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The Fiscal Viability of Malaysia's Smart School Project

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Abstract: Developing countries planning to embark on computers or information and communication technology in education must consider the cost of equipping schools to a level that ensures effective development of higher-order or metacognitive skills. Apart from the initial investment in hardware, the cost of educational software, teacher training, recurrent hardware and software maintenance and, more importantly, hardware renewal and retraining must be taken into account. It appears that the annual recurrent cost of the Malaysia's Smart School Project can be sustained. However, fiscal viability becomes a major issue when renewal costs of computers and related equipment, and retraining costs are taken into consideration. In particular, the Smart School Project may not be fiscally viable in the long-term. It is therefore important that alternatives and tradeoffs be considered. The alternatives include a bigger role for the private sector, concentrating limited resources on achieving the required critical mass in a small number of schools, exposing students to IT rather than immersing them in the full programme as proposed in the Smart School Project, and focusing our limited resources on the development of inspirational leadership, the quality of our teachers and their work environment to foster the development of metacognitive and affective skills among Malaysian youths.

1. Introduction

Developing countries planning to embark on the bandwagon of computers or information and communication technology (ICT) in education must consider the cost of equipping schools to a level that ensures that the new technology provides for effective learning. In the United States, for instance, the President's Committee of Advisors on Science and Technology (1997: 36; hereafter referred to as the President's Committee) notes that hardware cost projections depend heavily on the configuration. The President's Committee (1997: 15) argues that many experts consider a ratio of 4 to 5 students per computer to be a "reasonable level for the effective use" of computers within schools. Citing the McKinsey/NIIAC (1995) study, the President's Committee notes that projected nationwide initial cost of computers in education can range from a low of $11 billion to a high of $47 billion, depending on the level of technology usage. Likewise, annual recurrent cost can range from $4 billion to $14 billion. The lowest levels of initial outlay and recurrent costs are based on an average of 25 computers per school – a figure that is clearly below the "reasonable level for effective use." On the other hand, to achieve the "reasonable level for effective use" as defined by a student-computer ratio of five calls for the largest initial outlay and recurrent cost.

Apart from the cost of hardware, developing countries must also take into account the cost of educational software. As with the hardware, estimates of software cost vary widely too. For the United States, for instance, estimates for 1995 for instructional software range from $10 to $16 per student-year but even that sum, as the President's Committee (1997: 27)

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notes, will have to be increased very substantially if technology is to play a significant role in improving the quality of American education. The President's Committee (1997: 27) adds that unless there is sufficient funding, "software developers may not find adequate incentives to justify the substantial research and development expenditures that will be required to produce a new generation of school-based educational software products."

Another aspect of cost which developing countries must take into account is the cost of teacher training. Mann (1999: 4) emphasizes that the integration of technology into education is best accomplished by providing more professional development for teachers such as more in-service training and more released time for training. Mann *et al.* (1999: 17) emphasise the importance of investing in teachers. In fact, they argue that investment in teachers must be conducted as seriously as in technology. In particular, Mann *et al.* (1999: 30) argue that "Putting hardware in a room without training teachers or otherwise supporting the integration of technology into the classroom cannot be expected to make a difference. It is the cumulative effect of the several variables that compose the model that is important."

In addition to the initial outlay for hardware and software, and the recurrent costs for hardware and software maintenance, consumables and supplies, and personnel services, developing countries must also take into account replacement or renewal cost as hardware currently have a useful life of about four years (President's Committee 1997: 16; Anderson and Ronnkvist 1999: 6). A student-computer ratio of five implies that a primary school in Malaysia with an average enrolment of 400 pupils in the year 2000 would require 81 multimedia computers. This, in turn, implies a replacement of at least 20 computers per year. At the secondary school level, with an average enrolment of 1,100, 220 multimedia computers, plus a replacement of at least 55 computers per year per school. A failure to update or upgrade hardware will impede their usefulness. As the President's Committee (1997: 15) notes, older machines are able to run early educational applications but little or no new software is being written for these platforms. In addition, older hardware is "incapable of supporting much of the functionality incorporated in the most interesting current applications of technology to education."

Our principal objective here is to examine the fiscal viability of Malaysia's Smart School Project. The Smart School Project seeks to convert all public primary and secondary schools in Malaysia to Smart Schools by the year 2010. The principal aim of the Smart School, as the Ministry of Education (1997a: 9) emphasises, is to "(move) away from memory-based learning designed for the average student to an education that stimulates thinking, creativity, and caring in all students, caters to individual abilities and learning styles, and is based on more equitable access." In addition, the Ministry of Education (1997a: 11) emphasises that "The most distinctive feature of the Smart School will be a teaching and learning environment built on international best practices in primary and secondary education." In this respect, the Ministry (1997a: 14) notes that "Technology alone will not make a school smart. Only improved teaching-learning strategies, management and administrative processes, and capable, well-trained people with enthusiasm for their work can do that. However, information technology can enable this process of transforming traditional schools into Smart Schools. Consequently, a nation-wide system of Smart Schools will depend on advanced information technology at the school, district and national levels (our emphasis)." In short, the Ministry of Education clearly understands that it takes more than information technology to transform Malaysia's schools into Smart Schools. Nevertheless, it sees information technology or computers in education as a key enabling tool that can be used to transform Malaysian education into a stimulating environment that will foster the development of the key skills and competencies that are required for success in the global information economy. The realisation of this objective will, as we have seen above, call for vast sums of investment in hardware, software, teacher training and renewal.

The key question for Malaysia, as for any developing country, seeking to stay on the right side of the digital divide is the capacity of the government to afford the vast sums of money that will be required to achieve a "reasonable level for effective use." The question may be viewed at two levels. First, in terms of the initial investment outlay that will be required to achieve the desire level for effective use. Second, and more importantly from the perspective of long-term viability, is the annual recurrent expense required for the smooth operation of the entire system (in the form of software maintenance, personnel services, consumables and supplies, telecommunication, and retraining of teachers and administrators to ensure that they keep pace with developments in hardware and software) and the renewal cost that must be incurred as equipment outlive their useful life. The important questions then are:

1. Will the Government of Malaysia have sufficient fiscal resources to convert all primary and secondary schools into Smart Schools by the year 2010?
2. Will the Government of Malaysia have sufficient fiscal resources to maintain the Smart Schools?

The present discussion focuses on the second question: that is, on recurrent cost and renewal cost because these affect the long-term fiscal viability of the Project. Renewal cost must be incurred as computers and related equipment reach the end of their useful life (currently estimated at about four years). Fiscal viability is assessed with respect to government expenditure.

The rest of this chapter is organised as follows: Section 2 provides a brief look at the costs of the Smart School Project. Section 3 looks at past trends in federal government revenue and the share that accrues to education in the form of federal government recurrent expenditure. The focus is on federal government recurrent expenditure on primary and secondary schooling – the levels relevant to the Smart School Project. Section 4 presents various alternative models that may be used to project government revenue to the year 2010 at which point all Malaysian primary and secondary schools should have been converted into Smart Schools. One of these models will be used to project federal government revenue. Section 5 presents alternative models that may be used to project federal government recurrent spending on primary and secondary schooling. Combining the projections here with those from Section 4, we look at trends in federal government recurrent spending on primary and secondary schooling to see how they will change over the next ten years. Section 6 models growth in student numbers at the primary and secondary school levels, and then projects the number of primary and secondary schools that will be required over the 2000 to 2010 period. This provides the basis for estimating annual recurrent expenditure required for the smooth functioning of the Smart Schools. Section 7 looks at the implications for federal government recurrent expenditure at the primary and secondary levels, and the implications for federal government revenue as the primary and secondary schools are converted into Smart Schools. In particular, we focus on two kinds of costs – annual recurrent cost, and annual renewal and retraining costs. Section 8 closes with a summary of the key findings and some concluding remarks.

2. Cost Estimates of the Smart Schools Project

Malaysia's Smart School Pilot Project – the first step in the full utilisation of computers or ICT in education in all public schools by the year 2010 – will cover 21 primary and 69 secondary schools (Ministry of Education 1997b). This Pilot Project itself will cost an estimated RM 300 million. Capital cost (including hardware, school management system, teaching-learning materials, and project management and implementation) will account for 61 per cent of the total cost. Operating expenditure (including system design and installation, communication cost, maintenance and support) will account for 30 per cent of the total cost. These costs do not include the cost of teacher training. It should also be emphasised that in spite of the high cost, 88 per cent of the schools in the Pilot Project will have a student-computer ratio of 40. This ratio is eight times higher than the ratio of 5:1 that has been considered a "reasonable level for effective use" (cf. President's Committee *op cit.*: 15). Only 12 per cent of the schools in the Pilot Project have been targeted to have a student-computer ratio that could be considered reasonable for effective use.

At present, average enrolment stands at around 400 per school at the primary school level and 1,100 per school at the secondary school level. If the objective is to ensure that all schools attain a "reasonable level for effective use", this implies that each school must have a student-computer ratio of 5. The average primary school in Malaysia will then require the equivalent of the Ministry of Education's level B+ status and the average secondary school will require the equivalent of a Level A status.[1] Our current estimates place the annualised investment cost for a Level B+ school at RM 523,971, and the annual recurrent cost at RM 53,550 (see Appendix A). The annualised investment cost for a Level A secondary school is estimated at RM 1,571,505, and the annual recurrent cost at RM 215,927. The annualised investment cost refers to the quantum that must be spent annually over a period of four years to bring a school to the "reasonable level for effective use". At the primary school level, attaining a level B+ status calls for an annualised investment cost of RM 523,971 incurred over a four-year period. To convert all existing primary schools to Level B+ status would require a total investment outlay of around RM 14.7 billion while conversion of all existing secondary schools to Level A status would require a total investment of around RM 10.1 billion during the first year alone. If the total investment cost is spread out evenly over a 10 year-period such that one-tenth of existing primary and secondary schools are converted to Smart-School status each year over the next ten years, it would still require an annual investment outlay of over RM 2.5 billion (at constant year 1999 price level).

A more important issue relates to the recurrent cost entailed by the Smart School Project. While the initial investment expenses can be written off as sunk costs, subsequent maintenance

[1] A Level B+ school will be equipped with a LAN consisting of 86 computers distributed as follows: 60 computers in 15 classrooms/science labs (i.e. 4 PCs each), 10 in the Resource Centre, 10 in the Teachers Room, 3 in the Administration Office, and 3 Servers in the Server Room. The LAN is connected to the Data Centre with Help Desk Support using a leased line of 128/64 Kilobits per second. A Level A school will be equipped with a LAN consisting of 479 computers distributed as follows: 252 computers in 36 classrooms/science labs (7 PCs each), 20 in the Resource/Multimedia Development Centre, 70 in 2 computer labs (35 each), 30 in the Teachers Room, 5 in the Administration Office, 3 Servers in the Server Room. The LAN is connected to the Data Centre with Help Desk Support using a leased line of 512/256 Kilobits per second. For further details see: http://www.ppk.kpm.my/smartschool/levels.html. See also Ministry of Education (1999).

cost, and renewal and retraining costs cannot be written off in like manner. Maintenance or annual recurrent cost refers to the cost of hardware and software maintenance, cost of consumables and supplies, personnel services and telecommunication costs. These costs must be incurred annually. If installation of all equipment is spread evenly over four to five years, this implies that at least one-fifth of the computers and related equipment must be renewed or replaced each year starting in the fifth year. Similarly, teachers and administrators require retraining to keep pace with changes in hardware and software. We refer to expenditures of this nature as renewal and retraining costs. Both these costs must be incurred annually, starting in the fifth year, and therefore constitute a part of the recurrent expenditure of the Smart School Project.

If the conversion of all schools to Smart School status is implemented evenly over a ten-year period so that all primary and secondary schools are converted to Smart Schools by the year 2010, we estimate that the annual recurrent cost will start at around RM 69.40 million in the year 2000 and will rise to RM 896.81 million in the year 2010. Renewal of equipment will commence in the year 2004 and will continue beyond the present planning horizon (2000 to 2010). We estimate that the renewal and retraining costs will rise from around RM 349.49 million for primary schools in the year 2004 to RM 3.02 billion in the year 2010. The corresponding sums for the secondary schools are RM 245.15 million and RM 1.84 billion, respectively. Overall, the costs of renewal and retraining will rise from RM 594.64 million in the year 2004 to RM 4.86 billion in the year 2010.[2] These costs will clearly have significant implications for government spending on primary and secondary schooling in Malaysia.

3. Government Revenue and Education Sector Spending

Our cost estimates are based on 1999 prices. The discussion that follows on government revenue and government expenditure on primary and secondary education, and our subsequent projections of government revenue and recurrent expenditure on primary and secondary schooling will therefore be based on 1999 prices.

In the 1970s, real GNP (in 1999 prices) grew at an average annual rate of 7.8 per cent. In the 1980s, with the 1979 oil shock and the recession of 1985, average real GNP growth rate declined to 5.7 pe rcent per annum. In the 1990s real GNP grew at an average annual rate of 6.4 per cent in spite of the Asian crisis.[3] While the government can, through its fiscal policy, impact on the level of overall macroeconomic activity in the country, it is important to emphasise the other side of the coin. In particular, fluctuations in the level of macroeconomic activity can have important repercussions on government revenue. In the 1970s, real federal government revenue grew at an average annual rate of 10.4 per cent. With the slower rate of growth in real GNP in the 1980s, real federal government revenue grew at a slower average annual rate of 7.1 per cent. In the 1990s, although real GNP grew at a higher average annual

[2] The above cost estimates do not take into account the cost of teacher training. There are currently 263,314 teachers in primary and secondary schools. The Ministry of Education has targeted 6,000 teachers for the first round of training, a further 70,000 by 2005. The full implementation of the Smart Schools will require the training of about 450,000 teachers by 2010 (see Ministry of Education 1997a: 133).

[3] Prior to the Asian financial crisis of 1997, real GNP grew at an average annual rate of 8.8 per cent. For the rest of the 1990s, real GNP grew at an average annual rate of only 0.8 per cent.

rate than in the 1980s, the significantly slower growth in real GNP following the Asian financial crisis resulted in a much lower growth rate in real federal government revenue in the 1990s. In particular, growth in real federal government revenue declined sharply in the last three years of the 1990s resulting in an overall average annual growth rate in real federal government revenue of only 3.4 per cent throughout the decade.

Real federal government recurrent expenditure on education grew at an average annual rate of 14.6 per cent in the 1970s. However, with slower growth in real federal government revenue in the 1980s, real federal government recurrent expenditure on education grew at a slower rate of 6.7 per cent per annum in the 1980s. In the 1990s, real federal government recurrent expenditure on education grew at an even slower rate of 4.0 per cent per annum, in line with the overall slower growth in real federal government revenue.

At the levels that are relevant to the Smart School Project, real federal government recurrent expenditure on primary and secondary schooling grew at an average annual rate of 12.3 per cent in the 1970s. With the slower growth in overall federal government spending on education in the 1980s, real federal government recurrent spending on primary and secondary schooling declined; registering a growth of only 6.1 per cent per annum over the period. Similarly, with a further decline in the growth in federal government recurrent expenditure on education in the 1990s, the growth rate in real federal government recurrent expenditure in primary and secondary schooling declined further to only 4.2 per cent per annum.[4]

Throughout the 1970s, federal government recurrent expenditure on education averaged 4.5 per cent of real GNP. In the 1980s, with federal government recurrent expenditure on education growing at a higher average annual rate than real GNP, federal government recurrent expenditure on education as a proportion of real GNP rose to an average of 5.0 per cent. In the 1990s, particularly with relatively more severe cut backs in the growth rate of federal government recurrent expenditure on education, federal government recurrent expenditure on education as a proportion of real GNP fell to an average of 4.1 per cent.[5]

With rising competing needs, federal government recurrent expenditure on education as a proportion of federal government revenue has generally been on the decline. In the 1970s, federal government recurrent expenditure on education averaged 20.6 per cent of total federal government revenue. In the 1980s, the proportion fell to 18.1 per cent and in the 1990s to 16.4 per cent.[6] In addition to this decline, there has been a steady decline in federal government recurrent expenditure on primary and secondary schooling as a proportion of total federal government recurrent spending on education. In the 1970s, federal government recurrent expenditure on primary and secondary schooling as a proportion of total federal government

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4 The decline in the rate of growth in federal government expenditure on primary and secondary education can be attributed to several factors besides the growth in federal government revenue. First, Malaysia has achieved near universal primary education. Second, enrolment at the secondary level has approached a plateau. Third, the 1980s and 1990s saw the opening up of alternative forms of upper secondary education such as the matriculation programmes offered by the domestic universities and foreign matriculation programmes offered by the private colleges. Fourth, in line with the rise in demand for higher level manpower, the government has been giving greater emphasis to the development of tertiary education.

5 The overall picture here is similar to that described by the Ministry of Education (1996: 38).

6 The Ministry of Education (1996: Table 3, 38) shows that educational expenditure as a proportion of total government expenditure has been on a steady decline since 1987.

recurrent spending on education stood at an average of 81.5 per cent. In the 1980s the proportion fell to 67.8 per cent and in the 1990s to 65.0 per cent. This decline can be explained by the fact that Malaysia has achieved near universal primary education. In addition there has been a shift towards the development of tertiary education in line with demands for higher-level manpower.[7]

The Educational Planning and Research Division, Ministry of Education (1996: 42) notes that the share in total federal government recurrent expenditure on education accounted for by primary schooling has declined steadily from 35.7 per cent in 1987 to 29.4 per cent in 1995. On the other hand, the share accounted for by secondary schooling (including technical and vocational secondary schools) has remained around 30 per cent since 1987. A breakdown of recurrent spending shows that emoluments account for the largest share in total recurrent expenditure on education. In particular, emoluments account for over 70 per cent of total federal government recurrent expenditure in primary, secondary, teacher training and polytechnic education.[8]

Real federal government recurrent spending on education has risen from RM 1.5 billion in 1970 to RM 10.4 billion in 1999. Real federal government recurrent spending on primary and secondary schooling, on the other hand, has risen from RM 1.4 billion in 1970 to RM 6.9 billion in 1999. The former has grown at an average annual rate of 7.0 per cent while the latter has grown at an average annual rate of 5.8 per cent since 1970. These compare reasonably well with the average annual growth rate in real GNP of 6.5 per cent, and real federal government revenue over the same period. It is, however, important to note, as the above discussion shows, that federal government revenue can be affected by the overall economic fortunes of the country and that this can in turn have an impact on government spending on education.

4. Modeling Growth in Federal Government Revenue

The fiscal viability of the Smart School Project will depend clearly on government revenue and the allocations made to primary and secondary schooling, that is allocations to those levels of education that have been targeted for the development of the Smart School. The first step in our study of the fiscal viability of the Smart School Project is to examine how the level of macroeconomic activity affects federal government revenue. Second, we examine how changes in federal government revenue will affect government spending on education at the primary and secondary levels. This examination of the fiscal viability of the Smart School Project covers the period from the year 2000 to the year 2010 – the targeted date for the conversion of all primary and secondary schools into Smart Schools.

Gujarati (1995: 734) notes that there are, broadly speaking, four approaches to economic forecasting based on time series data: (i) simultaneous-equation regression models, (ii) single-equation regression models, (iii) autoregressive integrated moving average (ARIMA) models, and (iv) vector autoregression (VAR) models. Simultaneous-equation models dominated

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[7] See footnote 4.

[8] The proportion accounted for by emoluments has declined steadily from 77.1 per cent in 1987 to 73.4 per cent in 1995 (see Ministry of Education 1996: Table 4 – 41).

economic forecasting in the 1960s and 1970s. However, all these models, except OLS, are more data demanding than single-equation, ARIMA and VAR models. A more important reason for resorting to single-equation, ARIMA and VAR models lies in the Lucas critique.[9] In essence, the Lucas critique maintains that estimated parameters of a model are not policy invariant. In other words, the parameters estimated depend on the policy prevailing at the time the model was estimated and they will change with a change in policy. An econometric model based on past data will have little forecasting value when policies change (cf. Gujarati *ibid.*). For these reasons, we shall work only single-equation models. Furthermore, the use of autoregressive or dynamic regression models lessens the need for obtaining forecasts of regressor variables that are different from the dependent variable. It is, however, important to note that these models are also based on past data. Regular updating is therefore needed as and when new data become available.

The first step is to identify an appropriate model for forecasting the impact of GNP growth on government revenue. Toward this end, three models are presented and one is selected. The models estimated here have real government revenue (base-year 1999) as the dependent variable and real GNP (base-year 1999) and/or lagged real government revenue as the independent variable. We estimated our models based on data from 1970 to 1997, reserving 1998 and 1999 data to be used as standards for judging the predictive power of the models presented here.

For each model, the fit is assessed by examining the residual pattern, and by evaluating the variation in the dependent variable explained by the model (R^2). The first seeks to establish that the assumption of independence of the residuals is not violated. One specific test for a particular form of serial correlation uses the Durbin-Watson d statistic. This test, however, is not valid if the lagged dependent variable is one of the regressors. One alternative is the Durbin-Watson h statistic (Gujerati 1995: 605); however, that test requires large samples. We present below the d values, bearing in mind these considerations. In addition, we also checked that the autocorrelation function of the residuals resembled that of an independent random series. In addition, it should be emphasised that some regressors may turn out to be statistically insignificant but this is irrelevant for the principal purpose at hand; that is for the purpose of forecasting.

Regressions involving time series face the problem of spurious results especially when the results look as good as in this case. Granger and Newbold (1976) have suggested that an adjusted R^2 that is greater than the Durbin-Watson statistics is a good rule of thumb to suspect that the estimated regression suffers from spurious regression. [10] Gujarati (1995: 726) argues that if the two variables are cointegrated then "the regression on the levels of the two variables is meaningful (not spurious); and we do not lose any valuable long-term information, which would result if we were to use their first difference instead." Even if lnGR and lnGNP are nonstationary processes, the linear combination of the two variables might be stationary. If

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[9] See Lucas (1976). The Lucas critique is well illustrated by Sargent and Wallace (1975, 1976).

[10] Gujarati (1995: 725) notes that in the event of a spurious regression, one solution to the problem is to take the first difference in lnGR and lnGNP. However, Gujarati (ibid.) argues that "solving the nonstationarity problem in this fashion may be like throwing out the baby with the bath water; for in taking the first (or higher-order) difference, we may lose a valuable long-term relationship between (the two variables) that is given by the levels (as against the first difference) of the two variables."

they are, then, as Gujarati (1995: 726) argues, the variables are cointegrated and the regression of the two variables is meaningful. Where necessary, we have used the Dickey-Fuller test for a unit root to establish non-stationarity and the Engle-Granger test to test for cointegration.

4. 1 Model 1A

The first model is based on the argument that real federal government revenue (GR) in year t depends on GNP a year earlier; in other words GR in year *t* depends on GNP in year *t-1*. To stabilise the variance for both real federal government revenue and real GNP, we take the natural logarithm. Running lnGR against lnGNP we obtain the following results:

$$\widehat{\ln GR} = -0.317 + 0.274\ln GNP(-1) + 0.728\ln GR(-1) \qquad (1)$$
$$(0.536) \quad (1.525) \qquad\qquad (4.764)$$

$$\bar{R}^2 = 0.986 \qquad\qquad d = 2.003$$

Given that the adjusted R^2 is less than the Durbin-Watson statistics, this would suggest that spurious correlation is not a problem here. As we have noted above, this result must be interpreted with caution since the Durbin-Watson statistic is not appropriate where the lagged dependent variable is one of the regressors. This caveat holds in all subsequent discussion relating to the Durbin-Watson statistic.

To confirm that the regression estimated above is meaningful, we conducted the Dickey-Fuller test. The results confirm both variables to be non-stationary at the 10 per cent level, and the Engle-Granger confirmed that both variables are cointegrated of order 1 (see Appendix B). In other words the results of equation (1) are meaningful (not spurious).

4. 2 Model 1B

Our second model is a trend with a lagged dependent variable. The time trend begins with 1 for 1970 and effectively captures the linear trend in lnGR. Running lnGR against time and lnGR(-1), we obtain the following estimates:

$$\widehat{\ln GR} = 1.799 + 0.011t + 0.815\ln GR(-1) \qquad (2)$$
$$(1.522) \quad (1.116) \quad (6.278)$$

$$\bar{R}^2 = 0.985 \qquad\qquad d = 2.128$$

The Durbin-Watson leads to an acceptance of the null hypothesis, that is there is no autocorrelation, positive or negative at the 1 per cent level.

4. 3 Model 1C

Our third model is based on the first difference of the variables. We take the first difference of lnGR and lnGNP to produce stationarity and obtain the following results:

$$\widehat{D(\ln GR)} = \underset{(0.372)}{0.011} + \underset{(2.503)}{0.961}\, D(\ln GNP) \quad (3)$$

$$\bar{R}^2 = 0.200 \qquad d = 2.583$$

The Durbin-Watson does not lead to a rejection of the null hypothesis, that is, there is no negative autocorrelation at the 5 per cent level.

4. 4 Choice of Model and Projections of Federal Government Revenue

Our choice between the three models presented above is based on two criteria. First, how well the model predicts government revenue or changes in government revenue over the period from 1970 to 1999. Second, how well the model predicts government revenue during the exceptional years following the 1997 Asian financial crisis, that is, during 1998 and 1999.

The overall quality of the forecasts is evaluated on the basis of the Root Mean Squared Error (RMSE) calculated over the 1970 to 1999 period. The RMSE for Models 1A, 1B and 1C are 4484.6, 3860.6, and 6753.7, respectively. On this basis it is clear that Model 1B has the lowest RMSE and is to be preferred over Model 1A and Model 1C.

Table 1 shows the actual and fitted real GR for 1998 and 1999, and the percentage forecast errors obtained from each of the three models. As can be seen, Model 1B yields the smallest percentage forecast error for both 1998 and 1999. On the basis of the two criteria, Model 1B appears to be the best model. It produces the best forecasts of real federal government revenue for the years 1998 and 1999, and also has the smallest Root Mean Squared Error for the entire period included in the study.

Table 1: Percentage forecast error in federal government revenue for 1998 and 1999

Year	Actual GR	Model 1A		Model 1B		Model 1C	
		Fitted	Error	Fitted	Error	Fitted	Error
1998	57154	73367	28.4	71261	24.7	77098	34.9
1999	56690	65963	16.4	63329	11.7	66550	17.4

On the basis of Model 1B, we made projections of real federal government revenue in order to facilitate our examination of the fiscal viability of the Smart School Project. In particular, we made projections of real federal government revenue for the years 2000 to 2010. The projections are made under four scenarios of growth in government revenue – trend, low, moderate, and high. Throughout the period 1970-1999, federal government revenue grew at an average annual rate of 6.8 per cent. In the 1970s, federal government revenue grew at an average annual rate of 10.4 per cent per annum. In the 1980s, with the first recession since independence in 1957, federal government revenue grew at an average annual rate of 7.1 per cent. In the 1990s, with the most severe recession following the Asian financial crisis in 1997, federal government revenue grew at an average annual rate of only 3.4 per cent. In this context, we took a growth rate of 3 per cent in federal government revenue as a reflection of low growth, 6 per cent as moderate and 9 per cent as high.

Table 2 shows the projected growth in federal government revenue for the period 2000 to 2010 under the four different growth scenarios. Following the trend represented by Model

Table 2: Projected federal government revenue (RM million in constant 1999 prices)

Year	Federal government revenue growth scenario			
	Trend	Low	Moderate	High
2000	63,605.98	58,390.70	60,091.40	61,792.10
2001	70,634.73	60,142.42	63,696.88	67,353.39
2002	77,784.77	61,946.69	67,518.70	73,415.19
2003	85,074.81	63,805.09	71,569.82	80,022.56
2004	92,530.93	65,719.25	75,864.01	87,224.59
2005	100,184.43	67,690.82	80,415.85	95,074.81
2006	108,070.17	69,721.55	85,240.80	103,631.54
2007	116,225.42	71,813.20	90,355.25	112,958.38
2008	124,689.11	73,967.59	95,776.56	123,124.63
2009	133,501.33	76,186.62	101,523.16	134,205.85
2010	142,703.08	78,472.22	107,614.55	146,284.37

1B, real federal government revenue will increase from RM 63.6 billion in the year 2000 to RM 142.7 billion in the year 2010, at an average annual rate of 8.8 per cent. A low growth scenario will result in real federal government revenue increasing from RM 58.3 billion to RM 78.5 billion over the same period. A moderate growth scenario will result in federal government revenue increasing from RM 60.1 billion in the year 2000 to RM 107.6 billion in the year 2010. High growth, on the other hand, implies that federal government revenue will increase from RM 61.8 billion to RM 146.3 billion over the same period. As can be seen, trend growth scenario yields projected federal government revenue for the years 2000 to 2010 that are quite similar to those obtained from a high growth scenario. This is not unexpected since the trend growth as reflected by Model 1B implies an average annual growth rate that is close to 9 per cent per annum assumed under our high growth scenario.

5. Modeling Growth in Federal Government Recurrent Expenditure on Primary and Secondary Schooling

The next step in the exercise is to model federal government recurrent expenditure at primary and secondary levels where the Smart School Project applies. We examined several possible models and chose the one with the best predictive power. Here we report on three models.

The three models estimated here have real federal government recurrent expenditure on primary and secondary schooling (base-year 1999) as the dependent variable and real federal government revenue and/or lagged real federal government recurrent expenditure on primary and secondary schooling as the independent variable. As before, we estimated our models based on data from 1970 to 1997, reserving 1998 and 1999 data to be used as standards for judging the predictive power of the models presented here.

5. 1 Model 2A

Our first model is based on the argument that real recurrent expenditure on primary and secondary schooling (GPSE) in year *t* depends on real government revenue (GR) for that year. To reduce the variation in both real federal government recurrent expenditure on primary and secondary schooling and real federal government revenue, we took the natural logarithm of both variables. The augmented Dickey-Fuller tests show that lnGPSE is stationary while lnGR is not (see equations (4a) and (94b) in Appendix C). We, therefore, first differenced lnGPSE and lnGR to produce stationarity.[11] Running D(lnGPSE) against dlnGR yielded the following results:

$$\widehat{D(\ln GPSE)} = -\ 0.011 + 0.885D(\ln GR) \quad (5)$$
$$(0.238) \quad (2.139)$$

$$\bar{R}^2 = 0.155 \qquad d = 2.343$$

The Durbin-Watson leads to an acceptance of the null hypothesis, that is, there is no autocorrelation, positive or negative, at the 1 per cent level.

5. 2 Model 2B

Our second model is a trend with a lagged dependent variable. The time trend begins with 1 for 1970 and effectively captures the linear trend in lnGPSE. Running lnGPSE against time and lnGPSE(-1) we obtained the following estimates:

$$\widehat{\ln GPSE} = 6.187 + 0.039t + 0.184\ln GPSE(-1) \quad (6)$$
$$(4.382) \quad (3.602) \quad (0.969)$$

$$\bar{R}^2 = 0.901 \qquad d = 2.131$$

The Durbin-Watson leads to an acceptance of the null hypothesis, that is, there is no autocorrelation, positive or negative at the 1 per cent level.

5. 3 Model 2C

The bulk of government recurrent expenditure at the primary and secondary levels consists of emolument payments. In the Malaysian context, although the proportion has declined slightly over the years, emoluments accounts for over 70 per cent of total federal government recurrent expenditure for non-university education (Ministry of Education 1966: Table 4, p. 41). Given that emoluments are rarely reduced and are structured with more or less automatic annual increments, it may be argued that federal government recurrent expenditure on primary and secondary schooling will depend heavily on its past levels. In view of this argument, we also estimated a model in which current recurrent expenditure on primary and secondary schooling depends not only on government revenue but also on the previous year's recurrent expenditure. This yielded the following results:

$$\widehat{\ln GPSE} = 1.364 + 0.466\ln GR + 0.256\ln GPSE(-1) \quad (7)$$
$$(2.917) \quad (3.862) \qquad (1.598)$$

$$\bar{R}^2 = 0.906 \qquad d = 2.047$$

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[11] In Appendix B, D(lnGR,2) is equivalent to (lnGR – lnGR(-1) – (lnGR(-1) – lnGR(-2)). A similar expression applies to D(lnGNP,2).

The Durbin-Watson leads to an acceptance of the null hypothesis, that is, there is no autocorrelation, positive or negative, at the 1 per cent level.

Our choice between the three models presented above is based on two criteria. First, how well the model predicts government recurrent expenditure on primary and secondary schooling over the entire period from 1970 to 1999. Second, how well the model predicts government revenue during the exceptional years following from the 1997 Asian financial crisis, that is, during 1998 and 1999.

The overall quality of the forecasts can be evaluated on the basis of the Root Mean Squared Error (RMSE). The RMSE for Models 2A, 2B and 2C are 588.7, 536.0 and 466.3, respectively. On this basis it is clear that Model 2C has the lowest RMSE and is to be preferred over Model 2A and Model 2B.

Table 3 shows the actual and fitted real federal government recurrent expenditure on primary and secondary schooling for 1998 and 1999, and the percentage forecast errors obtained from each of the three models. As can be seen, Models 2A and 2C underestimate actual federal government recurrent expenditure on primary and secondary schooling while Model 2B overestimates. Model 2C yields the smallest percentage forecast error for 1998 while Model 2A yields the smallest percentage forecast error for 1999. On the average, over the 1998 and 1999 period, Model 2C yields the smallest forecast error while Model 2A yields the largest. Overall, Model 2C has the smallest Root Mean Squared Error for the entire period included in the study and also produces the smallest average percentage forecast error for 1998 and 1999. We therefore adopted it as our model for projecting federal government recurrent expenditure on primary and secondary schooling for the years 2000 to 2010.

On the basis of Model 2C, we made projections of real federal government recurrent expenditure on primary and secondary schooling in order to facilitate our examination of the fiscal sustainability of the Smart School Project. Since government recurrent expenditure on primary and secondary schooling under Model 2C is affected by government revenue, we made projections for the years 2000 to 2010, under four different growth scenarios in federal government revenue – trend, low, moderate, and high. As before, we took a growth rate of 3 per cent as a reflection of low growth, 6 per cent as moderate and 9 per cent as high.

Looking ahead then, Table 4 shows our forecast of federal government recurrent expenditure on primary and secondary schooling for the period 2000 to 2010 based on Model 2C under the four different scenarios for the growth in federal government revenue. Based on the model adopted here, real federal government recurrent spending on primary and secondary schooling will rise from RM 6.5 billion in the year 2000 to RM 10.4 billion in the year 2010, or at an average annual rate of 3.9 per cent over the period. Under a low growth scenario in real federal government revenue, recurrent spending on primary and secondary schooling is projected to rise from RM 6.2 billion in the year 2000 to RM 7.2 billion in the year 2010, or

Table 3: Percentage forecast error for 1998 and 1999

Year	Actual GPSE	Model 2A		Model 2B		Model 2C	
		Fitted	Error	Fitted	Error	Fitted	Error
1998	6405.2	5046.4	–21.2	7155.7	11.2	5941.8	–7.2
1999	6872.7	6289.6	–8.5	7560.8	10.0	6053.2	–11.9

at an average annual rate of only 0.5 per cent. The corresponding figures for a moderate growth scenario are RM 6.3 billion to RM 8.8 billion, at an average annual rate of 2.3 per cent. If government revenue grows at a high rate of 9 per cent per annum, then government recurrent spending on primary and secondary education is projected to rise from RM 6.4 billion to RM 10.6 billion over the same period. This implies an average annual growth rate of 4.0 per cent - about the same as the trend rate of growth.

The important question is how this projected growth in government recurrent spending will affect government revenue over the projection period. As discussed earlier, the average annual rate of growth in government expenditure on education has declined over the years from 14.6 per cent in the 1970s to 6.7 per cent in the 1980s and then to 4.0 per cent in the 1990s. In like manner, government recurrent spending on primary and secondary schooling has also seen a drop in its average rate of growth from 12.3 per cent per annum in the 1970s to 6.1 per cent in the 1980s and 4.2 per cent in the 1990s. Overall, these differences led to a drop in federal government recurrent expenditure on primary and secondary schooling as a proportion of total government revenue from an average of 16.8 per cent in the 1970s, to an average of 12.3 per cent in the 1980s and then to 10.7 per cent in the 1990s.

Table 5 shows projected federal government recurrent expenditure on primary and secondary schooling as a proportion of total federal government revenue under the four different growth scenarios. The proportions follow the same downward trend that has been the general pattern over the 1970 to 1999 period. The worst scenario, as expected, occurs when federal government revenue grows at a low rate of 3 per cent per annum. In this case, federal government recurrent expenditure on primary and secondary schooling as a proportion of total federal government revenue will decline from 10.7 per cent in the year 2000 to 9.2 per cent in the year 2010. If federal government revenue grows at a high rate of 9 per cent per annum, then the proportion accounted for by primary and secondary schooling will decline from 10.4 per cent in the year 2000 to only 7.2 per cent in 2010. If federal government revenue grows according to the estimated trend represented by equation (7), then the corresponding proportions will be 10.2 per cent and 7.3 per cent, respectively. These proportions are quite similar to those under a

Table 4: Projected federal government recurrent expenditure on primary and secondary schooling (RM million in constant 1999 prices)

Year	Federal government primary and secondary school recurrent expenditure growth scenario			
	Trend	Low	Moderate	High
2000	6,502.98	6,248.83	6,333.00	6,415.90
2001	6,732.51	6,183.02	6,333.50	6,562.22
2002	7,104.73	6,251.81	6,548.02	6,870.67
2003	7,510.37	6,356.49	6,785,88	7,236.80
2004	7,922.03	6,472.11	7,036.64	7,634.13
2005	8,333.99	6,592.23	7,297.81	8,056.43
2006	8,746.27	6,715.20	7,568.97	8,502.95
2007	9,160.40	6,840.63	7,850.28	8,974.44
2008	9,578.20	6,968.44	8,142.08	9,472.14
2009	10,001.44	7,098.65	8,444.72	9,997.47
2010	10,431.81	7,231.30	8,758.61	10,551.93

Table 5: Projected federal government recurrent expenditure on primary and secondary schooling as proportion of federal government revenue

Year	Federal government revenue growth scenario			
	Trend	Low	Moderate	High
2000	10.22	10.70	10.54	10.38
2001	9.53	10.28	9.94	9.74
2002	9.13	10.09	9.70	9.36
2003	8.83	9.96	9.48	9.04
2004	8.56	9.85	9.28	8.75
2005	8.32	9.74	9.08	8.47
2006	8.09	9.63	8.88	8.20
2007	7.88	9.53	8.69	7.94
2008	7.68	9.42	8.50	7.69
2009	7.49	9.32	8.32	7.45
2010	7.31	9.22	8.14	7.21

high growth scenario. This is not unexpected since trend growth rate in government revenue has been around 8.8 per cent over the 1970 to 1999 period.

Overall, it appears that the federal government's position in relation to its recurrent spending on primary and secondary schooling appears favourable. Over time, federal government recurrent expenditure as a proportion of total government revenue, is expected to continue its downward trend. The extent of the decline depends on the rate of growth in future federal government revenue. In all four scenarios assumed above, the important implication is that the federal government should have funds available for other activities including funds for the Smart School Project.

6. Projecting the Number of Primary and Secondary Students and Schools

In order to determine the impact of the Smart School Project on government recurrent expenditure on primary and secondary schooling and on government revenue the next step entails projecting student enrolment. Then, assuming that the average number of students per primary and secondary school does not change over time, we made projections of the number of primary and secondary schools that would be converted into Smart Schools by the year 2010.

Enrolment at the primary level has grown at a relatively constant rate throughout the 1970s, 1980s and 1990s. In the 1970s, primary school enrolment grew at an average annual rate of 1.92 per cent. The corresponding rates for the 1980s and 1990s were 1.86 and 1.95 per cent, respectively. Enrolment at the secondary level has, however, been growing at a declining rate over the same period.[12] In the 1970s, secondary school enrolment grew at an average

[12] Secondary school enrolment refers to enrolment at the lower secondary level and at all levels of upper secondary schooling, including enrolment in the technical and vocational schools.

annual rate of 6.80 per cent. The rate declined to 3.08 per cent in the 1980s and to 2.75 per cent in the 1990s, partly because enrolment rate had already reached a relatively high level and partly because of the opening up of alternative forms of secondary level education.[13]

Working with total enrolment numbers at the primary and secondary levels, we model total enrolment by assuming there is some functional relationship between total enrolment and time. In particular, the following will be used to project total enrolment at the primary and secondary levels for the years 2000 to 2010:

Primary School Enrolment

$$\widehat{PRI} = \underset{(2.092)}{178760.7} + \underset{(1.960)}{4984.668t} + \underset{(8.717)}{1.468PRI(-1)} - \underset{(3.483)}{0.576PRI(-2)} \quad (8)$$

$$\bar{R}^2 = 0.997 \qquad d = 2.349$$

Secondary School Enrolment

$$\widehat{SEC} = \underset{(0.422)}{222587.00} + \underset{(2.065)}{11903.92t} + \underset{(3.716)}{0.750SEC(-1)} - \underset{(0.283)}{0.056SEC(-2)} \quad (9)$$

$$\bar{R}^2 = 0.990 \qquad d = 2.040$$

The Durbin-Watson statistics in equation (8) and equation (9) lead to an acceptance of the null hypothesis, that is, there is no autocorrelation, positive or negative at the 1 per cent level.

Table 6 shows our projections of total primary and secondary school enrolment for the years 2000 to 2010 when the Smart School Project is scheduled for full implementation. In

Table 6: Projected enrolment and number of schools at the primary and secondary levels, 2000 to 2010

Year	Total enrolment		Number of schools	
	Primary	Secondary	Primary	Secondary
2000	2,932,925	1,889,241	7,332	1,717
2001	2,974,598	1,915,950	7,436	1,741
2002	3,020,600	1,946,581	7,552	1,770
2003	3,069,113	1,979,963	7,673	1,800
2004	3,118,816	2,015,188	7,797	1,831
2005	3,168,822	2,051,641	7,922	1,865
2006	3,218,587	2,088,912	8,046	1,899
2007	3,267,823	2,126,728	8,169	1,933
2008	3,316,421	2,164,907	8,291	1,968
2009	3,364,388	2,203,327	8,410	2,003
2010	3,411,795	2,241,908	8,529	2,038

[13] Including matriculation programmes attached to various domestic universities and enrolment in overseas matriculation programmes offered by domestic private colleges in conjunction with institutions abroad.

addition, assuming that average enrolment does not change over time but remains at around 400 at the primary level and 1,100 at the secondary level, we projected the number of primary and secondary schools for the same period.

The present Pilot Project aside, one possible strategy that will facilitate the conversion of all primary and secondary schools into Smart Schools by the year 2010 without a sudden surge in recurrent cost is to spread out the conversion process. By allocating existing and new schools proportionately over the available time period, the total cost of conversion will be spread over a period of 11 years, starting from the year 2000. In particular, the strategy would call, for instance, for a proportionate conversion of the projected 7,332 primary schools in the year 2000 over an eleven-year period (from 2000 to 2010), and the additional 104 primary schools that will be required in the year 2001 over a ten-year period (from 2001 to 2010). By the year 2010 all primary schools would have been converted to Smart School status. A similar approach would apply to the conversion of secondary schools.

Table 7 shows the number of schools that must be converted into Smart School status each year, starting from year 2000. Following this strategy, by the year 2010 all 8,520 primary schools and 2,038 secondary schools that are projected to come on-stream would have been converted into Smart Schools. One of the advantages of the strategy is that the number of schools scheduled for conversion into Smart Schools increases over time. This implies that the highest financial burden will be borne towards the end of the period when federal government revenue is projected to rise from RM 63.6 billion in the year 2000 to RM 142.7 billion in the year 2010, if the present trend continues.

7. Implications for Federal Government Recurrent Expenditure on Primary and Secondary Schooling

The policy objective of the Smart School Project calls for the conversion of all schools into Smart Schools by the year 2010. As noted earlier, effective implementation of computers in

Table 7: Annual number of primary and secondary schools for conversion to smart school status

Year	Number of schools	
	Primary	Secondary
2000	667	156
2001	672	158
2002	690	161
2003	704	165
2004	722	169
2005	743	176
2006	770	183
2007	800	191
2008	841	203
2009	901	220
2010	1,019	256
Total	8,529	2,038

education calls for a student-computer ratio of 5 or better. The Pilot Project aside, given that the average enrolment size of a primary school is around 400 pupils, this implies a need for around 80 computers. The nearest equivalent requirement would be a level B+ category Smart School. A level B+ school will be equipped with a LAN consisting of 86 computers with 60 located in 15 classrooms/science laboratories. Given that the focus is on computers that will be readily available to the pupils, the actual number of computers that is relevant in the present context would be the 60 that will be located in the classrooms/science laboratories. This effectively works out to a student-computer ratio of about 7, slightly higher than that recommended for effective implementation. As for secondary schools, with an average size of 1,100 pupils there will be a need for around 220 computers. The nearest equivalent to this number would be a level A Smart School. A level A school will be equipped with a LAN consisting of 479 computers, of which 252 will be located in classrooms/science laboratories. This effectively works out to a student-computer ratio of just under 5, marginally better than that required for effective implementation of computers in education.

As stated earlier, we define annual recurrent costs in terms of hardware maintenance, software maintenance, personnel services, consumables and supplies, and telecommunication costs (see Table A1, Appendix A for details).[14] The annual recurrent cost for a level B+ Smart School is estimated at RM 53,500 and that for a level A Smart School at the secondary level at RM 215,927, in 1999 prices. As the number of schools to be converted into Smart Schools rise over time, the annual total recurrent cost of the Smart Schools will also increase.

Table 8 shows the rise in total annual recurrent cost at the primary and secondary schools. In particular, the annual recurrent cost at the primary school level is expected to increase from RM 35.7 million in the year 2000, assuming that 667 primary schools are converted into Smart Schools, to RM 456.7 million by the year 2010 when all the primary schools have been converted into level B+ Smart Schools. At the secondary school level, the annual recurrent

Table 8: Projected total annual recurrent cost of the smart schools (RM million)

Year	Annual recurrent cost		
	Primary	Secondary	All
2000	35.72	33.68	69.40
2001	71.70	67.80	139.50
2002	108.65	102.57	211.22
2003	146.35	138.19	284.55
2004	185.02	174.68	359.70
2005	224.80	212.69	437.49
2006	266.04	252.20	518.24
2007	308.88	293.44	602.32
2008	353.91	337.28	691.19
2009	402.16	384.78	786.94
2010	456.73	440.06	896.79

[14] Annual recurrent costs of Data Centre Support and Help Desk Support have been excluded from this analysis as these are optional items.

cost is expected to increase from RM 33.7 million with the conversion of 156 secondary schools in the year 2000 to RM 440.1 million when all the secondary schools would have been converted into level A Smart Schools. The total annual recurrent cost of the Smart Schools is expected to rise from RM 69.4 million in the year 2000 to RM 896.8 million by the year 2010.

Overall, annual recurrent cost at the primary level is expected to increase at an average annual rate of 31.1 per cent and that at the secondary level by 31.4 per cent. Total annual recurrent cost is expected to grow at an average annual rate of 31.2 per cent. These rates are clearly far higher than the trend growth rate in federal government revenue of 8.8 per cent per annum and the growth rate in government recurrent expenditure on primary and secondary schooling of around 7.4 per cent per annum.

Table 9 shows the impact of the recurrent cost of the Smart Schools on federal government expenditure on primary and secondary schooling under four different growth scenarios in federal government recurrent spending on primary and secondary schooling. The first scenario assumes that government recurrent spending on primary and secondary schooling continues to grow according to the present trend as reflected by Model 2C above. The remaining growth scenarios assume growth rates in government revenue of 3 per cent (low growth), 6 per cent (moderate) and 9 per cent (high) per annum.

From Table 9 it can be seen that total recurrent cost of the Smart Schools will initially amount to an additional 1 per cent in total federal government recurrent expenditure on primary and secondary schooling. However, over time, the additional cost will rise. Under a low growth scenario, the additional cost will amount to 12 per cent of total federal government recurrent expenditure on primary and secondary schooling by the year 2010. The corresponding figures for the moderate growth and high growth scenarios will be 10 per cent and 9 per cent, respectively. Overall, regardless of the growth scenario, federal recurrent spending on IT will consume an increasing proportion of total federal government spending on primary and secondary schooling. Without an offsetting higher growth in the absolute sum of total federal government spending on primary and secondary schooling, it implies

Table 9: Total annual recurrent cost of smart schools as proportion of total federal government recurrent expenditure on primary and secondary schooling

Year	Federal government primary and secondary school recurrent expenditure growth scenario			
	Trend	Low	Moderate	High
2000	1.07	1.11	1.10	1.08
2001	2.07	2.26	2.20	2.13
2002	2.97	3.38	3.23	3.07
2003	3.79	4.48	4.19	3.93
2004	4.54	5.56	5.11	4.71
2005	5.25	6.64	5.99	5.43
2006	5.93	7.72	6.85	6.09
2007	6.58	8.81	7.67	6.71
2008	7.22	9.92	8.49	7.30
2009	7.87	11.09	9.32	7.87
2010	8.60	12.40	10.24	8.50

that there must be a cutback in other areas of recurrent spending at the primary and secondary levels.

Table 10 shows the impact of the annual recurrent cost of the Smart Schools on federal government revenue under four different growth scenarios in federal government recurrent spending on primary and secondary schooling. The first scenario assumes that government revenue continues to grow according to present trend as reflected by Model 1B above. The remaining growth scenarios assume growth rates in government recurrent spending on primary and secondary schooling of 3 per cent, 6 per cent and 9 per cent.

The first scenario assumes that government revenue and government recurrent spending on primary and secondary schooling grow according to their present trend. As Table 10 shows, with the inclusion of the annual recurrent cost of the Smart Schools total government recurrent expenditure on primary and secondary schooling as a proportion of total government revenue is expected to be around 10.3 per cent in the year 2000 and then to decline gradually to 7.9 per cent in the year 2010. Under a slow growth scenario, however, the corresponding proportion will decline but will still exceed 10 per cent – equivalent to the proportion that has been maintained throughout the 1990s. With moderate and high growth, the proportion will in fact decline to 9.0 per cent and 7.8 per cent, respectively.

An implicit assumption that we have made thus far is that the initial outlay for computers and related equipment, and training costs for teachers and administrators are treated as sunk costs rather than as recurrent expenditure (see Table A2, Appendix A for details). However, hardware currently has a useful life of about four years (President's Committee 1997: 16; Anderson and Ronnkvist 1999: 6). This implies that existing hardware should be replaced once every four to five years. In addition, teachers require retraining to keep pace with ICT and software developments.[15] To minimise the burden of renewal, we assume that renewal and retraining are evenly spread out over a five-year period, starting sometime during the fifth year. In other words, we assume that one-fifth of the equipment will be due for renewal

Table 10: Total federal government expenditure on primary and secondary schooling plus smart school recurrent expenditure as proportion of total federal government revenue

Year	Federal government revenue growth scenario			
	Trend	Low	Moderate	High
2000	10.33	10.82	10.65	10.50
2001	9.73	10.51	10.16	9.95
2002	9.41	10.43	10.01	9.65
2003	9.16	10.41	9.88	9.40
2004	8.95	10.40	9.75	9.16
2005	8.76	10.39	9.62	8.93
2006	8.57	10.37	9.49	8.71
2007	8.40	10.36	9.35	8.48
2008	8.24	10.36	9.22	8.25
2009	8.08	10.35	9.09	8.04
2010	7.94	10.36	8.97	7.83

[15] On the importance of teacher training, see Lee (1999).

and one-fifth of the teachers (and administrators) will undergo retraining starting in the fifth year. Under the strategy discussed above, the first batch of 667 primary and 156 secondary schools will begin the renewal process in the year 2004. Similarly, the second batch of 672 primary and 158 secondary schools will begin the their first renewal and retraining exercise in the year 2005 at which time the first batch of schools would be into the second year of their renewal and retraining exercise. Hence, in the year 2005 1,339 primary and 314 secondary schools will incur renewal and retraining costs. In the year 2010, it is estimated that 4,968 primary and 1,168 secondary schools will incur renewal and retraining costs.

Table 11 shows the annual renewal and retraining costs that will be incurred from year 2004 to the year 2010. As can be seen, the estimated renewal and retraining costs at the primary level will rise from RM 316.76 million to RM 2.34 billion by year 2010. Renewal and retraining costs at the secondary level will rise from RM 204.55 million in the year 2004 to RM 1.53 billion in year 2010. Total renewal and retraining costs will therefore amount to RM 521.32 million in the year 2004, rising to RM 3.89 billion in year 2010.

The implications in terms of federal government expenditure on primary and secondary schooling can be seen in Table 12. For the first four years, there will be no renewal and retraining costs at all since all equipment and training are assumed to have a useful life of four to five years. We assume that in the fifth year, the first batch of equipment and teachers for the first batch of primary and secondary schools come in for renewal and retraining, respectively. In the fifth year (2004), if federal government revenue continues to grow along its present trend (as represented by Model 2C), renewal and retraining costs will account for 6.6 per cent of projected recurrent spending on primary and secondary schooling. By the year 2010 the proportion would have risen to 37.3 per cent. If the growth in federal government revenue is a low of 3 per cent per annum over the period, then renewal and retraining costs would amount to 8.1 per cent in the year 2004, rising to 53.8 per cent in the year 2010. If, on the other hand, government revenue were to grow rapidly at an annual rate of 9 per cent, then the burden of renewal and retraining costs would be much smaller – 6.8 per cent in 2004 and 36.9 per cent in 2010. Again, this is close to trend growth in government revenue since the latter has averaged 8.8 percent per annum over the 1970-1999 period.

Clearly the costs of renewal and retraining cannot be sustained without substantial growth in federal government recurrent spending on primary and secondary schooling. Without the required increases in recurrent spending on primary and secondary schooling, the government would be required to reduce spending in other areas in primary and secondary schooling. For instance, by the year 2010, assuming government revenue continues to grow at its present

Table 11: Projected renewal and retraining costs of the smart schools (RM million)

Year	Renewal and retraining costs		
	Primary	Secondary	All
2004	316.76	204.55	521.32
2005	635.91	411.73	1,047.64
2006	963.60	622.84	1,586.44
2007	1,297.93	839.20	2,137.13
2008	1,640.82	1,060.80	2,701.62
2009	1,993.68	1,291.57	3,285.25
2010	2,359.36	1,531.53	3,890.89

trend, the government would have to reduce spending in other areas by an amount equivalent to 37.3 percentage points of the projected recurrent expenditure on primary and secondary schooling. Since emoluments amount to about 70 per cent of federal government expenditure on primary and secondary schooling, this would imply a need to cut expenditure on all other items of primary and secondary schooling to zero and, at the same time, cut emoluments down too. This is clearly not a viable option.

Table 13 shows the impact of adding the renewal and retraining costs to recurrent cost and government recurrent expenditure on primary and secondary schooling on government revenue. In particular, if federal government revenue continues to grow at it past average annual rate of 8.8 per cent, the addition of renewal and retraining costs would see total federal government expenditure on primary and secondary schooling as a proportion of total government revenue rise from 10.33 per cent in the year 2000 to 10.67 per cent in the year

Table 12: Total annual renewal and retraining costs of smart schools as proportion of total federal government recurrent expenditure on primary and secondary schooling

Year	Federal government primary and secondary school recurrent expenditure growth scenario			
	Trend	Low	Moderate	High
2000	0	0	0	0
2001	0	0	0	0
2002	0	0	0	0
2003	0	0	0	0
2004	6.58	8.05	7.41	6.83
2005	12.57	15.89	14.36	13.00
2006	18.14	23.62	20.96	18.66
2007	23.33	31.24	27.22	23.81
2008	28.21	38.77	33.18	28.52
2009	32.85	46.28	38.90	32.86
2010	37.30	53.81	44.42	36.87

Table 13: Federal government recurrent expenditure on primary and secondary schooling plus smart school recurrent, renewal and retraining costs as proportion of total federal government revenue

Year	Federal government revenue growth scenario			
	Trend	Low	Moderate	High
2000	10.33	10.82	10.65	10.50
2001	9.73	10.51	10.16	9.95
2002	9.41	10.43	10.01	9.65
2003	9.16	10.41	9.88	9.40
2004	9.51	11.19	10.44	9.76
2005	9.80	11.93	10.92	10.04
2006	10.04	12.65	11.35	10.24
2007	10.24	13.34	11.72	10.37
2008	10.40	14.01	12.04	10.45
2009	10.54	14.66	12.33	10.48
2010	10.67	15.32	12.59	10.49

2010. If federal government revenue were to grow at a low rate of 3 per cent per annum, the proportion would rise from 10.82 per cent in the year 2000 to 15.31 per cent in the year 2010. The corresponding proportions for a moderate and high growth scenarios in government revenue are 10.65 per cent and 12.60 per cent, and 10.50 per cent and 10.49 per cent, respectively.

Total federal government recurrent spending on primary and secondary schooling as a proportion of total federal government revenue averaged 16.8 per cent in the 1970s, declining to 12.3 per cent in the 1980s and 10.7 per cent in the 1990s. If the proportion that prevailed in the 1990s is maintained then the addition of the recurrent, renewal and retraining costs of the Smart Schools would be unsustainable in nearly every possible scenario save for a high growth (9 per cent per annum) in total federal government revenue. Over the 1970-1999 period total federal government revenue recorded an average annual growth rate of 6.84 percent. During the 1990s the annual growth rate averaged only 3.43 per cent. Hence, unless there is a change that leads to a high growth rate in total federal government revenue, the only other alternative is to divert additional government revenue away from other areas of spending to primary and secondary schooling. In the absence of high growth in federal government revenue and/or changes in federal government spending to divert more resources into primary and secondary schooling, the long-term fiscal viability of the Smart School Project must be called into question.[16]

8. Summary and Concluding Remarks

A major objective of the Malaysian Smart School Project is the conversion of all primary and secondary schools into Smart Schools by the year 2010. To examine the fiscal viability of the Project, we focused our attention on two types of recurrent cost incurred in the Smart School Project. The first type of recurrent cost, which we refer to as annual recurrent cost, covers hardware and software maintenance, consumables and supplies, personnel services and telecommunications. The second type refers to the cost of renewal of ICT equipment and the cost of retraining for teachers and administrators; we refer to these as renewal and retraining costs.

The present analysis of the fiscal viability of the Smart School Project is based on four major assumptions. First, we assumed that the government seeks to attain a student-computer ratio that is considered a "reasonable level for effective use" which is defined as a student-computer ratio of 5:1. A student-computer ratio that is less than a "reasonable level for effective use" would clearly lighten the fiscal burden and therefore increase the fiscal viability of the project but this would be achieved at the cost of less than effective use of ICT in education. Second, we assumed that the initial investment expenses will be written off as sunk costs. In other words, our analysis focuses only on recurrent, renewal and retraining costs because these affect the long-term viability of the Project. A separate but also major issue then is whether the public sector can afford the high investment cost of the project. This issue, however, lies outside the scope of the present discussion. Third, to lighten the fiscal

[16] Again, it must be emphasised that the calculations here assume that the initial outlays in terms of computers and related equipment, and training are regarded as sunk costs that are not taken into account since the focus of the present study is on recurrent, renewal and retraining costs.

burden, we assumed that the Smart School Project will be implemented over a ten-year period. This would call for an annual investment outlay of over RM 2.5 billion (at constant year 1999-price level). This process would, however, imply that some schools would have to wait several years before the students can benefit from the Smart School Project. It is inevitable that such an approach would bring us to face-to-face with issues of equity or unequal access. Fourth, we assumed that if student learning is ICT-based, the students will be examined in like manner. Teaching students on one platform (computers) and then examining them on another (pen and paper) can have serious negative impact on their measured achievement (Russell 1999). We have not taken into account any additional costs that may be incurred to ensure that students in the Smart Schools will be examined on the platform with which they have been taught.

Leaving aside the initial investment outlay, which we assumed as sunk cost, we focused on recurrent (annual maintenance cost), renewal and retraining costs of the Smart School Project. Overall, it appears that the annual recurrent cost of the Smart Schools can be sustained. Fiscal viability becomes an issue for concern when renewal costs of computers and related equipment, and retraining costs are taken into consideration. When these costs are taken into consideration, the most important implication of the Project in terms of its fiscal sustainability is that the government must cut out all other forms of spending on primary and secondary schooling and, at the same time, reduce emoluments. This is clearly an unviable scenario. The alternative requires that the government maintain its recurrent spending on primary and secondary schooling as a proportion of total government revenue at 11 per cent per annum. This scenario, however, assumes that real federal government revenue grows at a sustained high rate of 9 per cent per annum. A growth rate that is lower than 9 per cent per annum would call into question the fiscal viability of the full Smart School Project. Through the 1990s, real federal government revenue grew at an average annual rate of only 3.4 per cent.

In the light of our principal finding that the Smart School Project may not be fiscally viable in the long-term, it is important that alternatives and trade-offs be considered. One obvious option is to explore more fully the role of the private sector in the Smart School Project. Experience in countries that are more advanced in this endeavour shows that the private sector can play a critical and major role (Lee 1999). However, a more important issue is how the limited resources should be used. Here, we argue that it is best to concentrate the limited resources on achieving the required critical mass in a small number of schools rather than spreading the resources thinly over a large number of schools. The proposal to spread the implementation of the Smart School Project over a period of ten years is therefore a step in the right direction (cf. Ministry of Education 1997b, Executive Summary). The highest priority should be accorded to schools that have the largest proportions of students from low socio-economic status households, schools that have the largest proportions of students who are low-achievers and those that have the largest proportions of students with special learning problems. There are two basic reasons for setting these as the criteria for the implementation of the project. First, the experience of countries more advanced in the implementation of ICT in education demonstrate that an effective ICT in education calls for a critical mass in technology, teacher training, media-rich classrooms, constant assessments and critical evaluations, and consistent governmental support focused on the development of student creativity, critical thinking skills, co-operative learning, and learning for all (Lee 1999). Second, empirical evidence (drawn from education-production functions and meta-analyses) shows that the largest gains from the use of computers in education are often recorded for students of lower socio-economic status, low-achievers, and those with certain special learning problems (Lee 1999). Giving the highest priority to schools that have the largest proportions of students from low socio-economic status households, schools that have the largest proportion of students who are low-achievers and those that have the largest proportion of students with special learning problems would, therefore, be both equitable and efficient because the gains in student achievement are largest for these categories of students.[17]

On a more fundamental level, there is in fact a wide range of alternatives and trade-offs. For instance, instead of immersing students into the full programme as proposed in the Smart School Project, a more modest goal such as exposing students to IT may be considered. In this case a critical mass of the nature (briefly) discussed above would not be necessary. This may in fact prove to be a wiser step for the simple reason that the impact of instructional technology on student learning remains inconclusive, particularly in the area of higher order or metacognitive development. Heinecke *et al.* (1999: 3-4), for instance, note, "If one defines student learning as retention of basic skills and content information as reflected on norm referenced and criterion referenced standardised tests, the evidence suggests there is a positive relationship between certain types of technology and test results.... where the computer is used to manage the 'drill and skill' approach to teaching and learning, students will show gains on standardised test scores.... However, we have been less than successful in evaluating the impact of educational technology on higher order or metacognitive thinking skills." Focusing on student achievement defined in terms of the development of higher order or metacognitive skills opens up several other alternatives or trade-offs. For instance, student achievement thus defined could be enhanced by using the same amount of money to: a) train already employed and new teachers in teaching critical thinking and reflective judgement (see for instance Dewey 1933; 1938; King and Kitchener 1994; Salmon 1989); ii) retrain and upgrade the professional skills of already employed and new teachers; iii) attract better qualified individuals into the teaching profession; iv) award already employed teachers with higher pay for achieving the desired student outcomes; and/or e) hire additional teachers so that the student-teacher ratio can be lowered to a level that would facilitate achievement of desired student outcomes.

The current technological revolution and the development of the global information economy will strengthen the extent of polarisation between nations unless developing nations are able to invest more heavily in intangible capital, not tangible capital. Catching-up is possible only for those countries that have the institutional capacity to produce workers who possess the required skills, particularly in science and engineering and, more importantly, higher order or metacognitive thinking skills. It is the latter that will enable developing countries to compete successfully in the global information economy. It is, therefore, important to bear in mind that the principal objective of the Smart School Project is not that of equipping students with IT skills but that of developing a new generation of students who are imbued with critical and creative thinking skills (cf. Ministry of Education 1997a: 11).[18]

The importance of the higher order or metacognitive thinking skills can be clearly seen in the report of the President's Committee. The Committee (1997: 1) states, "it is widely believed

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[17] A listing of schools based on these criteria is likely to be very different from the present list of pilot schools.

[18] Other goals of the Smart School curriculum include the development of appropriate values and language proficiency (Ministry of Education 1997a: 11).

that workers in the next century will require not just a larger set of facts or a larger repertoire of specific skills, but the capacity to readily acquire new knowledge, to solve new problems, and to employ creativity and critical thinking in the design of new approaches to existing problems." For these reasons, and in the light of our finding that the Smart School Project may not be fiscally viable in the long-term, it is important to consider the alternatives that may prove more cost effective in enhancing the development of higher order or metacognitive thinking skills in Malaysian students. The jury is after all, as noted above, still out where the effectiveness of ICT in developing higher-order thinking or metacognitive skills is concerned. It is important to emphasise that ICT in education is only a means to an end, not the end in itself.

In closing, it is also important to remember that education is also a social process through which students learn to develop affective skills that enable them to interact effectively with others and to operate as individuals within community. Berliner (1993: 24) notes that employers worry most about the affective and motivational characteristics of workers, not their technical skills. If we fail to equip our students, and therefore our future workforce, with the right metacognitive and affective skills, we run the risk of being relegated to the lower rungs of the development ladder in the emerging global information economy. These skills, as the Ministry of Education (1997a: 14) rightly notes, cannot be cultivated by machines or technology alone. In the final analysis, as the Ministry of Education (1997a: 14) notes, "only improved teaching-learning strategies, management and administrative processes, and capable, well-trained people with enthusiasm for their work can do that." In short, we cannot place our hopes on the hardware and software of ICT in education. Our emphasis must still be on inspirational leadership, the quality of our teachers and the environment in which they work to foster the development of higher-order or metacognitive, and affective skills among Malaysian youths.

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References

Anderson, R.E. and A. Ronnkvist. 1999. The Presence of Computers in American Schools. Teaching, Learning and Computing: 1998 National Survey, Report No. 2. Center for Research on Information Technology and Organizations, University of Calfornia, Irvine and University of Minnesota.

Berliner, D.C. 1993, Education reform in an era of disinformation. *Education Policy Analysis Archives* **1**: 1–41.

Dewey, J. 1933. *How We Think: A Restatement of the Relations of Reflective Thinking to the Education Process.* Lexington, Massachusetts: Heath.

Dewey, J. 1938. *Logic: The Theory of Inquiry, Troy.* Montana: Holt, Rinehart and Winston.

Gujarati, D. N. 1995. *Basic Econometrics.* 3rd edn. Singapore: McGraw-Hill Book Company.

Granger, C. W. J. and P. Newbold. 1976. Spurious regression in econometrics. *Journal of Econometrics* **2(2)**: 111-120.

Heinecke, W.F., L. Blasi, N. Milman and L. Washington. 1999. New Directions in the Evaluation of the Effectiveness of Educational Technology. Paper presented at the *Secretary's Conference on Educational Technology – 1999.* Washington, DC.

King, P.A. and K.S. Kitchener. 1994. *Developing Reflective Judgement: Understanding and Promoting Intellectual Growth and Critical Thinking in Adolescents and Adults.* San Francisco: Jossey-Bass Publishers.

Lee, K.H. 1999. The benefits and viability of the Smart School Programme: lessons from the American Experience. *Malaysian Journal of Economic Studies* **36**: 17–44.

Lucas, R. E., 1976, Econometric Policy Evaluation: A Critique. In *The Phillips Curve.* Carnegie-Rochester Conference Series. Amsterdam: North-Holland.

Mann, D. 1999. Documenting the Effects of Instructional Technology: A Fly-Over of Policy Questions. Paper presented at the *Secretary's Conference on Educational Technology – 1999.* Washington, DC, USA.

Mann, D., C. Shakeshaft, J. Becker, and R. Kottkamp. 1999. *West Virginia Story: Achievement Gains from a Statewide Comprehensive Instructional Technology Program.* Santa Monica, California: Milken Family Production.

McKinsey & Company Inc. 1995. Connecting K-12 Schools to the Information Superhighway. Report prepared for the National Information Infrastructure Advisory Council, Palo Alto, California: McKinsey & Co. Inc.

Ministry of Education. 1996. *Cost Analysis in the Malaysian Education System*, Kuala Lumpur: Educational Management Information System, Educational Planning and Research Division (in collaboration with the Harvard Institute of International Development, Harvard University). Ministry of Education.

Ministry of Education. 1997a. *Smart School Flagship Application: The Malaysian Smart School – A Conceptual Blueprint.* Kuala Lumpur: Ministry of Education.

Ministry of Education. 1997b. *Malaysian Smart School Implementation Plan.* Kuala Lumpur: Ministry of Education.

Ministry of Education. 1999. Contract Signing Ceremony between the Government of Malaysia and Telekom Smart School Sdn. Bhd., additional information, mimeograph. Kuala Lumpur.

President's Committee of Advisors on Science and Technology, Panel on Educational Technology. 1997. Report to the President on the Use of Technology to Strengthen K-12 Education in the United States, Washington, DC.

Russell, M. 1999. Testing on computers: a follow-up study comparing performance on computer and on paper. *Education Policy Analysis Archives* **7(20)**: 1–45.

Salmon, M.H. 1989. *Logic and Critical Thinking*. Orlando, Florida: Harcourt Brace Jovanovich.

Sargent, T. J. and N. Wallace. 1975. Rational expectations, the optimal monetary instrument and the optimal money supply rule. *Journal of Political Economy* **83(2)**: 241–255.

Sargent, T. J. and N. Wallace. 1976. Rational expectations and the theory of economic policy. *Journal of Monetary Economics* **2(2)**: 169-183.

Appendix A

The estimated annualised expenditure on basic hardware, software and other expenses are based on 1999 prices and information obtained from the Curriculum Development Center and the Education Technology Division, Ministry of Education. Actual prices may differ from those estimated here for following reasons:

Better prices can be negotiated, such as a 10 per cent discount on most hardware and software;
Bulk purchases should result in further discounts (perhaps another 10 per cent);
Cash payments should also result in further price reduction;
Direct purchases may also result in price reduction; and
IT product prices are highly volatile.

Table A1: Estimated annual recurrent costs per school (RM)

Recurrent costs (RM)	Level B+ primary school	Level A secondaryschool
Hardware maintenance	12,258	70,385
Software maintenance	3,292	15,542
Personnel services	18,000	72,000
Consumables/Supplies	8,000	8,000
Telecommunication	12,000	50,000
Total Recurrent Cost (RM)	53,550	215,927

Table A2: Estimated annual renewal cost per school (RM)

IT renewal and retraining costs (RM)	Level B+ primary school	Level A secondary school
Hardware	122,582	703,858
Software	65,844	310,858
Teaching-Learning Materials	205,430	205,430
School Management System	69,704	69,704
Telecommunication	411	411
Training (Teachers & Administrators)	7,827	7,827
Non-IT Equipment	1,114	6,155
Renovation and Maintenance	2,000	7,000
Total Annualized Investment (RM)	474,912	1,311,243

Appendix B

To confirm that the results of equation (1) are not spurious, we tested for stationarity in lnGR and lnGNP. The augmented Dickey-Fuller tests produced the following results:

$$\widehat{D(\ln GR)} = \underset{(0.573)}{0.718} - \underset{(0.060)}{0.001t} - \underset{(0.454)}{0.062\ln GR(-1)} - \underset{(0.068)}{0.016D(\ln GR(-1))} \qquad (10)$$

$$\bar{R}^2 = 0.221 \qquad d = 1.970$$

$$\widehat{D(\ln GNP)} = \underset{(2.315)}{3.322} + \underset{(2.178)}{0.019t} - \underset{(2.273)}{0.305\ln GNP(-1)} + \underset{(2.044)}{0.400D(\ln GNP(-1))} \quad (11)$$

$$\bar{R}^2 = 0.255 \qquad d = 2.199$$

The 1 per cent, 5 per cent and 10 per cent critical values as computed by MacKinnon are –3.685, –2.971 and –2.624, respectively. In absolute terms, thee test statistic values of 0.454 and 2.273 of the lagged lnGR and lnGNP terms are less than the critical value even at the 10 per cent level. In addition, running the first difference of lnGR and lnGNP yielded the following results:

$$\widehat{D(\ln GR,2)} = \underset{(3.294)}{-0.560D(\ln GR(-1))} \quad (12)$$

$$\bar{R}^2 = 0.286 \qquad d = 2.281$$

$$\widehat{D(\ln GNP,2)} = \underset{(1.707)}{-0.186D(\ln GNP(-1))} \quad (13)$$

$$\bar{R}^2 = 0.097 \qquad d = 2.548$$

In absolute terms, the test statistic values of the first difference in lagged lnGR and lnGNP terms are 3.294 and 1.707, respectively. These are greater than the MacKinnon critical values at 1 per cent and 10 per cent levels, respectively. We therefore reject the null hypothesis in both cases. We conclude that lnGR and lnGNP are nonstationary, that is, they have unit root but the two series are integrated of order 1.

Going back to equation (1) and subjecting the residuals estimated from the regression to the Dickey-Fuller unit root test, we obtained the following results:

$$\widehat{D(u)} = \underset{(2.570)}{-0.838u(-1)} - \underset{(0.736)}{0.251D(u(-1))} \quad (14)$$

$$\bar{R}^2 = 0.543$$

The Engle-Granger critical values at 1 per cent, 5 per cent and 10 per cent levels are - 2.66, -–1.95 and –1.60, respectively. Since the absolute value of the estimated test statistic (2.570) exceeds the critical value, we conclude that the estimated u is stationary (that is, it does not have unit root) at the 5 per cent level and, therefore lnGR and lnGNP are cointegrated. In other words the results of equation (1) are meaningful (not spurious).

Appendix C

The augmented Dickey-Fuller tests in lnGPSE and lnGR yielded the following results:

$$\widehat{D(\ln GPSE)} = \underset{(4.378)}{6.226} + \underset{(3.602)}{0.039t} - \underset{(4.291)}{0.816 \ln GPSE(-1)} \qquad (4a)$$

$$\bar{R}^2 = 0.466 \qquad d = 2.131$$

$$\widehat{D(\ln GR)} = \underset{(1.519)}{1.811} - \underset{(1.116)}{0.011t} - \underset{(1.424)}{0.185 \ln GR(-1)} \qquad (4b)$$

$$\bar{R}^2 = 0.159 \qquad d = 2.128$$

The 1 per cent, 5 per cent and 10 per cent critical values as computed by MacKinnon are –4.338, –3.586 and –3.504, respectively. The absolute test statistic value of 4.291 for lagged lnGR leads to a rejection of the null hypothesis (nonstationary, unit root) at the 5 per cent level. However, the absolute test statistic value of 1.424 for lagged lnGPSE leads to acceptance of the null hypothesis.