedah was significantly lower after the implementation of the policy but the Malmquist index was significantly higher. Figure 6.5 shows the statistics of the performance of schools in Kedah. The number of schools in the decreased efficiency group increased while the number of schools in the other groups decreased after the implementation of the policy. In 2008, the average efficiency score of schools in the increased efficiency group dropped considerably but the average Malmquist index of schools in all groups increased. The percentage of pupils with good grade on exit for schools in the increased efficiency or no change in efficiency groups increased substantially but for schools in the decreased efficiency group, the percentage has dropped.

These findings indicate that schools in the increased efficiency group might have benefited from the policy since their percentage of pupils with good grade on exit had increased, which in turn pushed the efficient boundary up. However, the increase in the number of schools in the decreased efficiency group, which showed a decrease in the percentage of pupils with good grade on exit, indicates that the gap between their performance and the fully efficient one has widened. In general, schools in Kedah might have benefited from the PPSMI policy but at the same time, some schools might have been negatively affected by the implementation of the policy.

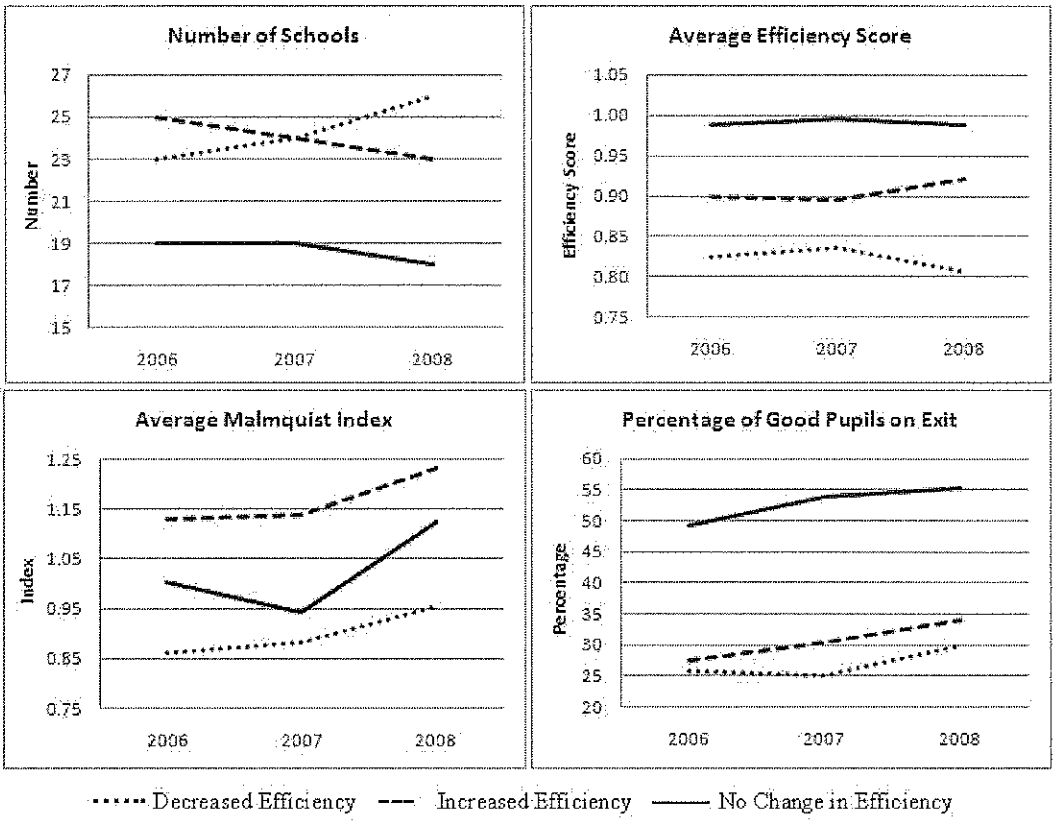
Figure 6.5: Performance of Schools in Kedah



6.4.2 Implications for the Performance of Schools in Penang

There was no significant difference in the average efficiency scores of schools in Penang before and after the implementation of the policy but the Malmquist index shows that their performance progressed significantly after the implementation of the policy. Figure 6.6 shows the statistics of school performance in Penang. In terms of the number of schools in each group, the trend in Penang is the same with Kedah where the number of schools in the decreased efficiency group increased while those in the increased efficiency and no change in efficiency groups decreased in 2007 and 2008. On the other hand, the average efficiency score of schools in the increased efficiency group and the percentage pupils with good grade on exit for all groups increased in 2008 unlike the trend in Kedah.

Figure 6.6: Performance of Schools in Penang



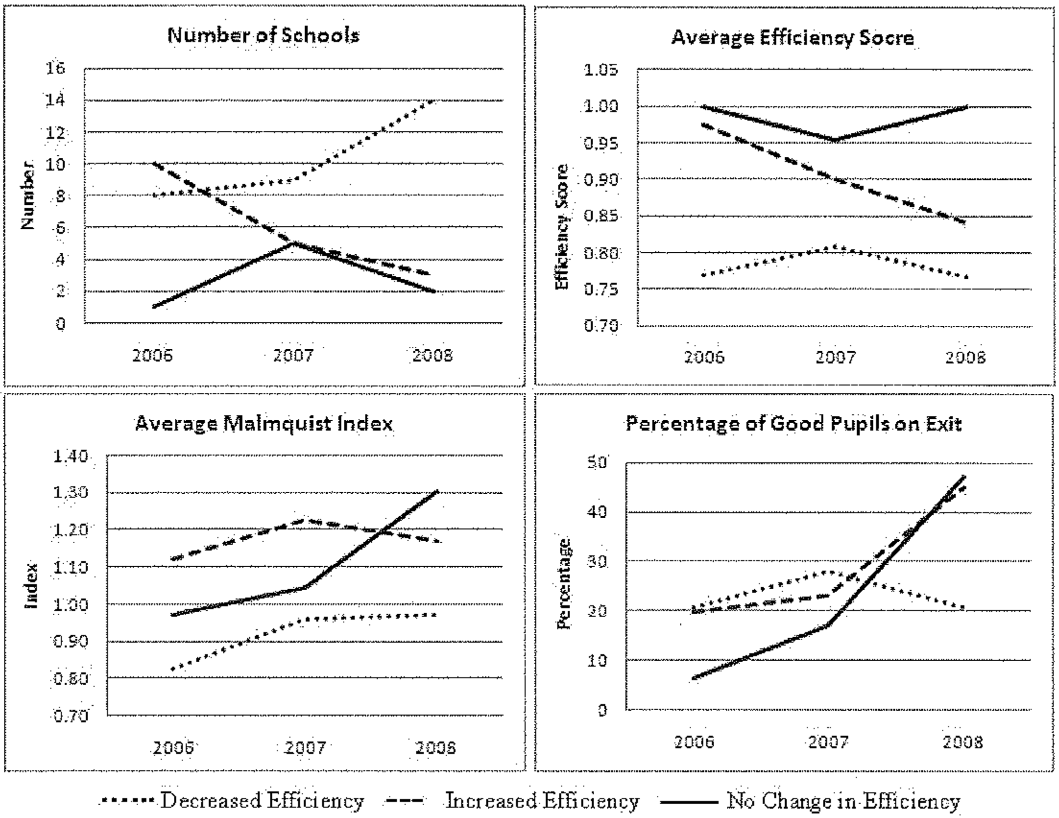
In general, these results indicate that the performance of schools in Penang started to progress significantly in 2008 when compared to their performance in 2007 where the efficient boundary had shifted upward due the increase in performance of fully efficient schools. On average, the performance of inefficient schools had also increased where their position relative to the new efficient boundary was about the same with their previous position relative to the previous boundary. Therefore, the difference between the average efficiency scores before and after the implementation of the policy was not significant. Hence, it could be concluded that the PPSMI policy might have benefited most of the schools in Penang.

6.4.3 Implications for the Performance of Schools in Perlis

The average efficiency score of schools in Perlis was significantly lower after the implementation of the policy but there was no significant difference in the Malmquist index in 2008 and 2007. Figure 6.7 shows the statistics of the school performance in Perlis. The trend for schools in Perlis was the same with the schools in Kedah and Penang where the number of lower efficiency schools increased after the implementation of the PPSMI policy.

However, the number of schools in the decreased efficiency was more than the number of schools in the increased efficiency or had no change in efficiency groups. The average efficiency scores and the Malmquist indices for schools in both increased and decreased efficiency groups decreased in 2008. The percentage of pupils with good grade on exit for the decreased efficiency group also dropped considerably in 2008. The large increase in the percentages of pupils with good grade on exit for schools in the increased efficiency and no change in efficiency groups indicates that these schools might have benefited from the policy. The Malmquist indices were not significantly different in the two periods (2008 and 2007) indicating that the efficient boundaries were about the same. However, the decline in performance of the inefficient schools increased the gap between them and the new efficient boundary.

Figure 6.7: Performance of Schools in Perlis



6.4.4 Summary of Implications for the Performance of Schools in Different States

The efficiency of schools in Kedah was significantly lower after the implementation of the policy but the change in performance as measured by the Malmquist index indicates that their performance started to progress significantly in 2008. This shows that the efficient boundary of schools in Kedah increased due to the increase in performance of efficient schools but it resulted in more schools became less efficient. In general, the policy might have benefited schools in Kedah but the variation in school efficiency has grown bigger.

The efficiency of schools in Penang shows no significant difference before and after the implementation of the policy but the Malmquist index indicates that their performance progressed significantly in 2008 when compared to their performance in 2007. These show that the performance of schools in Penang started to progress in the second year of the policy implementation. The average distances of schools relative to the efficient boundaries were about the same before and after the implementation of the policy and thus, the average efficiencies were not significantly difference. These findings indicate that the implementation of the PPSMI policy might have benefited schools in Penang. This is not surprising since most of the schools in Penang are located in urban area and there are more pupils with good command of English in Penang.

The efficiency of schools in Perlis was significantly lower after the implementation of the policy while the Malmquist index shows that there was no significant change in performance between their performance in 2008 and 2007. These indicate that the efficient boundaries in the two different periods of schools were about the same but the gap between the schools and the efficient boundary was bigger due to the decrease in performance of many schools after the implementation of the policy. These findings show that the performance of schools in Perlis might have been adversely affected by the implementation of the policy.

6.5 Implications for the Performance of Schools in Different Locations

Studies on the performance of urban and rural schools have reported mixed results. As Israel et al. (2001) indicate, there are various reasons why rural location would negatively affect educational outcomes, for example, socioeconomic disadvantage, increased inequality, physical and social isolation, and residential turnover. Cooksey et al. (1998) revealed that urban schools were more efficient than rural ones in Tanzania in terms of school access and performance. However, Soteriou et al. (1998) found no efficiency differences between rural and urban schools in Cyprus. Some studies indicate that rural schools perform better than their urban counterparts due to factors such as small school size, the orderly climate of the school, parental involvement, community support, teacher attentiveness, and more leadership opportunities for pupils (Illinois Institute for Rural Affairs, 2004, Raywid, 1999, Beck and Shoffstall, 2005). In Malaysia, many studies suggest that urban schools performed better than rural schools (Hamzah and Abdullah, 2009; Kiong et al., 2005; Long, 2005; Surif et al., 2006; Swetz et al., 1983).

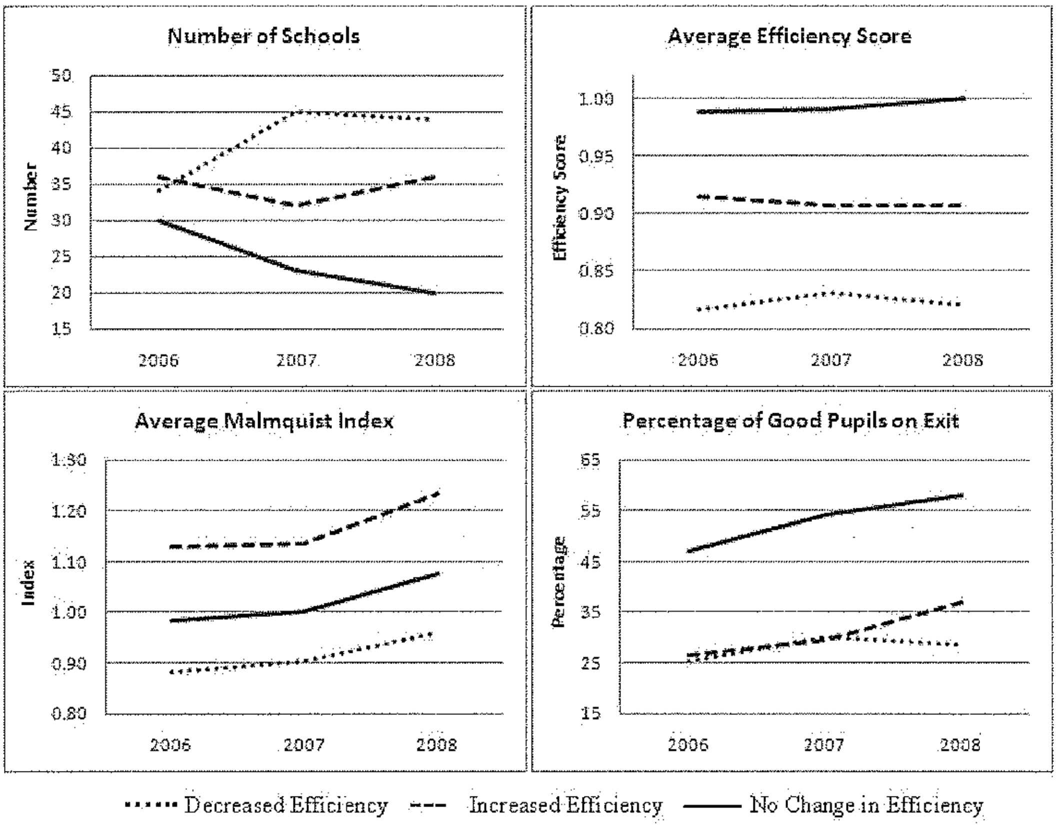
As shown in Chapter 4, the average efficiency of rural schools was higher than the average efficiency of urban schools before the implementation of the policy. After the policy was implemented, the efficiencies of schools in both locations decreased but the decrease in efficiency of rural schools is more than the decrease in efficiency of urban schools. In 2008, the percentage of fully efficient rural schools was much lower than the percentage of fully efficient urban schools. These show that the gap between the fully efficient and less efficient has widened and more schools in rural location became less efficient with regard to the new efficient boundary after the implementation of the policy.

The Malmquist indices based on both year on year productivity changes and 2005 as the base year show that the performance of schools in both locations was better in 2008 than in 2007. The progress attributed mainly to the increase in the technical change, which implies that the performance of the fully efficient schools that formed the efficient boundary progressed significantly after the implementation of the policy. The efficiency change however indicates that performance of urban schools progressed whereas performance of rural schools regressed after the implementation of the policy. There was no significant difference between the Malmquist indices of schools in urban and rural locations. A more detailed analysis according to the three groups as in the previous sections is given in the following subsections. The Malmquist index in this analysis is based on the year on year productivity changes.

6.5.1 Implications for the Performance of Schools in Urban Location

There was no significant difference in the average efficiency scores of urban schools before and after the implementation of the policy but the Malmquist index shows that their performance started to progress significantly in the second year of the policy implementation. Figure 6.8 shows the statistics of school performance in urban location. When the policy was first implemented in 2007, the number of schools in the decreased efficiency group increased but the number of schools in the increased efficiency and had no change in efficiency groups decreased. In 2008 however, the number of increased efficiency schools started to increase and the number of decreased efficiency schools started to decrease while schools that had no change in efficiency continue to drop further. The average efficiency scores for all groups have not changed much but the average Malmquist indices have increased. The percentages of pupils with good grade on exit for increased efficiency schools and schools that had no change in efficiency increased but for decreased efficiency schools, the percentage decreased after the policy was implemented.

Figure 6.8: Performance of Schools in Urban Location



These findings indicate that the performance of urban schools progressed in 2008 where the efficient boundary was significantly higher than in 2007. On average, the distance of urban schools relative to the new efficient boundary was about the same with the their distance relative to the previous efficient boundary and therefore, the difference in average efficiency scores before and after the implementation of the policy was not significant. However, some schools in urban location might have been adversely affected by the policy as shown by the lower percentage of pupils with good grade on exit in the decreased efficiency schools group. In general, we can conclude that many urban schools might have benefited from the implementation of the PPSMI policy.

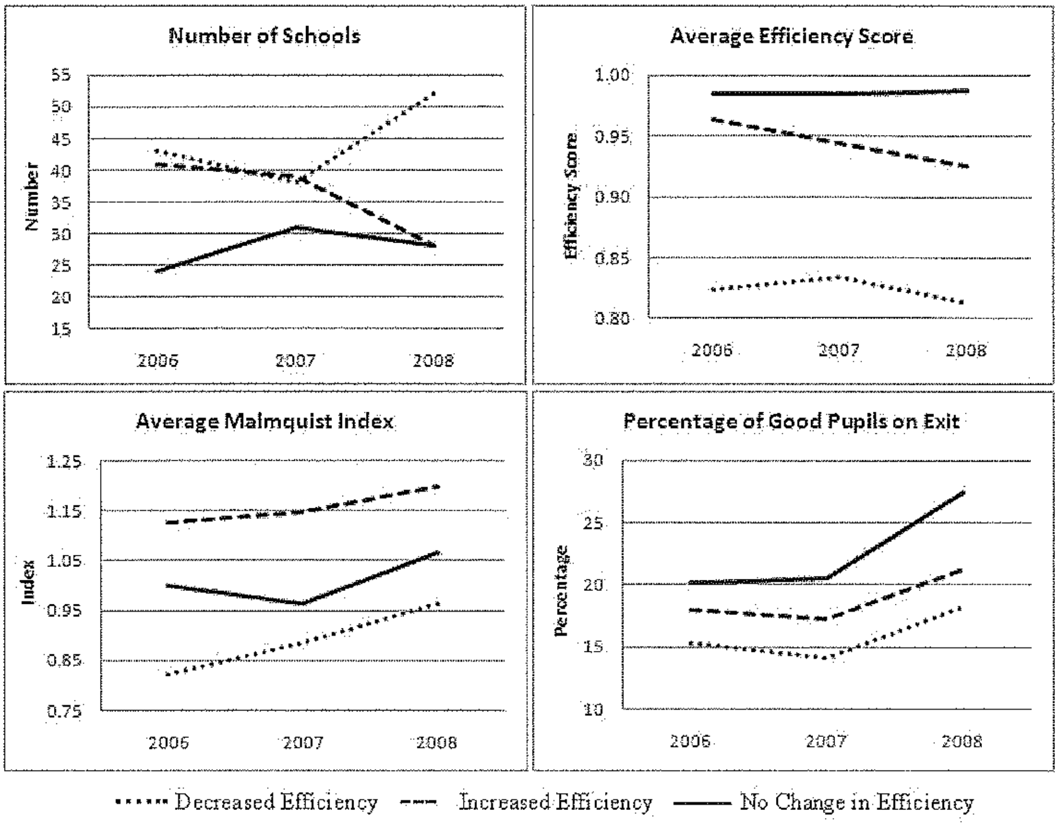
6.5.2 Implications for the Performance of Schools in Rural Location

The average efficiency score of rural schools was significantly lower after the implementation of the policy. However, the Malmquist index in 2008 was significantly higher than in 2007. This shows that the performance of schools in rural location started to improve in the second year of the policy implementation. Figure 6.9 shows the statistics of school performance in rural location. The number of schools in the decreased efficiency group increased considerably in 2008 while the number of schools in the other two groups decreased. The average efficiency scores of both increased efficiency and decreased efficiency groups decreased but the average Malmquist index and the percentage of good quality pupils on exit for all groups increased especially in 2008. The trend for the percentage of good quality pupils for rural schools in 2008 was different from urban schools where all three groups registered an increase. However, the percentages were much lower than the percentages of the same groups of urban schools. It indicates that the performance of urban schools improved more than the performance of rural schools thus creating a bigger distance between rural schools and the efficient boundary.

These findings show that more schools in rural location registered a lower efficiency after the implementation of the policy particularly in 2008. On average, rural schools performed better in the second year of the implementation of the policy and contributed to the higher Malmquist index in 2008. However, this lead to a bigger variation in the efficiency among rural schools where more schools in rural location became less efficient with regard to the new efficient boundary. This indicates that in general, schools in rural location benefited from the policy although some rural schools benefited much more and contributed to a higher efficient boundary and lead to a bigger gap between fully efficient and less efficient rural schools.

It is important to highlight that findings from this study and findings from other studies such as Hamzah and Abdullah (2009, Kiong et al. (2005), Long (2005), and Surif et al. (2006) are contradicted. This study shows that the performance of most schools increased started to increase in the second year of the implementation of the policy but other studies conclude that the implementation the PPSMI policy reduced the performance of both urban and rural schools. However, there is one similar finding between this study and other studies, i.e., the gap between the performance of urban and rural schools has widened after the PPSMI policy was implemented.

Figure 6.9: Performance of Schools in Rural Location



6.5.3 Summary of Implications for the Performance of Schools in Different Locations

There was no significant difference in the average efficiency scores of urban schools before and after the implementation of the policy but the Malmquist index shows that their performance started to progress significantly in the second year of the policy implementation. This indicates an increase in performance of both fully efficient and inefficient schools. In general, we can conclude that urban schools might have benefited from the implementation of the PPSMI policy.

The average efficiency score of rural schools was significantly lower after the implementation of the policy but the Malmquist index was significantly higher in the second year of the policy implementation. This indicates an increase in performance of both fully efficient and inefficient schools but the increase in performance of fully efficient schools was much higher than the increase in performance of inefficient schools thus creating a bigger variation in the efficiency of rural schools with regard to the new boundary.

6.6 Summary and Conclusion

This chapter discussed the implications of the PPSMI policy for the performance of secondary schools in mathematics and science subjects. Overall, the performance of the fully efficient schools progressed significantly after the implementation of the policy but this resulted in a bigger gap between the performance of efficient and inefficient schools. Based on the Malmquist index, the type of schools that might have benefited more from the policy are religious schools and urban national schools. The performance of the fully residential school-type, despite being fully efficient throughout the study period, unexpectedly regressed after the implementation of the policy. Among schools in the three states, schools in Penang and Kedah might have benefited the most from the policy. The progress in performance of urban schools could be associated with the progress of in performance of schools in Penang since most of the schools in Penang are located in urban location.

Generally, school performance regressed immediately after the policy was implemented in 2007 but started to progress significantly in 2008 when compared to their performance in 2007. One possible explanation for the drop in performance in 2007 is that the inability of both teachers and pupils to use English effectively. Another possible explanation is the new technology (courseware and LCD projector) might have not been fully utilised to facilitate the teaching and learning process due to shortcomings such as lack of knowledge and technical problems in using them.

Although the average efficiency seems to have dropped considerably in 2008, this is actually due to the drastic increase in the technical change, which created a greater distance between the inefficient schools and the efficient boundary, thus reducing the average efficiency. The drastic increase in the technical change in 2008 could result from the efforts by the MOEM to improve the implementation of the policy. It could also be the result of the initiatives from the school itself and the ability of teachers and pupils themselves where some schools have well-qualified and competent English-speaking teachers as well as many pupils from high socioeconomic background who would benefit from the use of English as a medium of instruction.

However, some people see the drastic increase in performance as doubtful because findings from many studies indicate that teachers and pupils were having problems to use English as the medium of instruction. Despite the problems, school performance had progressed drastically in 2008. This contributed to the suspicion that the increase was not genuine or the passing mark has been lowered to show that the policy is not affecting the performance in mathematics and science subjects but it was denied by the MOEM.

Based on the results of this study, it can be concluded that the MOEM should have continued with the PPSMI policy since schools performance was improving after the policy was implemented. The performance of some schools including in rural location have improved significantly under the policy. If the MOEM want to stick to its decision to revert to the use of Bahasa Malaysia, it might be a good idea to let the schools that have improved significantly to continue using English in the teaching and learning process of mathematics and science subjects. The objective of implementing the policy in the first place is to help pupils in accessing the information and knowledge in science and technological field where most of the information is in English. Significant resources have been spent and a great deal of efforts have been put to the implementation of this policy thus it would be great to let those who are benefiting from the policy to continue with it.

CHAPTER 7

CONCLUSION

7.1 Introduction

This study set out to investigate the implications of the PPSMI policy for the performance of Malaysian secondary schools in mathematics and science subjects. This was motivated by the need to assess the implications of the policy by using advanced techniques of efficiency measurement to enhance the current literature of the PPSMI policy studies and to get a better understanding of the implications of the policy for the school performance.

The techniques used in this study are the HRS-based Data Envelopment Analysis (DEA) and the Malmquist index. The HRS-based DEA model is a new extension in DEA based on the concept of selective proportionality in the relationship of input-output variables. It gives a better estimate compared to the original convex models, the CRS and VRS, when some of the inputs and outputs have proportional relationship while others do not. The Malmquist index is a tool for measuring efficiency over time. In this study HRS-based Malmquist index was developed to measure the change in school efficiency before and after the implementation of the PPSMI policy.

This chapter is set out as follows. Section 7.2 gives an overview of the research findings. Then, section 7.3 discusses the contributions of the study to the field of DEA and education. Section 7.4 provides direction for future research and lastly, section 7.5 offers some concluding remarks.

7.2 Overview of the Research Findings

An HRS-based DEA model utilising 10 inputs and 8 outputs was developed to assess the school efficiency in implementing the PPSMI policy. 221 schools from three states namely, Kedah, Penang, and Perlis, which comprise three different types, namely, the national, fully residential, and religious, were selected for this study. The school efficiency in implementing the PPSMI policy was computed using all three models, the CRS, VRS and HRS models and the scores were compared and tested for significant difference. The HRS model was found to be significantly the most discriminating compared to the CRS and VRS models where most of the scores under the HRS model were lower than the other two models. Some of the scores were the same with the other models while only a few were higher than those from the CRS model were. The efficiency scores from the HRS model were then used to analyse the performance of schools in different categories.

After the first year of the policy implementation, the overall school efficiency was not significantly different with the previous year but in 2008, the average efficiency was significantly lower than in the years before that. This resulted from the decrease in the number of fully efficient schools and the increase in the number of inefficient schools, which indicates that more schools were less efficient with respect to the new efficient boundary. The Malmquist index confirms that the lower efficiency was caused by the increase in the performance of fully efficient schools, which pushed the efficient boundary higher, thus increased the distance of the inefficient schools from the efficient boundary.

The Malmquist index indicates a progression in performance of the national and religious school types but a regression in performance of the fully residential school type in 2008. The change in performance attributed mostly to the technical change, which pushed the efficient boundary to be significantly higher in 2008 as compared to 2007 and 2006. The higher efficient boundary has led to a bigger variation in efficiencies. Among the three types of school, the national school type recorded a significantly lower efficiency score in 2008 whereas for the fully residential and religious school type, there was no significant difference in their efficiency scores before and after the implementation of the policy. However, the insignificant difference in the efficiency of the fully residential and religious schools might be due to small number of these types of school in this study.

The higher efficient boundary and the lower average efficiency of the national school type in 2008 means the performance of fully efficient national schools progressed significantly but the inefficient schools had either regressed, stagnated or did not progress as much as the fully efficient schools. Thus, the gap between the performance of the fully efficient and inefficient schools grew bigger and therefore reduced the average efficiency score with respect to the new efficient boundary. This means some of the national schools might have benefited much from the policy thus their performance increased significantly.

Analysis of the national schools performance in different states shows that schools in Penang might have benefited the most from the policy while schools in Perlis might have benefited the least from the policy. This is drawn from the Malmquist indexes and the average efficiency scores where in 2008; the Malmquist index of schools in Penang increased significantly but there was no significant difference in the average efficiency scores of 2008 and the years before that. This indicates an increase in performance of the fully efficient schools, which pushed the efficient boundary significantly higher, as well as an increase in the performance of the inefficient schools since their efficiency with respect to the new higher efficient boundary was about the same with their previous efficiency with respect to the previously lower efficient boundary.

Schools in Perlis on the other hand, did not show a significant difference in the Malmquist index, which means the performance of the fully efficient schools in Perlis that formed the efficient boundary, did not change significantly. However, the average efficiency with respect to the relatively the same efficient boundary was significantly lower. This demonstrates that the gap in performance of fully efficient and inefficient schools in Perlis was bigger in 2008 and this might be the result of the implementation of the PPSMI policy. For schools in Kedah, the Malmquist index progressed significantly but the average efficiency was significantly lower in 2008. This indicates a significant progress in the performance of fully efficient schools but the inefficient schools had either regressed, stagnated, or did not progress as much as the fully efficient schools. Thus, it can be concluded that some schools in Kedah benefited much from the policy thus reflected in their big performance increase while some schools might had no effect in their performance.

Analysis of the national schools efficiency in different locations reveals that urban schools performed better than rural schools after the policy was implemented. The average efficiency of rural schools was significantly lower in 2008 and there was no significant difference for urban schools. The Malmquist indexes of schools in both locations were significantly higher in 2008. The results of the Malmquist index indicate significant progression in performance of fully efficient schools in both locations while the lower average efficiency of rural schools with respect to the new efficient boundary means the performance of inefficient rural schools might have been negatively affected by the PPSMI policy. The progress in performance of urban schools could be associated with the progress of schools in Penang because many schools in Penang are located in urban locations.

The fully residential school type remained fully efficient after the policy was implemented but the Malmquist index shows that its performance regressed throughout the study especially in 2008. The regression in performance of the fully residential school type was unexpected due to the high quality of pupils attending this type of schools. The regress could be associated with the lower percentage of good quality pupils on exit although the percentage was the highest among all types of schools in this study. It could be the result of the inability of some pupils in these schools to use English effectively in the process of teaching and learning. As showed in the study by Nor and Aziz (2009), more than 20 percent of a fully residential school complained that their performance deteriorated after the policy was implemented. Since the percentage of good quality pupils in the residential type was normally nearly 100 percent, a relatively lower percentage (although still high compared to other schools) would result in the regression of performance.

Most of the religious schools in this study showed a progression in performance after the policy was implemented especially in 2008. Only two out of eight religious schools in this study showed a regression in performance. Thus, it can be concluded that the policy might have benefited the religious schools. However, the conclusion cannot be made with certainty because the change in performance could be the result of other factors that are not within the scope of this study. Findings about the religious schools could not be compared with other studies since there was no study that specifically measures the implications of the PPSMI policy for the religious schools.

In general, school performance regressed when the policy was first implemented in 2007 but started to progress significantly in 2008, two years after the implementation of the policy. This phenomenon might be associated with the inability of both teachers and pupils to use English effectively in the beginning. In 2008, the school performance progressed significantly as shown by the significantly drastic increase of the Malmquist index. It could result from the efforts by the MOEM to improve the implementation of the policy, the initiatives from the school itself and the ability of teachers and pupils with well-qualified and competent English-speaking teachers as well as many pupils from high socioeconomic background who would benefit from the use of English as a medium of instruction. However, some people doubted the drastic increase in performance because, based on findings from many studies, teachers and pupils were having problems to use English as the medium of instruction. They suspected that the increase was not genuine where the passing mark has been lowered to show that the policy is not affecting the school performance. This was dismissed by the MOEM (Malaysian Parliament, 2009).

The decision by the MOEM to revert the PPSMI policy contradicts with the findings from this study, which shows that the overall school performance started to progress after the second year of the policy implementation. Based on the findings from this study, the policy should be continued for many more years in order to gain the benefit from it. If the MOEM is firm with its decision to revert to the use of Bahasa Melayu in the teaching of mathematics and science subjects, schools that benefited much from this policy must be given the opportunity to continue with using English in the teaching and learning process of mathematics and science subjects. The objective of implementing the policy is to help pupils in accessing the information and knowledge in science and technological field where most of the information is in English and a lot of money has been spent and a great deal of efforts have been put to the implementation of this policy. Therefore, those who are benefiting from the policy and prefer to use English in the teaching and learning process must be allowed carry on with the PPSMI policy.

7.3 Contributions of Study

The main contributions of this study are as follows:

i. The development of a new method of measuring school efficiency in mathematics and science subjects based on the HRS DEA model. The model combined the assumption of CRS with respect to the selected sets of inputs and outputs, while preserving the VRS assumption with respect to the remaining indicators. The new methodology was used to measure the Malaysian school efficiency in implementing the PPSMI policy.

ii. The development of an HRS-based Malmquist index to measure change in efficiency over time. The HRS-based Malmquist index was developed by modifying the VRS-based Malmquist index to accommodate the C-HRS technology. C-HRS is the cone extension of the HRS technology just as CRS is the cone extension of the VRS technology. C-HRS is a technology resulting from the synchronisation of axioms in the CRS technology and the axiom of selective proportionality. Some Malmquist index studies utilised CRS technology and some studies utilised VRS technology in calculating the Malmquist index while some other studies used both models. This study is the first that utilised the HRS and C-HRS technologies in calculating the Malmquist index.

iii. The utilisations of HRS-based DEA model to assess the school performance in implementing the PPSMI policy. Podinovski (2004) introduced the HRS model and this is the first practical application of the HRS model.

iv. The use of HRS-based Malmquist index to evaluate the change in performance based on year on year productivity changes as well as by using 2005 as the base year which emphasis on two different periods, i.e. before and after the implementation of the PPSMI policy. This technique has never been used to measure the implications of the PPSMI policy for the school performance.

v. Analyse the implications of the PPSMI policy for the performance of schools in different school-types, states, and locations. Efficiency and change in efficiency of schools in different groups were analysed and tested using statistical tests to examine the difference in performance of schools in different groups.

This is the first study that utilised the HRS DEA model and the HRS-based Malmquist index to measure school performance. This study contributes to the evaluation of the PPSMI policy by looking at the implications of the policy from a different perspective. It is hoped that this study contributes to a better understanding of the implications of the policy for the schools performance and thus help MOEM to decide on the future direction of the policy.

7.4 Directions for Future Research

This study could be a template for future research in the assessment of school efficiency. Further extensions to this study are possible in a number of ways. Among them are:

i. The use of more specific variables to obtain results that are more accurate. Among the variables that could be used are quality of teachers such as teachers' experience and qualifications, school facilities such as the number of science laboratories, equipment, and books, and environmental variables such as parents' academic qualification and facilities at home.

ii. Measure the implications of the policy for the pupils' attainment in English. This is important since one of the objectives of the change in policy is to improve pupils' proficiency in English. However, it cannot be done in this study due to unavailable data.

iii. Include the second stage analysis to evaluate the factors contributing to the efficiencies. The results from this study could be associated with school-specific programmes to improve the implementation of the policy, which might have been conducted by the schools themselves. The second stage analysis might be able to correlate the efficiency scores to those programmes.

iv. Increase the number of schools from each group to improve the validity and reliability of the results, especially the number of schools in the fully residential and religious school types. The small number of schools in these groups has made it difficult to find any significant differences in their performances.

v. Add more groups in each category such as more states and more type of schools to obtain a more comprehensive result. There are 14 states and 6 types of secondary schools altogether. The inclusion of schools in all states and types would produce results that are more comprehensive and would be more useful in understanding the implications of the policy for the school performance. This study is limited to schools from three states and three school-type due to unavailability of data.

vi. Actually, by simply checking how students do in maths and sciences is not enough to assess the impact of the PPSMI policy. It is better to conduct a more comprehensive assessment of the impact of the PPSMI policy by following a cohort after leaving school to find out whether they cope better later in life with studies and work.

7.5 Concluding Remarks

The study opens up a new way of measuring school efficiency. Although the model developed in this study is specific for the assessment of the school efficiency in implementing the PPSMI policy, it can be generalised to measure the level of school efficiency in general by selecting suitable inputs and outputs. This study also opens up a new way of evaluating the implications of the PPSMI policy for the school performance.

Using the methods that are have not been used in the assessment of school performance in Malaysia is one of the main motivations for this study. By using a new method, this study gives a different perspective to the study of the PPSMI policy and ensures beneficial inputs to the understanding of the policy. This study may encourage future research on school efficiency based on the HRS DEA model or other DEA models especially in Malaysia where this method is not common.

APPENDIX TO CHAPTER 3

A3.1: The Output Oriented CRS Model

$$
\begin{aligned}
&\text{Max} \quad Z \\
&\text{Subject to} \\
&\sum_{j=1}^{n} MC_j \lambda_j \leq MC_o \\
&\sum_{j=1}^{n} SC_j \lambda_j \leq SC_o \\
&\sum_{j=1}^{n} PC_j \lambda_j \leq PC_o \\
&\sum_{j=1}^{n} CC_j \lambda_j \leq CC_o \\
&\sum_{j=1}^{n} BC_j \lambda_j \leq BC_o \\
&\sum_{j=1}^{n} GMS_j \lambda_j \leq GMS_o \\
&\sum_{j=1}^{n} GSS_j \lambda_j \leq GSSC_o \\
&\sum_{j=1}^{n} HSES_j \lambda_j \leq HSESC_o \\
&\sum_{j=1}^{n} MS_j \lambda_j \geq Z\, MS_o \\
&\sum_{j=1}^{n} SS_j \lambda_j \geq Z\, SS_o \\
&\sum_{j=1}^{n} PS_j \lambda_j \geq Z\, PS_o \\
&\sum_{j=1}^{n} CS_j \lambda_j \geq Z\, CS_o \\
&\sum_{j=1}^{n} BS_j \lambda_j \geq Z\, BS_o \\
&\sum_{j=1}^{n} GMS_j \lambda_j \geq Z\, GMS_o \\
&\sum_{j=1}^{n} GSS_j \lambda_j \geq Z\, GSS_o \\
&\sum_{j=1}^{n} GPS_j \lambda_j \geq Z\, GPS_o \\
&\sum_{j=1}^{n} GCS_j \lambda_j \geq Z\, GCS_o \\
&\sum_{j=1}^{n} CBS_j \lambda_j \geq Z\, GBS_o \\
&\lambda_j \geq 0 \quad \text{for all } j = 1, \ldots, n \\
&Z \; free
\end{aligned}
$$

The output oriented VRS model is almost the same as CRS model except for one extra condition: $\sum_{j=1}^{n} \lambda_j = 1$.

The output oriented HRS model in this study is as follows:

$$
\begin{aligned}
&\text{Max} \quad Z \\
&\text{Subject to} \\
&\sum_{j=1}^{n} MC_j\lambda_j + \sum_{j=1}^{n} MC_j\mu_j - \sum_{j=1}^{n} MC_j v_j \le MC_o \\
&\sum_{j=1}^{n} SC_j\lambda_j + \sum_{j=1}^{n} SC_j\mu_j - \sum_{j=1}^{n} SC_j v_j \le SC_o \\
&\sum_{j=1}^{n} PC_j\lambda_j + \sum_{j=1}^{n} PC_j\mu_j - \sum_{j=1}^{n} PC_j v_j \le PC_o \\
&\sum_{j=1}^{n} CC_j\lambda_j + \sum_{j=1}^{n} CC_j\mu_j - \sum_{j=1}^{n} CC_j v_j \le CC_o \\
&\sum_{j=1}^{n} BC_j\lambda_j + \sum_{j=1}^{n} BC_j\mu_j - \sum_{j=1}^{n} BC_j v_j \le BC_o \\
&\sum_{j=1}^{n} GMSN_j\lambda_j \le GMSN_o \\
&\sum_{j=1}^{n} GSSN_j\lambda_j \le GSSN_o \\
&\sum_{j=1}^{n} HSES_j\lambda_j \le HSES_o \\
&\sum_{j=1}^{n} MS_j\lambda_j + \sum_{j=1}^{n} MS_j\mu_j - \sum_{j=1}^{n} MS_j v_j \ge Z\,MS_o \\
&\sum_{j=1}^{n} SS_j\lambda_j + \sum_{j=1}^{n} SS_j\mu_j - \sum_{j=1}^{n} SS_j v_j \ge Z\,SS_o \\
&\sum_{j=1}^{n} PS_j\lambda_j + \sum_{j=1}^{n} PS_j\mu_j - \sum_{j=1}^{n} PS_j v_j \ge Z\,PS_o \\
&\sum_{j=1}^{n} CS_j\lambda_j + \sum_{j=1}^{n} CS_j\mu_j - \sum_{j=1}^{n} CS_j v_j \ge Z\,CS_o \\
&\sum_{j=1}^{n} BS_j\lambda_j + \sum_{j=1}^{n} BS_j\mu_j - \sum_{j=1}^{n} BS_j v_j \ge Z\,BS_o \\
&\sum_{j=1}^{n} GMSX_j\lambda_j - \sum_{j=1}^{n} GMSX_j v_j \ge Z\,GMSX_o \\
&\sum_{j=1}^{n} GSSX_j\lambda_j - \sum_{j=1}^{n} GSSX_j v_j \ge Z\,GSSX_o \\
&\sum_{j=1}^{n} GPSX_j\lambda_j - \sum_{j=1}^{n} GPSX_j v_j \ge Z\,GPSX_o \\
&\sum_{j=1}^{n} GCSX_j\lambda_j - \sum_{j=1}^{n} GCSX_j v_j \ge Z\,GCSX_o \\
&\sum_{j=1}^{n} GBSX_j\lambda_j - \sum_{j=1}^{n} GBSX_j v_j \ge Z\,GBSX_o \\
&\sum_{j=1}^{n} \lambda_j = 1 \\
&\lambda_j \ge v_j \qquad \text{for all } j = 1, \ldots, n \\
&\lambda_j,\ \mu_j,\ v_j \ge 0 \qquad \text{for all } j = 1, \ldots, n \\
&Z \ free
\end{aligned}
$$

Notations in the models are as follows:

MC	-	mathematics class
SC	-	science class
PC	-	physics class
CC	-	chemistry class
BC	-	biology class
GMSN	-	good mathematics pupils on entry
GSSN	-	good science pupils on entry
HSES	-	high socio economic status
MS	-	mathematics pupils
SS	-	science pupils
PS	-	physics pupils
CS	-	chemistry pupils
BS	-	biology pupils
GMSX	-	good mathematics pupils on exit
GSSX	-	good science pupils on exit
GPSX	-	good physics pupils on exit
GCSX	-	good chemistry pupils on exit
GBSX	-	good biology pupils on exit

A3.2: Calculation of Efficiency Scores under the HRS model

To calculate the efficiency scores of each school, data of all schools are placed in a table as in Table A3.1. The table is created in Ms Excel spreadsheet. A mathematical programming software is used to solve the models by reading the data from and outputting the results back in the same spreadsheet file.

Table A3.1: Example of Data Table

DMU	I1	I2	I3	I4	I5	I6	I7	I8	O1	O2	O3	O4	O5	O6	O7	O8	O9	O10
S1	6	5	1	1	1	70	30	6	156	132	24	24	24	52	23	8	10	6
S2	14	10	4	4	4	267	161	13	482	340	141	142	141	207	83	76	78	37
S3	9	7	2	2	2	73	62	14	267	224	29	43	39	34	39	3	5	3
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
S236	5	1	4	4	4	146	150	68	139	26	113	113	113	135	26	63	71	53
S237	4	1	3	3	2	138	139	37	116	23	93	93	64	110	22	23	23	20

The calculation of efficiency score under the HRS assumption is done by forming the following matrices based on Theorem 2 in Podinovski (2004) and data from the above table.

$$\overline{X} = \begin{pmatrix} 6 & 14 & 9 & \dots & 5 & 4 \\ 5 & 10 & 7 & \dots & 1 & 1 \\ 1 & 4 & 2 & \dots & 4 & 3 \\ 1 & 4 & 2 & \dots & 4 & 3 \\ 1 & 4 & 2 & \dots & 4 & 2 \\ 70 & 267 & 73 & \dots & 146 & 138 \\ 30 & 161 & 62 & \dots & 150 & 139 \\ 6 & 13 & 14 & \dots & 68 & 37 \end{pmatrix} \quad \overline{Y} = \begin{pmatrix} 156 & 482 & 267 & \dots & 139 & 116 \\ 132 & 340 & 224 & \dots & 26 & 23 \\ 24 & 141 & 29 & \dots & 113 & 93 \\ 24 & 142 & 43 & \dots & 113 & 93 \\ 24 & 141 & 39 & \dots & 113 & 64 \\ 52 & 207 & 83 & \dots & 135 & 110 \\ 23 & 83 & 39 & \dots & 26 & 22 \\ 8 & 76 & 3 & \dots & 63 & 23 \\ 10 & 78 & 5 & \dots & 71 & 23 \\ 6 & 37 & 3 & \dots & 53 & 20 \end{pmatrix}$$

$$\widehat{X} = \begin{pmatrix} 6 & 14 & 9 & \dots & 5 & 4 \\ 5 & 10 & 7 & \dots & 1 & 1 \\ 1 & 4 & 2 & \dots & 4 & 3 \\ 1 & 4 & 2 & \dots & 4 & 3 \\ 1 & 4 & 2 & \dots & 4 & 2 \\ 0 & 0 & 0 & \dots & 0 & 0 \\ 0 & 0 & 0 & \dots & 0 & 0 \\ 0 & 0 & 0 & \dots & 0 & 0 \end{pmatrix} \quad \widehat{Y} = \begin{pmatrix} 156 & 482 & 267 & \dots & 139 & 116 \\ 132 & 340 & 224 & \dots & 26 & 23 \\ 24 & 141 & 29 & \dots & 113 & 93 \\ 24 & 142 & 43 & \dots & 113 & 93 \\ 24 & 141 & 39 & \dots & 113 & 64 \\ 0 & 0 & 0 & \dots & 0 & 0 \\ 0 & 0 & 0 & \dots & 0 & 0 \\ 0 & 0 & 0 & \dots & 0 & 0 \\ 0 & 0 & 0 & \dots & 0 & 0 \\ 0 & 0 & 0 & \dots & 0 & 0 \end{pmatrix}$$

To assess the output radial efficiency of School 1, the model takes on the following form based the output oriented HRS model.

Max $\quad z$

Subject to

$6\lambda_1 + 14\lambda_2 + \dots + 5\lambda_{78} + 4\lambda_{79} + 6\mu_1 + 14\mu_2 + \dots + 5\mu_{78} + 4\mu_{79} - 6v_1 - 14v_2 - \dots - 5v_{78} - 4v_{79} \le 6$

$5\lambda_1 + 10\lambda_2 + \dots + 1\lambda_{78} + 1\lambda_{79} + 5\mu_1 + 10\mu_2 + \dots + 1\mu_{78} + 1\mu_{79} - 5v_1 - 10v_2 - \dots - 1v_{78} - 1v_{78} \le 5$

$1\lambda_1 + 4\lambda_2 + \dots + 4\lambda_{78} + 3\lambda_{79} + 1\mu_1 + 4\mu_2 + \dots + 4\mu_{78} + 3\mu_{79} - 1v_1 - 4v_2 - \dots - 4v_3 - 3v_4 \le 1$

$1\lambda_1 + 4\lambda_2 + \dots + 4\lambda_{78} + 3\lambda_{79} + 1\mu_1 + 4\mu_2 + \dots + 4\mu_{78} + 3\mu_{79} - 1v_1 - 4v_2 - \dots - 4v_3 - 3v_4 \le 1$

$1\lambda_1 + 4\lambda_2 + \dots + 4\lambda_{78} + 2\lambda_{79} + 1\mu_1 + 4\mu_2 + \dots + 4\mu_{78} + 2\mu_{79} - 1v_1 - 4v_2 - \dots - 4v_3 - 2v_4 \le 1$

$70\lambda_1 + 267\lambda_2 + \dots + 146\lambda_{78} + 138\lambda_{79} \le 70$

$30\lambda_1 + 161\lambda_2 + \dots + 150\lambda_{78} + 139\lambda_{79} \le 30$

$6\lambda_1 + 13\lambda_2 + \dots + 68\lambda_{78} + 37\lambda_{79} \le 6$

$156\lambda_1 + 482\lambda_2 + \dots + 139\lambda_{78} + 116\lambda_{79} + 156\mu_1 + 482\mu_2 + \dots + 139\mu_{78} + 116\mu_{79} - 156v_1 - 482v_2 - \dots - 139v_{78} - 116v_{79} \ge 156Z$

$132\lambda_1 + 340\lambda_2 + \dots + 26\lambda_{78} + 23\lambda_{79} + 132\mu_1 + 340\mu_2 + \dots + 26\mu_{78} + 23\mu_{79} - 132v_1 - 340v_2 - \dots - 26v_{78} - 23v_{79} \ge 132Z$

$24\lambda_1 + 141\lambda_2 + \dots + 113\lambda_{78} + 93\lambda_{79} + 24\mu_1 + 141\mu_2 + \dots + 113\mu_{78} + 93\mu_{79} - 24v_1 - 141v_2 - \dots - 113v_{78} - 93v_{79} \ge 24Z$

$24\lambda_1 + 142\lambda_2 + \dots + 113\lambda_{78} + 93\lambda_{79} + 24\mu_1 + 142\mu_2 + \dots + 113\mu_{78} + 93\mu_{79} - 24v_1 - 142v_2 - \dots - 113v_{78} - 93v_{79} \ge 24Z$

$24\lambda_1 + 141\lambda_2 + \dots + 113\lambda_{78} + 64\lambda_{79} + 24\mu_1 + 141\mu_2 + \dots + 113\mu_{78} + 64\mu_{79} - 24v_1 - 141v_2 - \dots - 113v_{78} - 64v_{79} \ge 24Z$

$52\lambda_1 + 207\lambda_2 + \dots + 135\lambda_3 + 110\lambda_4 - 52v_1 - 207v_2 - \dots - 135v_{78} - 110v_{79} \ge 52Z$

$23\lambda_1 + 83\lambda_2 + \dots + 26\lambda_3 + 22\lambda_4 - 23v_1 - 83v_2 - \dots - 26v_{78} - 22v_{79} \ge 23Z$

$8\lambda_1 + 76\lambda_2 + \dots + 63\lambda_3 + 23\lambda_4 - 8v_1 - 76v_2 - \dots - 63v_{78} - 23v_{79} \ge 8Z$

$10\lambda_1 + 78\lambda_2 + \dots + 71\lambda_3 + 23\lambda_4 - 10v_1 - 78v_2 - \dots - 71v_{78} - 23v_{79} \ge 10Z$

$6\lambda_1 + 37\lambda_2 + \dots + 53\lambda_3 + 20\lambda_4 - 6v_1 - 37v_2 - \dots - 53v_{78} - 20v_{79} \ge 6Z$

$\lambda_1 + \lambda_2 + \dots + \lambda_{78} + \lambda_{79} = 1$

$\lambda_j \ge v_j \quad$ for all $j = 1, \dots, 237$

$\lambda_j, \mu_j, v_j \ge 0 \quad$ for all $j = 1, \dots, 237$

z *free*

These procedures solve the mathematical programming in the HRS, VRS and CRS models. SETS defines the variables used in these procedures. DATA specifies the location of excel file that contains data for this study. MAX, FOR and SUM are used to represent the models. CALC and SOLVE are used to solve the model.

A3.3: LINGO Programming for HRS Model

```
SETS:
 SCHOOL: L, M, V, SCORE, EFF;
 FACTOR07;
 DXF(SCHOOL,FACTOR07): FCT7;
ENDSETS

DATA:
 SCHOOL, FCT7, FACTOR07 =
  @OLE( 'C:\AllSchool.XLS');
  @OLE( 'C:\AllSchool.XLS','HRS07')= EFF;
ENDDATA

MAX = Z;
 @FOR(FACTOR07(J)| J #EQ# 1:
    @SUM( SCHOOL( I): FCT7(I,J)* L(I) + FCT7(I,J) * M(I) - (FCT7(I,J) * V(I)))
<= FCT7(UNIT,J));

 @FOR(FACTOR07(J)| J #EQ# 2:
    @SUM( SCHOOL( I): FCT7(I,J)* L(I) + FCT7(I,J) * M(I) - (FCT7(I,J) * V(I)))
<= FCT7(UNIT,J));

 @FOR(FACTOR07(J)| J #EQ# 3:
    @SUM( SCHOOL( I): FCT7(I,J)* L(I) + FCT7(I,J) * M(I) - (FCT7(I,J) * V(I)))
<= FCT7(UNIT,J));

 @FOR(FACTOR07(J)| J #EQ# 4:
    @SUM( SCHOOL( I): FCT7(I,J)* L(I) + FCT7(I,J) * M(I) - (FCT7(I,J) * V(I)))
<= FCT7(UNIT,J));

 @FOR(FACTOR07(J)| J #EQ# 5:
    @SUM( SCHOOL( I): FCT7(I,J)* L(I) + FCT7(I,J) * M(I) - (FCT7(I,J) * V(I)))
<= FCT7(UNIT,J));

 @FOR(FACTOR07(J)| J #EQ# 6:
    @SUM( SCHOOL( I): FCT7(I,J)* L(I)) <= FCT7(UNIT,J));

 @FOR(FACTOR07(J)| J #EQ# 7:
    @SUM( SCHOOL( I): FCT7(I,J)* L(I)) <= FCT7(UNIT,J));

 @FOR(FACTOR07(J)| J #EQ# 8:
    @SUM( SCHOOL( I): FCT7(I,J)* L(I)) <= FCT7(UNIT,J));
```

```
 @FOR(FACTOR07(J)| J #EQ# 9:
    @SUM( SCHOOL( I): FCT7(I,J)* L(I) + FCT7(I,J) * M(I) - (FCT7(I,J) * V(I)))
>= FCT7(UNIT,J) * Z);

 @FOR(FACTOR07(J)| J #EQ# 10:
    @SUM( SCHOOL( I): FCT7(I,J)* L(I) + FCT7(I,J) * M(I) - (FCT7(I,J) * V(I)))
>= FCT7(UNIT,J) * Z);

 @FOR(FACTOR07(J)| J #EQ# 11:
    @SUM( SCHOOL( I): FCT7(I,J)* L(I) + FCT7(I,J) * M(I) - (FCT7(I,J) * V(I)))
>= FCT7(UNIT,J) * Z);

 @FOR(FACTOR07(J)| J #EQ# 12:
    @SUM( SCHOOL( I): FCT7(I,J)* L(I) + FCT7(I,J) * M(I) - (FCT7(I,J) * V(I)))
>= FCT7(UNIT,J) * Z);

 @FOR(FACTOR07(J)| J #EQ# 13:
    @SUM( SCHOOL( I): FCT7(I,J)* L(I) + FCT7(I,J) * M(I) - (FCT7(I,J) * V(I)))
>= FCT7(UNIT,J) * Z);

 @FOR(FACTOR07(J)| J #EQ# 14:
    @SUM( SCHOOL( I): FCT7(I,J)* L(I) - (FCT7(I,J) * V(I))) >= FCT7(UNIT,J)
* Z);

 @FOR(FACTOR07(J)| J #EQ# 15:
    @SUM( SCHOOL( I): FCT7(I,J)* L(I) - (FCT7(I,J) * V(I))) >= FCT7(UNIT,J)
* Z);

 @FOR(FACTOR07(J)| J #EQ# 16:
    @SUM( SCHOOL( I): FCT7(I,J)* L(I) - (FCT7(I,J) * V(I))) >= FCT7(UNIT,J)
* Z);

 @FOR(FACTOR07(J)| J #EQ# 17:
    @SUM( SCHOOL( I): FCT7(I,J)* L(I) - (FCT7(I,J) * V(I))) >= FCT7(UNIT,J)
* Z);

 @FOR(FACTOR07(J)| J #EQ# 18:
    @SUM( SCHOOL( I): FCT7(I,J)* L(I) - (FCT7(I,J) * V(I))) >= FCT7(UNIT,J)
* Z);
 @SUM(SCHOOL(I): L(I)) = 1;
 @FOR(SCHOOL(I): L(I) >= V(I));
 @FOR(SCHOOL(I): L(I) >= 0);
 @FOR(SCHOOL(I): M(I) >= 0);
 @FOR(SCHOOL(I): V(I) >= 0);

CALC:
   @SET( 'TERSEO', 2);
   @SET( 'STAWIN', 0);
 ! Solve the DEA model for every DMU;
  @FOR( SCHOOL( IU):
```

```
    UNIT = IU;
    @SOLVE();
     SCORE( IU) = Z;
    EFF(IU) = 1/SCORE(IU));
ENDCALC
```

A3.4: LINGO Programming for VRS Model

```
SETS:
 SCHOOL: L, M, V, SCORE, EFF;
 FACTOR07;
 DXF(SCHOOL,FACTOR07): FCT7;
ENDSETS

DATA:
 SCHOOL, FCT7, FACTOR07 =
  @OLE( 'C:\AllSchool.XLS');
  @OLE( 'C:\AllSchool.XLS','VRS07')= EFF;
ENDDATA

MAX = Z;

 @FOR(FACTOR07(J)| J #EQ# 1:
    @SUM( SCHOOL( I): FCT7(I,J)* L(I)) <= FCT7(UNIT,J));

 @FOR(FACTOR07(J)| J #EQ# 2:
    @SUM( SCHOOL( I): FCT7(I,J)* L(I)) <= FCT7(UNIT,J));

 @FOR(FACTOR07(J)| J #EQ# 3:
    @SUM( SCHOOL( I): FCT7(I,J)* L(I)) <= FCT7(UNIT,J));

 @FOR(FACTOR07(J)| J #EQ# 4:
    @SUM( SCHOOL( I): FCT7(I,J)* L(I)) <= FCT7(UNIT,J));

 @FOR(FACTOR07(J)| J #EQ# 5:
    @SUM( SCHOOL( I): FCT7(I,J)* L(I)) <= FCT7(UNIT,J));

 @FOR(FACTOR07(J)| J #EQ# 6:
    @SUM( SCHOOL( I): FCT7(I,J)* L(I)) <= FCT7(UNIT,J));

 @FOR(FACTOR07(J)| J #EQ# 7:
    @SUM( SCHOOL( I): FCT7(I,J)* L(I)) <= FCT7(UNIT,J));

 @FOR(FACTOR07(J)| J #EQ# 8:
    @SUM( SCHOOL( I): FCT7(I,J)* L(I)) <= FCT7(UNIT,J));

 @FOR(FACTOR07(J)| J #EQ# 9:
    @SUM( SCHOOL( I): FCT7(I,J)* L(I)) >= FCT7(UNIT,J) * Z);
```

```
@FOR(FACTOR07(J)| J #EQ# 10:
   @SUM( SCHOOL( I): FCT7(I,J)* L(I)) >= FCT7(UNIT,J) * Z);

@FOR(FACTOR07(J)| J #EQ# 11:
   @SUM( SCHOOL( I): FCT7(I,J)* L(I)) >= FCT7(UNIT,J) * Z);

@FOR(FACTOR07(J)| J #EQ# 12:
   @SUM( SCHOOL( I): FCT7(I,J)* L(I)) >= FCT7(UNIT,J) * Z);
@FOR(FACTOR07(J)| J #EQ# 13:
   @SUM( SCHOOL( I): FCT7(I,J)* L(I)) >= FCT7(UNIT,J) * Z);

@FOR(FACTOR07(J)| J #EQ# 14:
   @SUM( SCHOOL( I): FCT7(I,J)* L(I)) >= FCT7(UNIT,J) * Z);

@FOR(FACTOR07(J)| J #EQ# 15:
   @SUM( SCHOOL( I): FCT7(I,J)* L(I)) >= FCT7(UNIT,J) * Z);

@FOR(FACTOR07(J)| J #EQ# 16:
   @SUM( SCHOOL( I): FCT7(I,J)* L(I)) >= FCT7(UNIT,J) * Z);

@FOR(FACTOR07(J)| J #EQ# 17:
   @SUM( SCHOOL( I): FCT7(I,J)* L(I)) >= FCT7(UNIT,J) * Z);

@FOR(FACTOR07(J)| J #EQ# 18:
   @SUM( SCHOOL( I): FCT7(I,J)* L(I)) >= FCT7(UNIT,J) * Z);

@SUM(SCHOOL(I): L(I)) = 1;
@FOR(SCHOOL(I): L(I) >= 0);

CALC:

  @SET( 'TERSEO', 2);
  @SET( 'STAWIN', 0);

 ! Solve the DEA model for every DMU;
  @FOR( SCHOOL( IU):
    UNIT = IU;
    @SOLVE();
     SCORE( IU) = Z;
    EFF(IU) = 1/SCORE(IU)
    );
ENDCALC
```

A3.5: LINGO Programming for CRS Model

LINGO programming for CRS model

```
SETS:
 SCHOOL: L, M, V, SCORE, EFF;
 FACTOR07;
 DXF(SCHOOL,FACTOR07): FCT7;
ENDSETS

DATA:
 SCHOOL, FCT7, FACTOR07 =
  @OLE( 'C:\AllSchool.XLS');
  @OLE( 'C:\AllSchool.XLS','CRS07')= EFF;
ENDDATA

MAX = Z;

 @FOR(FACTOR07(J)| J #EQ# 1:
    @SUM( SCHOOL( I): FCT7(I,J)* L(I)) <= FCT7(UNIT,J));

 @FOR(FACTOR07(J)| J #EQ# 2:
    @SUM( SCHOOL( I): FCT7(I,J)* L(I)) <= FCT7(UNIT,J));

 @FOR(FACTOR07(J)| J #EQ# 3:
    @SUM( SCHOOL( I): FCT7(I,J)* L(I)) <= FCT7(UNIT,J));

 @FOR(FACTOR07(J)| J #EQ# 4:
    @SUM( SCHOOL( I): FCT7(I,J)* L(I)) <= FCT7(UNIT,J));

 @FOR(FACTOR07(J)| J #EQ# 5:
    @SUM( SCHOOL( I): FCT7(I,J)* L(I)) <= FCT7(UNIT,J));

 @FOR(FACTOR07(J)| J #EQ# 6:
    @SUM( SCHOOL( I): FCT7(I,J)* L(I)) <= FCT7(UNIT,J));

 @FOR(FACTOR07(J)| J #EQ# 7:
    @SUM( SCHOOL( I): FCT7(I,J)* L(I)) <= FCT7(UNIT,J));

 @FOR(FACTOR07(J)| J #EQ# 8:
    @SUM( SCHOOL( I): FCT7(I,J)* L(I)) <= FCT7(UNIT,J));

 @FOR(FACTOR07(J)| J #EQ# 9:
    @SUM( SCHOOL( I): FCT7(I,J)* L(I)) >= FCT7(UNIT,J) * Z);

 @FOR(FACTOR07(J)| J #EQ# 10:
    @SUM( SCHOOL( I): FCT7(I,J)* L(I)) >= FCT7(UNIT,J) * Z);

 @FOR(FACTOR07(J)| J #EQ# 11:
    @SUM( SCHOOL( I): FCT7(I,J)* L(I)) >= FCT7(UNIT,J) * Z);
```

```
@FOR(FACTOR07(J)| J #EQ# 12:
   @SUM( SCHOOL( I): FCT7(I,J)* L(I)) >= FCT7(UNIT,J) * Z);

@FOR(FACTOR07(J)| J #EQ# 13:
   @SUM( SCHOOL( I): FCT7(I,J)* L(I)) >= FCT7(UNIT,J) * Z);

@FOR(FACTOR07(J)| J #EQ# 14:
   @SUM( SCHOOL( I): FCT7(I,J)* L(I)) >= FCT7(UNIT,J) * Z);

@FOR(FACTOR07(J)| J #EQ# 15:
   @SUM( SCHOOL( I): FCT7(I,J)* L(I)) >= FCT7(UNIT,J) * Z);

@FOR(FACTOR07(J)| J #EQ# 16:
   @SUM( SCHOOL( I): FCT7(I,J)* L(I)) >= FCT7(UNIT,J) * Z);

@FOR(FACTOR07(J)| J #EQ# 17:
   @SUM( SCHOOL( I): FCT7(I,J)* L(I)) >= FCT7(UNIT,J) * Z);

@FOR(FACTOR07(J)| J #EQ# 18:
   @SUM( SCHOOL( I): FCT7(I,J)* L(I)) >= FCT7(UNIT,J) * Z);

@FOR(SCHOOL(I): L(I) >= 0);

CALC:

  @SET( 'TERSEO', 2);
  @SET( 'STAWIN', 0);

 ! Solve the DEA model for every DMU;
  @FOR( SCHOOL( IU):
    UNIT = IU;
    @SOLVE();
     SCORE( IU) = Z;
    EFF(IU) = 1/SCORE(IU)
    );
ENDCALC
```

APPENDIX TO CHAPTER 4

A4.1 School's efficiency under HRS, VRS and CRS models

CODE	SCHOOL	HRS				VRS				CRS			
		2005	2006	2007	2008	2005	2006	2007	2008	2005	2006	2007	2008
KEA0035	SMK BALING	0.85	0.97	0.87	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
KEA0036	SMK SIONG	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
KEA0064	SMK TELOI KANAN	0.87	0.68	1.00	0.91	0.93	0.79	1.00	0.96	0.92	0.77	1.00	0.91
KEA0065	SMK TANJONG PUTERI	0.95	0.91	1.00	0.91	1.00	0.98	1.00	0.96	1.00	0.91	1.00	0.95
KEA0067	SMK JERAI	0.83	0.95	0.90	1.00	0.92	1.00	1.00	1.00	0.91	1.00	1.00	1.00
KEA0068	SMK PARIT PANJANG	0.93	1.00	1.00	1.00	0.93	1.00	1.00	1.00	0.93	1.00	1.00	1.00
KEA0069	SMK SYED ABU BAKAR	0.87	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.93	1.00	1.00	1.00
KEA0070	SEKOLAH MODEL KHAS BALING	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
KEA0071	SMK BAKAI	1.00	1.00	0.97	0.94	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
KEA1002	SMK LUBOK BUNTAR	0.92	0.76	1.00	1.00	1.00	0.80	1.00	1.00	1.00	0.77	1.00	1.00
KEA2090	SMK SULTANAH BAHIYAH	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
KEA2091	SMK DATO' SYED OMAR	0.84	0.78	0.78	0.66	1.00	0.87	0.85	0.82	1.00	0.85	0.76	0.78
KEA2093	SMK KEPALA BATAS	1.00	1.00	1.00	0.77	0.88	0.73	0.72	0.79	0.87	0.72	0.68	0.78
KEA2094	SMK SEBERANG PERAK	0.81	0.86	0.74	0.62	0.85	0.94	0.77	0.65	0.84	0.94	0.76	0.64
KEA2095	SMK LANGGAR	1.00	1.00	1.00	0.96	1.00	1.00	1.00	0.99	1.00	1.00	1.00	0.96
KEA2096	SMK DATO' WAN MOHD SAMAN	0.88	0.82	1.00	0.95	0.90	0.94	1.00	1.00	0.89	0.94	1.00	1.00
KEA2097	SMK KEAT HWA 2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
KEA2161	SMK TAJAR	1.00	0.95	1.00	0.90	1.00	1.00	1.00	0.91	1.00	1.00	1.00	0.88
KEA2178	SMK JABI	0.89	1.00	0.80	0.90	1.00	1.00	0.93	1.00	1.00	1.00	0.92	1.00
KEA2179	SMK SYED MOHAMED AL-BUKHARY (INTEG)	0.80	0.81	0.72	0.96	0.83	0.88	0.77	0.82	0.83	0.88	0.75	0.81
KEA2180	SMK MERGONG	0.89	0.80	0.78	0.76	0.95	0.92	0.80	0.84	0.92	0.86	0.79	0.82
KEA2181	SM SAINS POKOK SENA	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
KEA2182	SMK SIMPANG KUALA	1.00	1.00	0.74	0.84	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
KEA2183	SMK KUBANG ROTAN	1.00	0.97	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
KEA2184	SMK BUKIT PAYONG	1.00	1.00	0.84	1.00	1.00	1.00	0.87	1.00	1.00	1.00	0.84	1.00
KEA2185	SMK SERI PANTAI	1.00	0.98	1.00	0.76	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
KEA3046	SMK KHIR JOHARI	0.82	0.74	0.79	0.88	0.87	0.85	1.00	1.00	0.85	0.78	0.90	0.96
KEA3105	SMK TUNKU ISMAIL	0.97	1.00	0.89	0.95	0.98	1.00	0.91	0.99	0.98	1.00	0.91	0.99
KEA3106	SMK SUNGAI PASIR	1.00	0.89	0.84	0.81	1.00	1.00	0.91	0.92	1.00	0.97	0.88	0.83
KEA3107	SMK KOTA KUALA MUDA	1.00	1.00	1.00	0.96	1.00	1.00	1.00	0.96	1.00	1.00	1.00	0.96
KEA3108	SMK BUKIT SELAMBAU	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
KEA3109	SMK BANDAR SUNGAI PETANI	1.00	0.92	1.00	0.97	1.00	1.00	1.00	1.00	1.00	0.95	1.00	0.97
KEA3110	SMK SERI BADONG	0.78	0.80	0.79	0.82	0.80	0.80	0.82	0.83	0.80	0.80	0.81	0.83
KEA3111	SMK AMAN JAYA	0.97	0.88	0.99	0.96	1.00	1.00	1.00	1.00	1.00	0.89	1.00	1.00
KEA3112	SMK BATU 5, JALAN JENIANG	1.00	0.76	0.92	0.74	1.00	0.81	0.84	0.80	1.00	0.78	0.81	0.77
KEA3113	SMK SUNGAI LAYAR	0.83	0.97	0.93	0.95	0.86	0.98	0.94	1.00	0.85	0.96	0.93	1.00
KEA3114	SMK TAMAN RIA JAYA	0.97	0.93	1.00	0.81	1.00	1.00	1.00	1.00	0.95	1.00	1.00	0.97
KEA3115	SMK PENGKALAN LEBAI MAN	0.81	0.80	0.86	0.91	0.86	0.95	1.00	0.93	0.81	0.87	0.98	0.92

CODE	SCHOOL	HRS				VRS				CRS			
		2005	2006	2007	2008	2005	2006	2007	2008	2005	2006	2007	2008
KEA3116	SMK PINANG TUNGGAL	1.00	0.86	0.85	0.88	1.00	0.86	0.85	0.91	1.00	0.86	0.85	0.91
KEA3117	SMK BAKAR ARANG	1.00	1.00	0.98	0.95	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
KEA4035	SMK BANDAR BUKIT KAYU HITAM	0.68	1.00	0.75	1.00	0.71	1.00	0.75	1.00	0.69	1.00	0.72	1.00
KEA4036	SM SULTAN ABDUL HALIM	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
KEA4038	SMK TUNKU SERI INDERA PUTERA	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
KEA4058	SMK CHANGLUN	0.97	0.91	1.00	0.98	0.98	1.00	1.00	0.98	0.98	1.00	1.00	0.97
KEA4059	SMK PERMATANG BONGLAI	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
KEA4060	SMK MEGAT DEWA	1.00	0.82	1.00	0.96	1.00	0.87	1.00	1.00	1.00	0.87	1.00	1.00
KEA4061	SMK TUNKU ANUM TUNKU ABDUL RAHMAN	0.76	0.75	0.73	0.76	0.76	0.75	0.73	0.82	0.76	0.73	0.73	0.82
KEA4062	SMK HOSBA	0.91	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
KEA4063	SMK TANJUNG PAUH	0.73	0.93	0.99	0.89	0.83	0.93	1.00	0.96	0.83	0.89	1.00	0.95
KEA4065	SMK BANDAR BARU SINTOK	0.80	1.00	1.00	0.87	0.80	1.00	1.00	0.90	0.80	1.00	1.00	0.87
KEA4066	SMK BANDAR BARU DARULAMAN	1.00	0.74	0.94	0.90	1.00	0.74	0.94	0.91	1.00	0.74	0.94	0.91
KEA5023	SMK SUNGAI KOB	1.00	1.00	1.00	0.84	1.00	1.00	1.00	0.92	1.00	1.00	1.00	0.91
KEA5024	SMK KULIM	0.79	1.00	0.87	0.77	0.79	1.00	0.95	0.82	0.79	1.00	0.95	0.81
KEA5025	SMK DATO LELA PAHLAWAN	0.93	0.92	0.86	1.00	0.95	0.97	0.98	1.00	0.95	0.93	0.91	1.00
KEA5026	SMK KELADI	0.83	0.79	1.00	0.74	1.00	1.00	1.00	0.90	1.00	1.00	1.00	0.88
KEA5067	SMK LABU BESAR	0.93	0.93	0.76	0.79	1.00	1.00	0.84	0.99	1.00	1.00	0.84	0.99
KEA5068	SMK SUNGAI KARANGAN	0.92	0.83	0.78	0.71	1.00	0.89	0.98	0.93	1.00	0.88	0.88	0.91
KEA5069	SMK LUNAS	0.95	0.95	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
KEA5070	SMK JUNJUNG	0.74	0.83	1.00	0.80	0.76	0.83	1.00	0.89	0.74	0.83	1.00	0.83
KEA5071	SMK TAMAN SELASIH	0.88	0.98	0.88	0.74	0.88	0.98	0.90	0.82	0.88	0.97	0.88	0.82
KEA5072	SMK TAMAN KENARI	0.80	0.79	0.76	0.88	0.92	0.89	1.00	1.00	0.92	0.83	0.92	1.00
KEA5073	SMK JALAN PAYA BESAR	0.82	0.67	0.81	0.68	1.00	0.69	0.85	0.80	1.00	0.68	0.85	0.79
KEA5074	SMK AIR MERAH	1.00	1.00	0.78	0.80	1.00	1.00	0.82	0.85	0.95	1.00	0.81	0.84
KEA5075	SMK TAMAN HITECH	0.83	1.00	0.85	0.77	1.00	1.00	0.92	1.00	0.81	1.00	0.84	0.96
KEA6014	SMK AYER HANGAT	0.71	0.70	0.67	1.00	0.93	0.95	0.98	1.00	0.92	0.95	0.96	1.00
KEA6015	SMK TUNKU PUTRA	0.79	0.97	1.00	1.00	1.00	1.00	0.90	0.91	1.00	0.99	0.88	0.90
KEA6016	SMK KEDAWANG	0.82	0.66	1.00	0.85	0.87	0.70	1.00	0.85	0.85	0.69	1.00	0.85
KEA6017	SMK LANGKAWI, P.TUBA	0.70	0.50	1.00	0.77	0.77	1.00	1.00	0.89	0.67	0.53	0.69	0.77
KEA7017	SMK PADANG TERAP	1.00	0.91	0.75	0.74	1.00	0.93	0.76	0.77	1.00	0.93	0.75	0.77
KEA7018	SMK LUBOK MERBAU	0.89	1.00	1.00	0.84	0.97	1.00	1.00	0.87	0.95	1.00	1.00	0.87
KEA7019	SMK NAKA	1.00	1.00	0.96	0.77	1.00	1.00	0.97	0.82	1.00	0.95	0.95	0.82
KEA7020	SMK PEDU	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
KEA8020	SMK SERI ENGGANG	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99
KEA8021	SMK GULAU	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
KEA8022	SMK CHEPIR	0.90	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
KEA9001	SMK SUNGAI LIMAU YAN	0.80	1.00	0.87	0.94	0.85	1.00	0.91	1.00	0.84	1.00	0.91	1.00
KEA9002	SMK BATU 17	1.00	0.86	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.83	1.00	1.00
KEA9003	SMK DULANG	1.00	0.92	0.85	0.85	1.00	0.94	1.00	1.00	1.00	0.93	1.00	1.00

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		2005	2006	2007	2008	2005	2006	2007	2008	2005	2006	2007	2008
KEAA091	SMK TOKAI	0.89	0.64	0.57	1.00	0.93	0.65	0.89	1.00	0.91	0.63	0.86	1.00
KEAA092	SMK KUBOR PANJANG	0.94	1.00	1.00	1.00	0.96	1.00	1.00	1.00	0.95	0.96	1.00	1.00
KEAA164	SMK AYER PUTEH DALAM	0.70	1.00	0.82	0.95	0.86	1.00	0.99	1.00	0.84	1.00	0.88	1.00
KEAA180	SMK TANAH MERAH	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.93	1.00	1.00	1.00	0.92
KEAA181	SMK SYED IBRAHIM	0.88	1.00	1.00	1.00	0.91	1.00	1.00	1.00	0.89	0.99	1.00	1.00
KEAA183	SMK TUNKU TEMENGGUNG	0.87	0.82	0.97	0.77	0.90	0.92	1.00	1.00	0.89	0.86	1.00	1.00
KEAA184	SMK TOBIAR	1.00	0.93	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.91	1.00	1.00
KEB0037	SMK TUNKU PUTERA BALING	0.89	0.90	0.92	0.85	1.00	1.00	1.00	1.00	0.95	0.95	1.00	0.90
KEB2093	SMK DARULAMAN	0.89	0.66	0.71	0.78	0.95	0.70	0.79	0.79	0.95	0.69	0.79	0.79
KEB2094	SMK KEAT HWA	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
KEB2095	SMK SULTANAH ASMA	1.00	1.00	0.94	1.00	1.00	1.00	0.95	1.00	1.00	1.00	0.95	1.00
KEB2096	KOLEJ SULTAN ABDUL HAMID	0.87	0.80	0.94	1.00	0.94	1.00	1.00	1.00	0.94	0.80	0.94	1.00
KEB2097	SMK ST MICHAEL	1.00	1.00	1.00	0.87	1.00	1.00	1.00	0.89	1.00	1.00	1.00	0.88
KEB2098	SMK CONVENT (M)	1.00	1.00	0.92	0.89	1.00	1.00	0.93	0.90	1.00	1.00	0.92	0.89
KEB2162	SMK TUNKU SOFIAH	0.95	0.91	0.71	1.00	0.96	0.91	0.71	1.00	0.95	0.88	0.71	0.99
KEB3047	SMK DATO BIJAYA SETIA	1.00	1.00	0.90	0.87	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.94
KEB3048	SMK CONVENT FATHER BARRE	0.91	1.00	0.84	0.80	0.98	1.00	0.87	0.87	0.98	1.00	0.86	0.86
KEB3049	SMK IBRAHIM	1.00	0.98	0.90	0.92	1.00	0.99	0.95	0.93	1.00	0.98	0.94	0.92
KEB3050	SMK ST THERESA (M)	0.76	1.00	1.00	1.00	0.82	1.00	1.00	1.00	0.81	1.00	1.00	1.00
KEB3051	SMK SIN MIN (CF)	1.00	1.00	0.93	1.00	1.00	1.00	0.94	1.00	1.00	1.00	0.84	1.00
KEB5025	SMK CHIO MIN (CF)	0.94	0.99	1.00	1.00	0.97	1.00	1.00	1.00	0.96	1.00	1.00	1.00
KEB5026	SMK TUNKU PANGLIMA BESAR	0.73	1.00	1.00	0.86	0.86	1.00	1.00	1.00	0.83	1.00	1.00	1.00
KEB5027	SMK SULTAN BADLISHAH	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.97	1.00	1.00
KEB5028	SMK ST PATRICK (M)	0.61	0.80	0.83	1.00	0.68	1.00	0.93	1.00	0.66	1.00	0.76	0.90
KEB5029	SMK ST ANNE'S CONVENT	0.87	1.00	0.68	0.87	0.91	1.00	0.78	1.00	0.89	1.00	0.74	0.92
KEE0038	SMK KUALA KETIL	0.96	0.80	0.86	0.85	1.00	1.00	1.00	0.98	1.00	1.00	0.97	0.97
KEE0039	SMK KUALA PEGANG	0.91	0.98	1.00	1.00	0.92	0.98	1.00	1.00	0.88	0.98	1.00	1.00
KEE1017	SMK SULTAN AHMAD TAJUDDIN	0.95	0.87	0.97	0.82	1.00	0.87	0.97	0.82	1.00	0.87	0.97	0.82
KEE1018	SMK SERDANG	0.76	0.79	0.89	0.85	0.79	0.87	0.96	0.92	0.77	0.80	0.94	0.90
KEE2100	SMK TUNKU ABDUL MALIK	1.00	1.00	0.86	1.00	1.00	1.00	0.97	1.00	0.93	0.97	0.81	1.00
KEE2101	SMK ALOR JANGGUS	0.84	0.79	0.76	0.93	0.91	0.95	0.82	1.00	0.90	0.86	0.80	0.94
KEE2102	SMK MUADZAM SHAH	1.00	1.00	0.98	0.90	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
KEE2104	SMK TUNKU ABDUL AZIZ	0.84	1.00	1.00	1.00	0.90	1.00	1.00	1.00	0.90	1.00	1.00	1.00
KEE2106	SMK POKOK SENA	0.93	0.88	0.77	0.85	1.00	1.00	0.90	0.96	1.00	0.86	0.80	0.82
KEE2107	SMK TUN SHARIFAH RODZIAH	0.76	1.00	0.98	0.82	0.81	1.00	0.98	0.85	0.78	1.00	0.97	0.84
KEE2108	SMK TENGKU LAKSAMANA	0.68	0.94	0.90	0.86	0.70	0.95	0.91	0.87	0.70	0.94	0.90	0.87
KEE2160	SMK SERI GUNONG	0.85	0.76	0.86	0.91	1.00	0.93	0.98	1.00	1.00	0.90	0.97	1.00
KEE3052	SMK BEDONG	0.96	1.00	0.94	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
KEE3053	SMK CHE TOM 'SRT'	0.88	0.88	0.91	0.68	0.88	0.89	0.91	0.71	0.88	0.89	0.91	0.71
KEE3054	SMK GURUN	0.95	0.78	0.98	0.82	1.00	0.90	1.00	0.95	1.00	0.81	1.00	0.88

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		2005	2006	2007	2008	2005	2006	2007	2008	2005	2006	2007	2008
KEE3055	SMK MERBOK	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
KEE3056	SMK PEKULA JAYA	0.83	0.92	1.00	0.83	0.85	0.92	1.00	1.00	0.85	0.92	1.00	1.00
KEE3057	SMK TUNKU SULONG	0.90	0.87	0.74	0.93	0.94	0.88	0.85	0.98	0.92	0.87	0.85	0.98
KEE3105	SM SAINS SULTAN MOHAMAD JIWA	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
KEE4037	SMK JITRA	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
KEE4038	SMK SERI MAHAWANGSA	0.84	0.87	0.90	0.86	0.99	0.95	0.92	0.88	0.85	0.87	0.91	0.88
KEE4039	SMK TUNKU BENDAHARA	0.89	0.91	0.84	0.86	0.90	0.95	0.85	0.93	0.89	0.92	0.84	0.93
KEE4040	SMK PULAU NYIOR	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
KEE4041	SMK AYER HITAM	0.81	1.00	0.84	0.99	0.91	1.00	0.97	1.00	0.83	1.00	0.87	1.00
KEE5030	SMK MAHANG	0.93	0.68	1.00	0.89	0.98	0.75	1.00	1.00	0.95	0.73	1.00	0.99
KEE5031	SMK PADANG SERAI	0.82	0.85	0.80	0.77	0.89	0.94	0.89	0.78	0.88	0.94	0.87	0.77
KEE6016	SMK MAHSURI	0.97	0.80	0.92	0.89	1.00	0.90	1.00	0.94	0.96	0.83	0.89	0.89
KEE7017	SMK DATO' SYED AHMAD	0.95	0.88	1.00	1.00	1.00	0.88	1.00	1.00	0.85	0.75	1.00	1.00
KEE8018	SMK SIK	1.00	0.88	0.79	0.86	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.98
KEE9023	SMK GUAR CHEMPEDAK	0.83	0.84	0.89	0.97	0.93	0.96	0.99	1.00	0.87	0.83	0.92	0.97
KEE9024	SMK YAN	0.85	0.98	0.80	0.83	0.98	1.00	0.83	1.00	0.97	1.00	0.83	1.00
KEEA103	SMK PENDANG	0.91	0.91	0.93	0.95	0.99	1.00	1.00	0.98	0.85	0.88	0.90	0.94
KEEA105	SMK SUNGAI TIANG	0.79	0.99	0.80	0.75	0.94	1.00	0.92	0.83	0.93	1.00	0.82	0.83
KRA0001	SMK AGAMA BALING	1.00	1.00	1.00	0.91	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.91
KRA2001	SMK AGAMA KEDAH	0.92	1.00	1.00	0.87	0.96	1.00	1.00	0.98	0.96	1.00	1.00	0.91
KRA8001	SMK AGAMA SIK	0.97	0.96	1.00	1.00	0.97	1.00	1.00	1.00	0.96	0.95	1.00	1.00
KRA9001	SMK AGAMA YAN	1.00	0.90	1.00	0.90	1.00	1.00	1.00	0.98	1.00	0.91	1.00	0.91
PEA0001	SMK PRAI	0.85	0.79	0.85	0.95	0.86	0.90	0.89	1.00	0.86	0.86	0.87	1.00
PEA0002	SMK BERAPIT	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
PEA0003	SMK GUAR PERAHU	0.81	0.81	0.86	0.93	0.91	0.95	0.97	1.00	0.85	0.83	0.87	0.92
PEA0004	SMK SEBERANG JAYA	0.71	0.92	0.81	0.80	0.83	0.94	0.87	0.85	0.76	0.93	0.85	0.84
PEA0005	SMK PERMATANG RAWA	1.00	0.94	0.85	1.00	1.00	1.00	1.00	1.00	1.00	0.97	0.99	1.00
PEA0006	SMK SAMA GAGAH	0.59	0.76	1.00	1.00	0.89	1.00	1.00	1.00	0.85	0.83	1.00	1.00
PEA0007	SMK TAMAN INDERAWASIH	0.73	0.85	0.98	0.78	0.79	0.95	1.00	0.79	0.78	0.94	1.00	0.79
PEA0008	SMK ALMA	0.97	0.75	0.78	0.59	1.00	0.75	0.85	0.73	0.94	0.75	0.82	0.73
PEA0009	SMK MENGKUANG	1.00	1.00	0.93	0.63	1.00	1.00	1.00	0.86	1.00	1.00	1.00	0.83
PEA1090	SMK ABDULLAH MUNSHI	0.65	0.62	0.76	0.78	0.87	0.76	0.88	1.00	0.84	0.75	0.85	1.00
PEA1091	SMK (P) SRI MUTIARA	0.88	1.00	0.84	0.86	0.90	1.00	0.88	1.00	0.88	0.98	0.86	1.00
PEA1093	SMK BUKIT GAMBIR	0.76	0.77	0.82	0.75	1.00	0.81	0.85	0.93	1.00	0.81	0.81	0.92
PEA1094	SMK AIR ITAM	0.93	0.81	0.88	0.69	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00
PEA1211	SMK TELOK KUMBAR	1.00	0.99	0.89	0.92	1.00	1.00	0.96	0.99	1.00	1.00	0.90	0.99
PEA2051	SMK PERMATANG TOK JAYA	1.00	0.92	0.76	0.85	1.00	1.00	0.86	1.00	1.00	1.00	0.86	1.00
PEA2052	SMK DATUK HAJI AHMAD SAID	1.00	0.81	0.92	0.84	1.00	0.81	0.97	0.87	1.00	0.79	0.96	0.87
PEA2053	SMK DATUK ONN	0.76	0.78	0.75	0.84	0.86	0.79	0.82	0.94	0.84	0.79	0.77	0.94
PEA2054	SMK DATUK HAJI AHMAD BADAWI	0.61	0.63	0.86	1.00	0.62	0.64	0.93	0.97	0.62	0.63	0.90	0.94

CODE	SCHOOL	HRS				VRS				CRS			
		2005	2006	2007	2008	2005	2006	2007	2008	2005	2006	2007	2008
PEA2055	SMK SRI MUDA	0.87	1.00	1.00	0.83	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
PEA2056	SMJK CHUNG LING BUTTERWORTH	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
PEA2057	SMK TELOK AIR TAWAR	0.82	0.87	0.92	0.76	0.89	0.87	1.00	0.84	0.85	0.85	1.00	0.81
PEA2058	SMK PAYA KELADI	1.00	1.00	1.00	0.76	1.00	1.00	1.00	0.96	1.00	1.00	1.00	0.92
PEA2082	SMK MAK MANDIN	1.00	1.00	0.93	0.84	1.00	1.00	1.00	0.99	1.00	1.00	1.00	0.96
PEA2083	SMK BAGAN JAYA	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
PEA3033	SMK RAJA TUN UDA	0.88	0.62	0.79	0.71	1.00	1.00	1.00	1.00	0.99	0.87	0.90	1.00
PEA3034	SMK SERI BALIK PULAU	0.89	0.83	0.85	0.75	0.97	1.00	1.00	0.90	0.97	0.84	0.99	0.85
PEA3035	SMK BATU MAUNG	0.80	0.90	0.80	0.80	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
PEA4001	SMK SUNGAI ACHEH	1.00	0.81	0.88	0.78	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
PEA4002	SMK VALDOR	1.00	1.00	0.89	1.00	1.00	1.00	0.95	1.00	1.00	1.00	0.93	1.00
PEA4003	SMK SERI NIBONG	1.00	1.00	1.00	0.96	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
PEA4004	SMK MUTIARA IMPIAN	0.98	0.95	0.89	0.98	0.98	0.95	0.90	0.99	0.97	0.95	0.90	0.99
PEB0042	SMK TINGGI BUKIT MERTAJAM	1.00	1.00	0.90	0.74	1.00	1.00	1.00	0.91	1.00	1.00	0.98	0.89
PEB0043	SMK JALAN DAMAI	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
PEB0044	SMK CONVENT (M) BUKIT MERTAJAM	0.90	1.00	0.89	0.86	0.90	1.00	0.90	0.87	0.89	1.00	0.90	0.87
PEB0045	SMJK JIT SIN (CF)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
PEB1093	SMJK PEREMPUAN CHINA PULAU PINANG	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
PEB1094	SMK PENANG FREE	1.00	0.95	0.96	0.93	1.00	1.00	1.00	0.94	1.00	0.99	1.00	0.91
PEB1095	SMJK CHUNG HWA CONFUCIAN (CF)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
PEB1096	SMJK CHUNG LING (CF)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
PEB1097	SMK CONVENT GREEN LANE	0.97	1.00	1.00	1.00	0.97	1.00	1.00	1.00	0.97	1.00	1.00	1.00
PEB1098	SMJK CONVENT DATUK KERAMAT	0.97	1.00	0.97	1.00	0.97	1.00	0.97	1.00	0.97	1.00	0.97	1.00
PEB1099	SMK CONVENT LEBUH LIGHT	0.89	1.00	0.98	0.90	0.89	1.00	0.98	0.92	0.89	0.99	0.97	0.91
PEB1100	SMK CONVENT PULAU TIKUS	0.94	0.86	0.80	0.87	0.96	0.88	0.83	0.88	0.94	0.86	0.81	0.87
PEB1102	SMK GEORGETOWN	0.80	0.78	0.71	0.70	0.86	0.87	0.87	0.90	0.85	0.86	0.87	0.89
PEB1103	SMJK HENG EE (CF)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
PEB1106	SMK (L) METHODIST	0.89	0.78	0.76	0.77	0.89	0.79	0.94	0.98	0.88	0.78	0.93	0.98
PEB1107	SMK (P) METHODIST	0.87	0.89	0.94	0.89	0.87	0.90	0.96	0.92	0.87	0.89	0.94	0.89
PEB1108	SMJK PHOR TAY	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
PEB1109	SMK (P) ST GEORGE	0.89	0.83	0.98	1.00	0.95	0.83	1.00	1.00	0.95	0.82	1.00	1.00
PEB1110	SMK ST XAVIER	1.00	0.85	1.00	0.97	1.00	0.89	1.00	1.00	1.00	0.87	1.00	1.00
PEB1112	SMK TUNKU PUAN HABSAH	0.81	0.88	0.73	0.77	0.88	1.00	1.00	0.79	0.88	1.00	0.94	0.77
PEB1113	SMJK UNION	1.00	1.00	1.00	0.99	1.00	1.00	1.00	0.99	1.00	1.00	1.00	0.99
PEB1114	SMK WESTLANDS	0.76	0.76	0.71	1.00	1.00	1.00	0.92	1.00	1.00	1.00	0.92	1.00
PEB2059	SMK CONVENT BUTTERWORTH	0.87	0.84	0.95	1.00	0.92	0.88	1.00	1.00	0.92	0.85	1.00	1.00
PEB2060	SMK KAMPONG KASTAM	0.85	1.00	0.79	0.86	1.00	1.00	1.00	1.00	0.87	1.00	0.94	1.00
PEB2062	SMK ST MARK (M)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
PEB3036	SMJK SACRED HEART	1.00	0.92	1.00	1.00	1.00	0.94	1.00	1.00	1.00	0.94	1.00	1.00
PEB3037	SMK ST GEORGE (M)	0.94	1.00	0.88	0.82	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.89

CODE	SCHOOL	HRS				VRS				CRS			
		2005	2006	2007	2008	2005	2006	2007	2008	2005	2006	2007	2008
PEB3038	SMK SUNGAI ARA	0.83	0.82	0.93	0.82	0.94	1.00	1.00	0.97	0.94	0.92	1.00	0.94
PEB4038	SMK METHODIST (M), NIBONG TEBAL	0.97	1.00	0.94	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
PEE0040	SMK BUKIT MERTAJAM	1.00	1.00	0.96	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
PEE0041	SMK PENANTI	1.00	1.00	0.90	0.87	1.00	1.00	1.00	1.00	0.87	1.00	1.00	1.00
PEE0051	SM (SAINS) TUN SYED SHEH SHAHABUDDIN	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
PEE1092	SMK TANJONG BUNGA	0.65	1.00	1.00	1.00	0.77	1.00	1.00	1.00	0.77	1.00	1.00	1.00
PEE1101	SMK DATUK HJ. MOHAMED NOR AHMAD	0.79	0.62	0.79	0.80	0.98	0.65	1.00	1.00	0.93	0.64	1.00	1.00
PEE1104	SMK JELUTONG	0.78	0.78	0.75	0.71	1.00	0.98	1.00	1.00	1.00	0.98	1.00	1.00
PEE1111	SMK HAJI ZAINUL ABIDIN	0.70	0.83	1.00	1.00	1.00	0.94	1.00	1.00	1.00	0.86	1.00	1.00
PEE1115	SMK PADANG POLO	0.60	0.77	0.78	1.00	0.73	0.84	0.82	1.00	0.69	0.84	0.78	1.00
PEE2056	SMK BAKTI	1.00	0.93	0.93	0.88	1.00	0.95	1.00	1.00	1.00	0.94	1.00	1.00
PEE4036	SMK TUN SYED SHEH BARAKBAH	0.81	0.85	0.79	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
PEE4037	SMK TUNKU ABDUL RAHMAN	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
PRA1001	SMKA (L) AL-MASHOOR	0.88	0.83	0.79	0.88	0.91	0.86	0.87	0.87	0.90	0.85	0.83	0.76
PRA1002	SMKA (P) ALMASHOOR	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00
PRA2003	SMKA AL-IRSHAD	0.99	1.00	1.00	1.00	0.99	1.00	1.00	1.00	0.99	1.00	1.00	1.00
PRA4001	SMKA NIBONG TEBAL	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
REA0054	SMK DATO' SHEIKH AHMAD	0.78	0.91	1.00	1.00	0.81	0.92	1.00	1.00	0.80	0.91	1.00	1.00
REA0055	SMK SYED AHMAD	0.75	0.98	0.97	0.74	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
REA0056	SMK SYED HASSAN	0.75	0.67	0.86	0.95	0.79	0.69	1.00	1.00	0.76	0.68	0.95	1.00
REA0074	SMK RAJA PUAN MUDA TENGKU FAUZIAH	0.86	0.77	0.77	0.72	0.89	0.78	0.86	0.88	0.89	0.77	0.84	0.88
REA0076	SMK KUALA PERLIS	0.83	1.00	1.00	0.84	0.89	1.00	1.00	0.90	0.88	1.00	1.00	0.89
REA0077	SMK DATUK JAAFAR HASSAN	0.74	0.73	0.70	0.64	0.81	0.92	0.94	1.00	0.78	0.76	0.82	0.89
REA0078	SMK ARAU	0.82	1.00	0.66	0.61	0.88	1.00	0.78	0.78	0.88	1.00	0.74	0.72
REA0079	SMK SANGLANG	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
REA0080	SMK ABI	1.00	0.80	0.87	0.76	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.94
REA0081	SMK PADANG BESAR UTARA	0.81	1.00	0.85	0.58	0.81	1.00	0.91	0.60	0.81	1.00	0.89	0.60
REA0082	SMK PADANG SIDING	0.71	1.00	0.81	0.79	0.79	1.00	1.00	0.85	0.79	1.00	1.00	0.84
REA0083	SMK SERIAB	0.76	0.69	0.57	0.61	1.00	0.73	0.61	0.70	0.92	0.73	0.61	0.68
REB0057	SMK PUTRA	0.72	1.00	1.00	0.89	0.75	1.00	1.00	0.89	0.73	1.00	1.00	0.88
REB0058	SMK PERLIS	0.85	0.87	0.86	0.75	0.87	0.95	0.96	0.84	0.86	0.86	0.88	0.76
REE0059	SMK DERMA	0.99	0.92	0.88	0.96	1.00	0.94	0.94	0.99	1.00	0.93	0.93	0.98
REE0060	SMK SYED ALWI	1.00	0.80	0.90	0.90	1.00	1.00	1.00	1.00	1.00	0.99	0.94	0.88
REE0061	SMK SYED SAFFI	0.89	0.99	0.97	0.90	0.95	1.00	0.98	0.92	0.95	0.99	0.97	0.92
REE0062	SMK SYED SIRAJUDDIN	0.75	1.00	1.00	0.81	0.84	1.00	1.00	0.90	0.77	1.00	1.00	0.79
REE0063	SMK TENGKU SULAIMAN	0.89	0.78	0.87	0.81	0.97	0.98	1.00	1.00	0.93	0.74	0.90	0.96
REE0072	SM (SAINS) TUANKU SYED PUTRA	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00
RRA0001	SMKA ARAU	1.00	1.00	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
RRA0002	SMKA (P) ALAWIYAH	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

A4.2 – List of Schools Causing Infeasibility in the Computation of the Malmquist Index

CODE	SCHOOL
KEA0068	SMK PARIT PANJANG
KEA0070	SEKOLAH MODEL KHAS BALING
KEA1002	SMK LUBOK BUNTAR
KEA2095	SMK LANGGAR
KEA6014	SMK AYER HANGAT
KEA6016	SMK KEDAWANG
KEAA0091	SMK TOKAI
KEAA184	SMK TOBIAR
KEB2095	SMK SULTANAH ASMA
KEB2096	KOLEJ SULTAN ABDUL HAMID
KEB5027	SMK SULTAN BADLISHAH
KRA9001	SMK AGAMA YAN
PEA2082	SMK MAK MANDIN
PEA4002	SMK VALDOR
PEB0042	SMK TINGGI BUKIT MERTAJAM
PRA1001	SMKA(L) AL-MASHOOR

A4.3 – Statistical Tests for Section 4.2

1. Hypothesis test summary for the Wilcoxon Signed Ranks Test to examine the differences in the efficiency scores of different models (i.e. HRS, VRS, and CRS).

   a. Differences between the HRS and VRS models in 2005

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between HRS2005 and VRS2005 equals 0.	Related-Samples Wilcoxon Signed Ranks Test	.000	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

   b. Differences between the HRS and CRS models in 2005

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between HRS2005 and CRS2005 equals 0.	Related-Samples Wilcoxon Signed Ranks Test	.000	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

   c. Differences between the HRS and VRS models in 2006

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between HRS2006 and VRS2006 equals 0.	Related-Samples Wilcoxon Signed Ranks Test	.000	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

   d. Differences between the HRS and CRS models in 2006

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between HRS2006 and CRS2006 equals 0.	Related-Samples Wilcoxon Signed Ranks Test	.000	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

e. Differences between the HRS and VRS models in 2007

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between HRS2007 and VRS2007 equals 0.	Related-Samples Wilcoxon Signed Ranks Test	.000	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

f. Differences between the HRS and CRS models in 2007

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between HRS2007 and CRS2007 equals 0.	Related-Samples Wilcoxon Signed Ranks Test	.000	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

g. Differences between the HRS and VRS models in 2008

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between HRS2008 and VRS2008 equals 0.	Related-Samples Wilcoxon Signed Ranks Test	.000	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

h. Differences between the HRS and CRS models in 2008

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between HRS2008 and CRS2008 equals 0.	Related-Samples Wilcoxon Signed Ranks Test	.000	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

A4.4 – Statistical Tests for Section 4.3

1. Hypothesis test summary for the Friedman's Two-Way Analysis of Variance by Ranks

	Null Hypothesis	Test	Sig.	Decision
1	The distributions of HRS2005, HRS2006, HRS2007 and HRS2008 are the same.	Related-Samples Friedman's Two-Way Analysis of Variance by Ranks	.030	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

2. Hypothesis test summary for the Wilcoxon Signed Ranks Test to examine the differences in the efficiency scores of different years.

2. Differences between the efficiency scores in 2005 and 2006

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between HRS2005 and HRS2006 equals 0.	Related-Samples Wilcoxon Signed Ranks Test	.195	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

3. Differences between the efficiency scores in 2005 and 2007

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between HRS2005 and HRS2007 equals 0.	Related-Samples Wilcoxon Signed Ranks Test	.516	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

4. Differences between the efficiency scores in 2005 and 2008

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between HRS2005 and HRS2008 equals 0.	Related-Samples Wilcoxon Signed Ranks Test	.126	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

5. Differences between the efficiency scores in 2006 and 2007

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between HRS2006 and HRS2007 equals 0.	Related-Samples Wilcoxon Signed Ranks Test	.507	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

6. Differences between the efficiency scores in 2006 and 2008

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between HRS2006 and HRS2008 equals 0.	Related-Samples Wilcoxon Signed Ranks Test	.008	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

7. Differences between the efficiency scores in 2007 and 2008

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between HRS2007 and HRS2008 equals 0.	Related-Samples Wilcoxon Signed Ranks Test	.008	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

3. Hypothesis test summary for the Friedman's Two-Way Analysis of Variance by Ranks to examine the differences in the distribution of the Malmquist index in three different period

	Null Hypothesis	Test	Sig.	Decision
1	The distributions of MI06, MI07 and MI08 are the same.	Related-Samples Friedman's Two-Way Analysis of Variance by Ranks	.000	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

4. Hypothesis test summary for the Wilcoxon Signed Ranks Test to examine the differences in the Malmquist indexes of different periods

a. Differences between the Malmquist indexes in 2005-2006 and 2006-2007

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between MI06 and MI07 equals 0.	Related-Samples Wilcoxon Signed Ranks Test	.349	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

b. Differences between the Malmquist indexes in 2005-2006 and 2007-2008

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between MI06 and MI08 equals 0.	Related-Samples Wilcoxon Signed Ranks Test	.000	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

c. Differences between the Malmquist indexes in 2006-2007 and 2007-2008

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between MI07 and MI08 equals 0.	Related-Samples Wilcoxon Signed Ranks Test	.001	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

A4.5 - Statistical Tests for Section 4.4

1. Hypothesis test summary for the Kruskal-Wallis Test to examine the differences in the distributions of efficiency scores across school type.

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of HRS2005 is the same across categories of Type.	Independent-Samples Kruskal-Wallis Test	.005	Reject the null hypothesis.
2	The distribution of HRS2006 is the same across categories of Type.	Independent-Samples Kruskal-Wallis Test	.005	Reject the null hypothesis.
3	The distribution of HRS2007 is the same across categories of Type.	Independent-Samples Kruskal-Wallis Test	.001	Reject the null hypothesis.
4	The distribution of HRS2008 is the same across categories of Type.	Independent-Samples Kruskal-Wallis Test	.002	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

2. Hypothesis test summary for the Mann-Whitney U Test to examine the pairwise differences in the distribution of efficiency scores:
   a. Across **national and fully residential school type**.

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of HRS2005 is the same across categories of Type.	Independent-Samples Mann-Whitney U Test	.011	Reject the null hypothesis.
2	The distribution of HRS2006 is the same across categories of Type.	Independent-Samples Mann-Whitney U Test	.045	Reject the null hypothesis.
3	The distribution of HRS2007 is the same across categories of Type.	Independent-Samples Mann-Whitney U Test	.013	Reject the null hypothesis.
4	The distribution of HRS2008 is the same across categories of Type.	Independent-Samples Mann-Whitney U Test	.008	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

b. Across **national and religious school type.**

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of HRS2005 is the same across categories of Type.	Independent-Samples Mann-Whitney U Test	.035	Reject the null hypothesis.
2	The distribution of HRS2006 is the same across categories of Type.	Independent-Samples Mann-Whitney U Test	.010	Reject the null hypothesis.
3	The distribution of HRS2007 is the same across categories of Type.	Independent-Samples Mann-Whitney U Test	.004	Reject the null hypothesis.
4	The distribution of HRS2008 is the same across categories of Type.	Independent-Samples Mann-Whitney U Test	.015	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

c. Across **fully residential and religious school type.**

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of HRS2005 is the same across categories of Type.	Independent-Samples Mann-Whitney U Test	.073	Retain the null hypothesis.
2	The distribution of HRS2006 is the same across categories of Type.	Independent-Samples Mann-Whitney U Test	.816	Retain the null hypothesis.
3	The distribution of HRS2007 is the same across categories of Type.	Independent-Samples Mann-Whitney U Test	.429	Retain the null hypothesis.
4	The distribution of HRS2008 is the same across categories of Type.	Independent-Samples Mann-Whitney U Test	.245	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

3. Hypothesis test summary for the Friedman's Two-Way Analysis of Variance by Ranks to examine the differences in the distribution of efficiency scores in different years of:

a. **national school type**

	Null Hypothesis	Test	Sig.	Decision
1	The distributions of HRS05, HRS06, HRS07 and HRS08 are the same.	Related-Samples Friedman's Two-Way Analysis of Variance by Ranks	.027	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

b. **fully residential school type**

	Null Hypothesis	Test	Sig.	Decision
1	The distributions of HRS05, HRS06, HRS07 and HRS08 are the same.	Related-Samples Friedman's Two-Way Analysis of Variance by Ranks	.392	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

c. **religious school type**

	Null Hypothesis	Test	Sig.	Decision
1	The distributions of HRS05, HRS06, HRS07 and HRS08 are the same.	Related-Samples Friedman's Two-Way Analysis of Variance by Ranks	.529	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

4. Hypothesis test summary for the Wilcoxon Signed Ranks Test to examine the differences in the distribution of efficiency scores of **the national school type** in different years

(i) Between 2005 and 2006

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between HRS05 and HRS06 equals 0.	Related-Samples Wilcoxon Signed Ranks Test	.208	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

(ii) Between 2005 and 2007

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between HRS05 and HRS07 equals 0.	Related-Samples Wilcoxon Signed Ranks Test	.551	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

(iii) Between 2005 and 2008

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between HRS05 and HRS08 equals 0.	Related-Samples Wilcoxon Signed Ranks Test	.144	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

(iv) Between 2006 and 2007

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between HRS06 and HRS07 equals 0.	Related-Samples Wilcoxon Signed Ranks Test	.497	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

(v) Between 2006 and 2008

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between HRS06 and HRS08 equals 0.	Related-Samples Wilcoxon Signed Ranks Test	.010	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

(vi) Between 2007 and 2008

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between HRS07 and HRS08 equals 0.	Related-Samples Wilcoxon Signed Ranks Test	.012	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

5. Hypothesis test summary for the Friedman's Two-Way Analysis of Variance by Ranks to examine the differences in the distribution of the Malmquist index in three different period

a. National School type

	Null Hypothesis	Test	Sig.	Decision
1	The distributions of MI06, MI07 and MI08 are the same.	Related-Samples Friedman's Two-Way Analysis of Variance by Ranks	.000	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

b. Fully Residential School Type

	Null Hypothesis	Test	Sig.	Decision
1	The distributions of MI06, MI07 and MI08 are the same.	Related-Samples Friedman's Two-Way Analysis of Variance by Ranks	.854	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

c. Religious School Type

	Null Hypothesis	Test	Sig.	Decision
1	The distributions of MI06, MI07 and MI08 are the same.	Related-Samples Friedman's Two-Way Analysis of Variance by Ranks	.140	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

6. Hypothesis test summary for the Wilcoxon Signed Ranks Test to examine the differences in the distribution of the Malmquist index of the national school type:

a. Between 2005/2006-2006/2007

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between MI06 and MI07 equals 0.	Related-Samples Wilcoxon Signed Ranks Test	.351	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

b. Between 2005/2006-2007/2008

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between MI06 and MI08 equals 0.	Related-Samples Wilcoxon Signed Ranks Test	.000	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

c. Between 2006/2007-2007/2008

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between MI07 and MI08 equals 0.	Related-Samples Wilcoxon Signed Ranks Test	.001	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

7. Hypothesis test summary for the Kruskal-Wallis Test to examine the differences in the distribution of the Malmquist index across the different school types

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of MI06 is the same across categories of Type.	Independent-Samples Kruskal-Wallis Test	.757	Retain the null hypothesis.
2	The distribution of MI07 is the same across categories of Type.	Independent-Samples Kruskal-Wallis Test	.943	Retain the null hypothesis.
3	The distribution of MI08 is the same across categories of Type.	Independent-Samples Kruskal-Wallis Test	.140	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

A4.6 - Statistical Tests for Section 4.5

1. Hypothesis test summary for the Kruskal-Wallis Test to examine the differences in the distribution of efficiency scores across Kedah, Penang, and Perlis.

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of HRS05 is the same across categories of State.	Independent-Samples Kruskal-Wallis Test	.021	Reject the null hypothesis.
2	The distribution of HRS06 is the same across categories of State.	Independent-Samples Kruskal-Wallis Test	.490	Retain the null hypothesis.
3	The distribution of HRS07 is the same across categories of State.	Independent-Samples Kruskal-Wallis Test	.380	Retain the null hypothesis.
4	The distribution of HRS08 is the same across categories of State.	Independent-Samples Kruskal-Wallis Test	.010	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

2. Hypothesis test summary for the Mann-Whitney U Test to examine the pairwise differences in the distribution of efficiency scores:

   a. Between **Kedah and Penang**

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of HRS05 is the same across categories of State.	Independent-Samples Mann-Whitney U Test	.941	Retain the null hypothesis.
2	The distribution of HRS08 is the same across categories of State.	Independent-Samples Mann-Whitney U Test	.734	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

b. Between **Kedah and Perlis**

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of HRS05 is the same across categories of State.	Independent-Samples Mann-Whitney U Test	.004	Reject the null hypothesis.
2	The distribution of HRS08 is the same across categories of State.	Independent-Samples Mann-Whitney U Test	.003	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

c. Between **Penang and Perlis**

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of HRS05 is the same across categories of State.	Independent-Samples Mann-Whitney U Test	.023	Reject the null hypothesis.
2	The distribution of HRS08 is the same across categories of State.	Independent-Samples Mann-Whitney U Test	.006	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

3. Hypothesis test summary for the Friedman's Two-Way Analysis of Variance by Ranks to examine the differences in the distribution of efficiency scores in different years of:

a. schools in Kedah

	Null Hypothesis	Test	Sig.	Decision
1	The distributions of HRS05, HRS06, HRS07 and HRS08 are the same.	Related-Samples Friedman's Two-Way Analysis of Variance by Ranks	.199	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

b. schools in Penang

	Null Hypothesis	Test	Sig.	Decision
1	The distributions of HRS05, HRS06, HRS07 and HRS08 are the same.	Related-Samples Friedman's Two-Way Analysis of Variance by Ranks	.577	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

c. schools in Perlis

i. 0.05 level of significant

	Null Hypothesis	Test	Sig.	Decision
1	The distributions of HRS05, HRS06, HRS07 and HRS08 are the same.	Related-Samples Friedman's Two-Way Analysis of Variance by Ranks	.093	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

ii. 0.10 level of significant

	Null Hypothesis	Test	Sig.	Decision
1	The distributions of HRS05, HRS06, HRS07 and HRS08 are the same.	Related-Samples Friedman's Two-Way Analysis of Variance by Ranks	.093	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .10.

4. Hypothesis test summary for the Wilcoxon Signed Ranks Test to examine the differences in the distribution of efficiency scores of **schools in Perlis** in different years

(vii) Between 2005 and 2006

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between HRS05 and HRS06 equals 0.	Related-Samples Wilcoxon Signed Ranks Test	.170	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .10.

(viii) Between 2005 and 2007

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between HRS05 and HRS07 equals 0.	Related-Samples Wilcoxon Signed Ranks Test	.384	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .10.

(ix) Between 2005 and 2008

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between HRS05 and HRS08 equals 0.	Related-Samples Wilcoxon Signed Ranks Test	.248	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .10.

(x) Between 2006 and 2007

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between HRS06 and HRS07 equals 0.	Related-Samples Wilcoxon Signed Ranks Test	.530	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .10.

(xi) Between 2006 and 2008

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between HRS06 and HRS08 equals 0.	Related-Samples Wilcoxon Signed Ranks Test	.028	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .10.

(xii) Between 2007 and 2008

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between HRS07 and HRS08 equals 0.	Related-Samples Wilcoxon Signed Ranks Test	.011	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .10.

5. Hypothesis test summary for the Friedman's Two-Way Analysis of Variance by Ranks to examine the differences in the distribution of the Malmquist index in three different period

a. Kedah

	Null Hypothesis	Test	Sig.	Decision
1	The distributions of MI06, MI07 and MI08 are the same.	Related-Samples Friedman's Two-Way Analysis of Variance by Ranks	.000	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

b. Penang

	Null Hypothesis	Test	Sig.	Decision
1	The distributions of MI06, MI07 and MI08 are the same.	Related-Samples Friedman's Two-Way Analysis of Variance by Ranks	.001	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

c. Perlis

	Null Hypothesis	Test	Sig.	Decision
1	The distributions of MI06, MI07 and MI08 are the same.	Related-Samples Friedman's Two-Way Analysis of Variance by Ranks	.756	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .10.

6. Hypothesis test summary for the Wilcoxon Signed Ranks Test to examine the differences in the distribution of the Malmquist index of schools in

a. Kedah

i. Between 2005/2006-2006/2007

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between MI06 and MI07 equals 0.	Related-Samples Wilcoxon Signed Ranks Test	.465	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

ii. Between 2005/2006-2007/2008

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between MI06 and MI08 equals 0.	Related-Samples Wilcoxon Signed Ranks Test	.001	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

iii. Between 2006/2007-2007/2008

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between MI07 and MI08 equals 0.	Related-Samples Wilcoxon Signed Ranks Test	.023	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

b. Penang

i. Between 2005/2006-2006/2007

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between MI06 and MI07 equals 0.	Related-Samples Wilcoxon Signed Ranks Test	.767	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

ii. Between 2005/2006-2007/2008

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between MI06 and MI08 equals 0.	Related-Samples Wilcoxon Signed Ranks Test	.000	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

iii. Between 2006/2007-2007/2008

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between MI07 and MI08 equals 0.	Related-Samples Wilcoxon Signed Ranks Test	.009	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

7. Hypothesis test summary for the Kruskal-Wallis Test to examine the differences in the distribution of the Malmquist index across the different school types in three different periods.

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of MI06 is the same across categories of State.	Independent-Samples Kruskal-Wallis Test	.887	Retain the null hypothesis.
2	The distribution of MI07 is the same across categories of State.	Independent-Samples Kruskal-Wallis Test	.267	Retain the null hypothesis.
3	The distribution of MI08 is the same across categories of State.	Independent-Samples Kruskal-Wallis Test	.356	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

A4.7 - Statistical Tests for Section 4.6

1. Hypothesis test summary for the Mann-Whitney Test to examine the differences in the distribution of efficiency scores between urban and rural locations.

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of HRS05 is the same across categories of Location.	Independent-Samples Mann-Whitney U Test	.503	Retain the null hypothesis.
2	The distribution of HRS06 is the same across categories of Location.	Independent-Samples Mann-Whitney U Test	.854	Retain the null hypothesis.
3	The distribution of HRS07 is the same across categories of Location.	Independent-Samples Mann-Whitney U Test	.065	Retain the null hypothesis.
4	The distribution of HRS08 is the same across categories of Location.	Independent-Samples Mann-Whitney U Test	.909	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

2. Hypothesis test summary for the Friedman's Two-Way Analysis of Variance by Ranks to examine the differences in the distribution of efficiency scores in different years of:

a. Urban schools

	Null Hypothesis	Test	Sig.	Decision
1	The distributions of HRS05, HRS06, HRS07 and HRS08 are the same.	Related-Samples Friedman's Two-Way Analysis of Variance by Ranks	.145	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

b. **Rural schools**

	Null Hypothesis	Test	Sig.	Decision
1	The distributions of HRS05, HRS06, HRS07 and HRS08 are the same.	Related-Samples Friedman's Two-Way Analysis of Variance by Ranks	.095	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .10.

3. Hypothesis test summary for the Wilcoxon Signed Ranks Test to examine the differences in the distribution of efficiency scores of **rural schools** in different years

(xiii) Between 2005 and 2006

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between HRS05 and HRS06 equals 0.	Related-Samples Wilcoxon Signed Ranks Test	.518	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

(xiv) Between 2005 and 2007

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between HRS05 and HRS07 equals 0.	Related-Samples Wilcoxon Signed Ranks Test	.308	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

(xv) Between 2005 and 2008

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between HRS05 and HRS08 equals 0.	Related-Samples Wilcoxon Signed Ranks Test	.147	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

(xvi) Between 2006 and 2007

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between HRS06 and HRS07 equals 0.	Related-Samples Wilcoxon Signed Ranks Test	.875	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

(xvii) Between 2006 and 2008

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between HRS06 and HRS08 equals 0.	Related-Samples Wilcoxon Signed Ranks Test	.025	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

(xviii) Between 2007 and 2008

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between HRS07 and HRS08 equals 0.	Related-Samples Wilcoxon Signed Ranks Test	.003	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

4. Hypothesis test summary for the Friedman's Two-Way Analysis of Variance by Ranks to examine the differences in the distributions of the Malmquist index in three different period for

a. urban schools

	Null Hypothesis	Test	Sig.	Decision
1	The distributions of MI06, MI07 and MI08 are the same.	Related-Samples Friedman's Two-Way Analysis of Variance by Ranks	.000	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

b. rural schools

	Null Hypothesis	Test	Sig.	Decision
1	The distributions of MI06, MI07 and MI08 are the same.	Related-Samples Friedman's Two-Way Analysis of Variance by Ranks	.001	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

5. Hypothesis test summary for the Wilcoxon Signed Ranks Test to examine the differences in the distribution of the Malmquist index of schools in

a. urban location

i. Between 2005/2006-2006/2007

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between MI06 and MI07 equals 0.	Related-Samples Wilcoxon Signed Ranks Test	.802	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

ii. Between 2005/2006-2007/2008

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between MI06 and MI08 equals 0.	Related-Samples Wilcoxon Signed Ranks Test	.001	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

iii. Between 2006/2007-2007/2008

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between MI07 and MI08 equals 0.	Related-Samples Wilcoxon Signed Ranks Test	.003	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

b. rural location

i. Between 2005/2006-2006/2007

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between MI06 and MI07 equals 0.	Related-Samples Wilcoxon Signed Ranks Test	.285	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

ii. Between 2005/2006-2007/2008

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between MI06 and MI08 equals 0.	Related-Samples Wilcoxon Signed Ranks Test	.000	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

iii. Between 2006/2007-2007/2008

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between MI07 and MI08 equals 0.	Related-Samples Wilcoxon Signed Ranks Test	.092	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

6. Hypothesis test summary for the Mann-Whitney U Test to examine the differences in the distributions of the Malmquist index of schools in different locations in three different periods, 2005-2006, 2006-2007, and 2007-2008.

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of MI06 is the same across categories of Location.	Independent-Samples Mann-Whitney U Test	.416	Retain the null hypothesis.
2	The distribution of MI07 is the same across categories of Location.	Independent-Samples Mann-Whitney U Test	.873	Retain the null hypothesis.
3	The distribution of MI08 is the same across categories of Location.	Independent-Samples Mann-Whitney U Test	.430	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

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