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Abstract

This paper examines a recent view of Pritchett (2006) that there is a wide gap between growth literature and the policy needs of the developing countries. Growth literature has focussed on the long term growth outcomes but policy makers of the developing countries need rapid improvements in the growth rate in the short to medium terms. We take the view that this gap can be reduced if attention is given to the dynamic effects of policies. With data on Singapore, Malaysia and Thailand we argue that an extended version of the Solow (1956) model is well suited for this purpose. We found that the short to medium term growth effects of investment rate are much higher than its long run effects. Dynamic simulations for Singapore showed that these short run growth effects are significantly higher than the steady state growth rate for up to 10 years.

JEL: O11

Keywords: Solow Growth Model, Endogenous Growth, Dynamic Growth Effects of Investment Rate, Policies for Developing Countries.

1. Introduction

The literature on the economics and econometrics of growth is vast. It has used mainly two types of theoretical growth models viz., the Solow (1956) exogenous growth model and the canonical endogenous growth models of Uzawa (1968), Romer (1986,1990), Lucas (1988) and Barro (1990) and their variants.[1] The empirical growth literature has used a variety of econometric techniques which range from country specific time series methods to three types of cross country techniques. The latter are: pure cross section methods, panel data methods ignoring the time series properties of the variables and panel data methods which take into account the time series properties. These econometric techniques have been used to estimate both the exogenous and endogenous growth models and for the developed and developing countries to identify some key determinants of the long run level and growth of per capita income.

However, Pritchett (2006) has recently observed that in spite of much progress in the growth literature there remains a tension between the logic of academic interests and the needs of policy practitioners of the developing countries. According to him nearly everything about the first-generation growth models was at odds with the needs and perspectives of policy makers of the developing countries. Endogenous models focus on the very long run and on the incentives for expanding the technological frontiers. This is not particularly useful for most developing countries, whose primary interest is in restoring short-to medium-term growth and accelerating technological catch-up by adopting already known innovations.

[1] Ignoring refinements and extensions, these canonical endogenous models use different factors to explain the observed persistent growth in per capita incomes in the advanced countries. In Uwaza (1968) and Romer (1986) persistent growth is due to investment with externalities. In Romer (1990) this is due to accumulation of knowledge through research and development. In Lucas (1988) it is human capital and in Barro (1990) government expenditure on infrastructure causes growth. In comparison, in the exogenous model of Solow (1956) persistent growth is due to the exogenous (unexplained) growth of knowledge i.e., growth in total factor productivity (*TFP*).

The aim of this paper is to addresses the tension noted by Pritchett and to provide some guidelines to narrow the gap between academic research and the needs of the developing country policy makers.[2] We take the view that the potential of the Solow model to narrow this gap is inadequately explored. This is despite a prevalent view that the Solow (1956) model does not have significant policy implications for growth, even for the developed countries, and the view of Hicks (1965) that "Growth Theory (as we shall understand it) has no particular bearing on underdevelopment economics, nor has the underdevelopment interest played any essential part in its development."[3]

The structure of this paper is as follows. Section 2 examines the needs and constraints of policy makers of the developing countries. Section 3 reviews the potential of the Solow model to meet some of these needs. Section 4 presents empirical results to show that the Solow model has considerable potential to meet the needs of the developing country policy makers. Section 5 briefly examines an empirical endogenous growth model and its use for policy. Section 6 concludes.

2. Growth Literature and Needs of the Policy Makers

Policy makers of the developing countries (often abbreviated as policy makers) want to know the likely consequences of public sector actions over their *relevant time horizons*; Pritchett (2006). However, these time horizons are different for the policy makers and the academic economists. Policy makers' time horizons are generally short spanning over one or two terms of office. In contrast much of the growth literature, based mainly on the endogenous models, is interested in the long run determinants of growth and the effects of policies on growth spanning over decades. Consequently, it seems necessary to distinguish between policies that can be effectively implemented in the short to medium runs from those that take decades to be effective. Existing growth literature, by and large, has ignored this distinction because, as noted by Hicks (1965), developments in growth theory did not have any bearing on the needs of the development economists and policy makers. However, as

[2] We ignore the growth policies for the developed countries for two reasons: (1) the use of the existing growth literature for policies in the developed countries is less controversial and (2) policies for growth seem to be more urgent for the developing world.

[3] Quoted by Pritchett (2006).

stated earlier the potential of the Solow (1986) model and some extended variants of this model, e.g., Mankiw, Romer and Weil (1992), to meet the needs of the policy makers is inadequately explored. The Solow model can be used to analyse both the short and long run effects of changes in the investment rate on the level of income and its medium term use of the dynamics of growth rate during the transition period. These medium term transitory growth effects are of considerable interest to policy makers of the developing countries because raising the investment rate is a relatively simple policy to implement compared to implementing institutional reforms, effective property rights and rule of law etc. These policies need longer periods to implement and to be effective. Furthermore, there is a significant support that investment ratio is an important determinant of the long run growth rate in the cross country works of De Long and Summers (1991), Levine and Renelt (1992) and Sala-i-Martin (1997). More recently Greiner, Semmler and Gong (2005) found, with country specific data, that investment is an important determinant of the long run growth rate in the early stages of development of a country. However, in all these studies there is no distinction between the long and short to medium term growth effects of the investment rate. In contrast to these works we shall examine the dynamics of the growth effects of the investment ratio. An implication of our observation is that there already exist some models and techniques to bridge the gap between growth literature and the needs of policy makers. However, there seem to be some other neglected areas which may have widened the gap noted by Pritchett. Technocrat policy makers need simpler and unambiguous guidelines on the selection and specification of models, policy variables and techniques for estimation and simulation. These are important for an understanding of the dynamics of the growth during the long transition of the economy between two steady states. Endogenous growth models, which have rekindled research on growth theory and policy, are only interested in the long term effects of policies on growth and neglect the dynamics of the effects of policies because they use mainly cross country methods. Furthermore, the theoretical models are difficult to understand and estimate although the theoretical models are important to understand what factors potentially determine the growth rate and how to sustain this growth rate in the long run. Structural endogenous models are hard to estimate with country specific time series data. Therefore, they are estimated mainly with the cross country methods and with *ad hoc* specifications of the growth equation and an arbitrary selection of the explanatory variables; see Durlauf, Kourtellos, and

Tan (2008). Easterly, Levine and Roodman (2004) have expressed concerns on such *ad hoc* specifications as follows: "This literature has the usual limitations of choosing a specification without clear guidance from theory, which often means there are more plausible specifications than there are data points in the sample." On the arbitrary nature of the selection of the explanatory variables it is appropriate to note that Durlauf, Johnson, and Temple (2005) have found that the number of potential growth improving variables, used in various empirical works, is as many as 145. Often these growth enhancing variables are highly trended and correlated. Consequently, it is hard to estimate with precision their individual effects even if only a handful of the variables are retained in the growth regressions. The issue of model selection is further complicated because different authors choose different empirical proxies for variables in the same growth theory; see Durlauf, Johnson, and Temple (2005).[4] There is also disagreement on the relative merits of the estimation techniques. Much of the empirical work is dominated by the cross country methods where variables from a number of developed and developing countries are averaged over the entire sample period or divided into averages of shorter panels of 5 to 10 years. Recently, panel data techniques with the time series methods of unit roots and cointegration have also become popular. If endogenous growth models are about the relationship between the long run or the steady state growth rate (*SSGR*) and its major determinants, then it is hard to accept that average growth rates over short panels are good proxies for the unobservable *SSGR*. Therefore, there will be some misspecification biases in the estimated coefficients.[5] Conceptually the unobservable *SSGR* is similar to the natural rate of unemployment. Both are to be derived by estimating appropriate dynamic non-steady state models and by imposing the steady state conditions.

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[4] Further, there is no endogenous theoretical model in which more than one or two variables are used to explain the persistent positive growth rate. In general any variable that has externalities can cause positive growth in the long run. This explains why a large number of growth variables have been used in the empirical works.

[5] We conjecture that the growth effects of variables will be overestimated because rate of growth proxied with the averages over short panels has both the short and long run components.

The main objective of the cross country studies is to examine which set of variables can best explain the large variations in the per capita incomes or their growth rates across countries. This has important policy implications in spite of the standard criticism that cross country studies make the tenuous assumption that one size fits all. Cross country methods are a pragmatic option when country specific data on growth enhancing variables are not available for longer periods and if such data were available the variance of the variables is too small. Therefore, cross country studies are useful for identifying the more important (fundamental) determinants of growth. Durlauf, Kourtellos, and Tan (2005) summarise the findings by several cross country studies as follows. The fundamental determinants of growth are (1) economic institutions (2) legal and political systems (3) climate (4) geographical isolation (5) ethnic fractionalization and (6) culture. However, it is hard to imagine that any one of these variables will interest policy makers of the developing countries and their politicians. The latter want quick improvement in per capita income and its growth rate. Among these fundamental factors (3) to (5) are virtually impossible to change through short and medium term policies although their adverse effects can be somewhat mitigated. Since these fundamental growth variables are non-pragmatic policy options for many developing countries, it is left to the international aid and credit giving agencies to force them to implement long run reforms to improve economic, legal and political environment.[6]

Country specific time series studies to identify some fundamental determinants of growth are mostly encouraged by the findings in the cross country studies and the availability of long enough time series data. However, it is impossible to test the growth significance of factors like climate and geographical remoteness with country specific data. Nevertheless, country specific studies are more appropriate for country specific growth policies and Greiner, Semmler and Gong (2005) strongly defend this approach over cross country studies. The "one size fits all" criticism against cross country studies has also received support from Levine and Zervos (1993) and Durlauf, Kourtellos, and Tan (2008). Levine and Zervos are critical of estimating regressions with a sample of a large number of countries with diverse economic structures and interpreting the coefficients of the policy variables as their growth elasticise. Durlauf

[6] These are known as the conditionality of the international aid giving agencies.

et. al., find evidence for unexplained regional and parameter heterogeneity in the aggregate production functions in cross country works. Similarly Luintel, Khan, Arestis and Theodoridis (2008) think that country specific time series studies are more reliable and useful for policy.

Country specific time series studies have investigated the growth effects of variables like the investment ratio, trade openness, education, budget deficits, public investment in the infrastructure, aid per capita and progress of the financial sector etc. Time series data on these variables are generally available for many developing countries for longer periods. These variables can be quickly influenced by the policy makers compared to reforming institutions. Durlauf, Kourtellos, and Tan (2008), using cross country approach and evaluation techniques, also found support for the growth effects of short to medium term macroeconomic policies. However, as noted earlier, the specifications used by many country specific works are as *ad hoc* as in the cross country studies. They do not make clear whether their specifications are based on the exogenous or an endogenous growth model and how they have derived their specifications from the theoretical growth models. They simply regress the annual growth rate of per capita or per worker output on a single or a small number of selected growth enhancing variables. Furthermore, none of them seem to have generated and studied the dynamic growth effects of the policy variables. It is hard, therefore, to depend on the findings by these *ad hoc* studies for growth policies.[7]

In spite of the aforesaid weaknesses, debates on growth economics and econometrics are useful for hopefully reaching a broad agreement on model selection, estimation methods and to identify some fundamental growth factors. It is also important that the dynamic effects of policy variables on growth are also analysed wherever possible. In this context it is of interest to note that Greiner et. al. (2005) have found with time series data on the OECD countries and with specifications based on various endogenous models that in the early stages of development investment with a potential for externalities are important for growth. Human capital formation and expenditure on research and development (R&D) are likely to play important roles in

[7] We desist from increasing the number of references by citing these works because they are too many and citing a few may give the impression that we are pillorying some authors.

the later stages of development. The first finding is important for policies in the developing countries and needs attention in the time series studies. With this backdrop we examine now what is useful in the existing growth literature for policies in the developing countries.

3. Useful Models and Technique for Policy

Policy makers—politico and technocrat—are interested in knowing which models and techniques are useful for policies and how to use them to generate the dynamic effects of contemplated policies on the level and growth of income. A related issue is whether a policy has only temporary or permanent growth effects and if temporary, how long they may last. An example is a policy to increase the investment ratio which has only temporary growth effects in the exogenous model of Solow, but may have permanent growth effects in the endogenous models if investment has externalities. From the perspective of a typical politico policy maker, a policy that is quick to implement and can quickly increase the growth rate—irrespective of whether it is transitory or permanent—is a more attractive policy than institutional reforms that may need change in the long standing traditional values of a country. Although reforms may have lasting growth effects, they need decades to be effective. For this purpose both the exogenous and endogenous models can be used. However, as noted earlier, it is hard to estimate endogenous models because the parametric structure is nonlinear and the identification restrictions are inadequate. Therefore, often calibration methods are used to simulate the growth effects of these models; see Albelo and Manresa (2005). In contrast, the Solow model is simpler to estimate and simulate to understand the dynamics of growth. Other than this it is hard to say at this stage which of these models is better although there are some strong views against the merits of the endogenous models.[8]

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[8] Mankiw, Romer and Weil (1992) have argued that the Solow model can explain the observed facts better than the endogenous models. Jones (1995) argued that observed time series facts do not support the conclusions of the endogenous models. Solow (2000, p.153) himself said that "The second wave of runaway interest in growth theory—the endogenous growth literature sparked by Romer and Lucas in the 1980s, following the neoclassical wave of the 1950s and 1960s—appears to be dwindling to a modest flow of normal science. This is not a bad thing." See also Parente (2001) for other criticisms of endogenous models.

For a long time the Solow model has been used to test one of its predictions viz., the convergence hypothesis. Its ability to explain the dynamics of growth with country specific time series data did not receive similar attention. Testing for convergence is an indirect test of the Solow model if it is adequate for explaining the large differences in the level of incomes across countries with diverse structures. The majority of the empirical works on convergence, which have used data from both the developed and developing countries, did not support convergence and implied that the Solow model is inadequate for explaining these differences in incomes. This in turn has partly induced the interest in the endogenous growth models as alternatives. However, the more important reason for the development of the endogenous models is that the Solow model cannot explain why countries grow at a sustained rate for long periods. Its explanation that this is due to exogenous growth in the stock of knowledge, i.e., total factor productivity (*TFP*), is unsatisfactory. Although testing the convergence hypothesis may have some methodological merits, policy makers of developing countries are least interested in knowing whether per capita income in their country will converge, in about 200 years, to the level of per capita income in the USA.

Subsequent extensions to the Solow model by Mankiw, Romer and Weil (1992) have shown that the Solow model, if augmented with human capital, can satisfactorily explain cross country differences in the levels of income. In particular their results showed that the steady state levels of income differ across countries and incomes converge to the country specific steady state level. Therefore, if a sample includes countries with approximately the same steady state levels of income, then countries with lower initial levels of income grow faster during the transition period.

The main conclusions of Mankiw, Romer and Weil are as follows. Firstly, the Solow model in which the production function is augmented with human capital explains about 80% of the variation in the levels of incomes across countries compared to 60% of the basic Solow model. Second, ignoring human capital in the specification of the production function causes overestimation of the share of profits which may also overestimate the level of the steady state income. Third, the augmented Solow model predicts that per capita income converges to its country specific steady state level.

This is known as conditional convergence. Finally, the Solow model helps to explain the (slow) speed of convergence to the steady state due to changes in the investment rate. These are all useful for growth policies in the developing countries. However, they need to be re-examined and tested with country specific time series data if the policy makers main objective is to quickly increase income and its growth.

3.1 The Solow Model for Policy

Senhadji (2000) is the earliest to use the framework of Mankiw, Romer and Weil with country specific time series data. He has estimated augmented production functions with the time series methods of unit roots and cointegration for 88 countries for the period 1960-1994. His specification of the augmented production function is:[9]

$$Y_t = A_t K_t^{\alpha} (H_t L_t)^{1-\alpha} \qquad (1)$$

where A is the stock of knowledge, Y is income , K is capital, L is employment and H is a measure of human capital which is the same in Mankiw, Romer and Weil viz., number of years of schooling. Equation (1) can be expressed in skill adjusted per worker terms as follows:

$$y_t^{:} = \left(k_t^{:}\right)^{\alpha} \qquad (2)$$

where $y^{:} = (Y / AHL)$ and $k^{:} = (K / AHL)$. The solution for the steady state level of income, which is well known, is:

$$y^{:*} = \left(\frac{s}{d+g+n}\right)^{\frac{\alpha}{1-\alpha}} A \qquad (3)$$

[9] The Mankiw, Romer and Weil for cross country specification is: $Y_t = L_t^{1-\alpha-\beta} K_t^{\alpha} H_t^{\beta}$ and the implied specification for the time series data is: $Y_t = (A_t L_t)^{1-\alpha-\beta} K_t^{\alpha} H_t^{\beta}$. The advantage of Senhadji's specification is that it simplifies the solution for the steady state level of income and the closed form solution, to be discussed shortly, to simulate the dynamics of growth.

where $y^{*}(=Y/HL)$ is the steady state level of income per skill adjusted worker. The meaning of other symbols is as follows: s = the ratio of investment to income, d = depreciation rate of capital, g = the rate of change of income and n = the rate of growth of skill adjusted labour.

If policies to increase the investment rate are implemented, it is easy to compute the new steady state level of income with (3). However, two methods can be used to understand the dynamics of growth between the steady states. Firstly, the much neglected but useful Sato's (1963) closed form solution for the actual level of income is:

$$Y_t = A_0 e^{gt} L_0 e^{nt} \left[\frac{s}{d+g+n}(1-e^{(1-\lambda t)}) + \left(\frac{Y_0}{A_0}\right)^{[(1-\alpha)/\alpha]} e^{-\lambda t} \right]^{\frac{\alpha}{1-\alpha}} \qquad (4)$$

where the new symbols are: A_0 = the initial stock of knowledge, L_0 = initial skill adjusted employment, Y_0 = the initial level of income, Y_t = income in the t^{th} period and λ=(1-α)$(d+g+n)$. The rate of growth can be easily computed from (4) with the estimates of α and by using the actual data for other variables. The second approach is proposed by Mankiw, Romer and Weil in their equation (13) which is:

$$\Delta \ln y_t = \lambda(y_t^* - y_t) \qquad (5)$$

where y_t^* =is the steady state income per worker in period t, which can be computed with a variant of (3) because of the presence of human capital as an additional input in Mankiw, Romer and Weil; see their equation (12). y_t =is actual level of income per worker. λ can be estimated or computed as λ=(1-$\alpha-\beta$)$(d+g+n)$, where β is the exponent of human capital. If λ is computed, then it is also possible to analytically solve the difference equation in (5) and Mankiw, Romer and Weil's solution in their equation (14) is:

$$\ln y_t = (1-e^{-\lambda t})\ln y^* + e^{-\lambda t} \ln y_0 \qquad (6)$$

y_0 = the initial period income per worker.

Senhadji has estimated only the production function in equation (2) but did not estimate the steady state incomes using equation (3) or compute the transitional dynamics of growth using equations (4) or (6). However, he has used the estimates of country specific αs to conduct growth accounting exercises to decompose the contributions of factor accumulation ($\alpha \Delta \ln(\dot{k})$) and technical progress ($\Delta \ln(\dot{y}) - \alpha \Delta \ln(\dot{k})$) to growth. Next, he regressed the estimated technical progress (*TFP*) on some potential determinants viz., initial conditions, life expectancy, external shocks (proxied by the terms of trade shocks), macro variables (inflation rate, public consumption, real exchange rate, ratio of reserves to imports and level of external debt), trade regime (current account and capital account convertibility) and political stability (proxied with the ratio of war casualties to the population).[10] His major findings are: (1) the contribution of *TFP* to growth is generally small in many developing countries;[11] (2) there is support for conditional convergence, thus validating the use of the augmented Solow model for a large number of countries and with diverse economic structures; (3) the significant explanatory variables of *TFP*, with the expected signs in brackets, are: life expectancy (positive), public consumption (negative), real exchange rate (negative), reserves to import ratio (positive), external debt to GDP ratio (negative), capital account convertibility (positive) and the ratio of war casualties to population (negative); and (4) the insignificant variables are: terms of trade shocks (positive), inflation (negative) and current account convertibility (wrong sign and negative).

Some, if not all, of his findings are useful for policies in the developing countries. From the short to medium term perspectives, policies with a potential to increase *TFP* are: reductions in the share of public consumption, lower real exchange rates,

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[10] See Section III in Senhadji (2000) for further details on how these variables are defined and measured. He has used cross methods of estimation by grouping countries into regional groups.

[11] In the East Asian countries, with an average value of $\alpha = 0.48$, factor accumulation contributed 77.5% to growth. In the South Asian countries, where the average $\alpha = 0.56$, *TFP*'s contribution was half at only 12%. The rate of growth of *TFP* was negative in the Sub-Saharan Africa, Middle East and North Africa and Latin America.

increases in the ratio of reserves to imports through export promotion and trade liberalisation policies and reduction in external debt. Many of them have been successfully used by the East Asian countries to enjoy higher growth rates. China and India have also followed these countries and their growth rates have increased quickly to unprecedented rates. Whether these high growth rates in the Asian countries are temporary or permanent is an interesting issue but they seemed to have continued for a number of years. Policies needing longer periods to implement are political stability, institutional reforms, improvements in health and human capital formation etc. Policy makers are likely to be motivated to implement these longer term policies once they enjoy higher levels of income and growth rate in the short to medium terms.

To quickly improve the level of income and its transitional growth rate, an attractive short to medium term policy is an increase in the investment rate which was not examined by Senhadji. Its potential level and growth effects can be computed with equations (3) and (4). Simulations with equation (4) to understand the dynamics of growth can be implemented with Excel or a standard regression software; see Rao (2007). For illustration, equation (4) is simulated for 100 periods with the assumptions that $\alpha = 0.4$, $g = 0.01$, $n = 0.005$, $d = 0.05$ and the initial investment rate is $(s) = 0.15$. The steady state per worker income (when $s = 0.15$) is set to 1000.[12] When s is increased from 0.15 to 0.18, the new steady state level of income will be 1127.5. This is a 12% increase in the level of income because the elasticity of income with respect to the investment rate is $\alpha(1-\alpha)^{-1} = 0.67$.

What are the dynamics of the increase in income between these two steady states? Our simulations showed that the rate of growth of actual income will increase from 1% to 5.2% after one period. It will continue to grow by 3% even after 10 periods before converging to the *SSGR* of 1% in about after 50 periods. These results are broadly consistent with the view of Jones (1995, p.510) that perhaps a permanent increase in invest rate increases transitional growth rate for 25 to 30 years. An

[12] This is set by assuming a value for the initial stock of knowledge so that initial income is 1000.

increase in the investment rate by 3 percentage points, from 15 to 18 percent, is not a hard target to achieve in the short to medium terms in many developing countries.[13]

3.2. Solow Model for Policy: Alternative Methods

The above simulation results of dynamic growth effects are analytical and may not hold in practice in all countries. An increase in the investment ratio by 3 percentage points may have larger dynamic growth effects in a country with stronger backward and forward linkages than in a country with weaker linkage effects. Furthermore, if investments are made in sectors that have large economy wide externalities, the growth effects of investment may be permanent; see Greiner and Semmler (2002). These externalities may be due to learning by doing because investment in new and improved machines needs new skills and training for the workers and management. Although endogenous growth models are appropriate to analyze such growth effects due to externalities, with the exception of Greiner et. al., (2005), there are no systematic studies with time series data. However, the Solow model can also be extended empirically to capture some types externalities and the long run growth effects. The rest of this section examines this. Conceptually our procedure is similar to Senhadji's, but it is a one step procedure instead of three separate steps in Senhadji.[14] To illustrate we shall use the standard textbook model of Solow with the Harrod neutral technical progress. The specification of the production function is:

$$Y_t = K_t^{\alpha} \left(A_t L_t \right)^{1-\alpha} \tag{7}$$

where A is the stock of knowledge, Y is income , K is capital and L is employment. The solution for the steady state level of per worker income is the same as equation (3), given below as (3a) for convenience.

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[13] We did not simulate with the Mankiw, Romer and Weil equation (6) because there are three inputs in their production function.

[14] These are: (a) estimation of the production function (b) obtaining the Solow residual to estimate *TFP* from the growth accounting exercise and (c) regressing this on some potential explanatory variables.

$$y^{*} = \left(\frac{s}{d + g + n} \right)^{\frac{\alpha}{1-\alpha}} A \qquad (3a)$$

where $y = (Y / L)$. The steady state growth rate, when the parameters in the brackets remain constant, is simply:

$$\Delta \ln y^{*} = \Delta \ln A = g \qquad (8)$$

In the Solow model the stock of knowledge (A) is assumed to be exogenously determined and it is common to assume that A grows at a constant rate of g. Therefore,

$$A_t = A_0 e^{gt} \qquad (9)$$

where A_0 is the stock of knowledge in the initial period. But this does not change the fact that growth rate is exogenous in this model. However, this assumption helps to estimate *TFP* directly instead of conducting a growth accounting exercise to estimate it as a residual.

Two well known limitations of the Solow model are its assumptions that saving and investment rate (s) and the rate of technical progress (g) are determined exogenously. Endogenous growth model relax these assumptions, where optimising households and firms make saving and investment decisions and the rate of technical progress depends on the externalities of variables like investment, education, trade openness, R&D expenditure and quality of institutions etc. Some of these externalities like learning by doing take place without the need for additional resources and others like R&D and human capital formation need additional resources and depend on the decisions of households and firms and the policy incentives.

However, the Solow model can also be extended, albeit from an empirical perspective, by making the stock of knowledge to depend, besides time, on some variables, Z_i, identified to be growth enhancing by the endogenous models. This is as follows:

$$A_t = A_0 e^{(g_0 + g_i Z_{it})t} \quad (10)$$

The advantage of this extension is that it is relatively easy to estimate and examine the significance of the permanent growth effects of Z_i with country specific time series data. In equation (10) the rate of growth of technical progress is: $g = g_0 + \sum g_i Z_i$.

g_0 captures the effects of the neglected but trended variables. This is useful because it is not possible to include more than a handful of important variables into the specification because of limited sample sizes and potential multi-colinearity among some variables. Thus the long run growth rate depends, besides on trend, on the level of the Z_i variables, as in the endogenous models, because these variables may have externalities.[15]

The growth enhancing variables in Z_i, which we have selected in our empirical work are: trade openness measured as the ratio of exports plus imports to GDP (*TRAT)*, the share of government expenditure in GDP (*GRAT*), ratio of investment to GDP (*IRAT*) and number of years of schooling (*EDU)* or human capital (*HK).*[16] Data from

[15] Other specifications are:

$$A_t = f(T, Z) = A_0 e^{g\,t} Z_t^{\theta}$$
$$A_t = f(T, Z) = A_0 e^{g\,t} e^{\kappa Z_t}$$

These imply respectively that the rate of growth of *A* are: $g + \theta\,\Delta \ln Z$ and $g + \kappa \Delta Z$. The difference between these formulations and (9) is that *A* depends on the level of *Z* in (9) and on the changes in *Z* in the above. In our empirical applications in the lab tutorials with data of a number of countries we found that the specification in equation (10) performed far better.

[16] We have tried the number of years of schooling (*EDU*) in place of *HK* but found that *HK* performed better. *HK* is itself computed using *EDU* and they are highly correlated. For example, in Singapore the correlation coefficient between these two is 0.997.

Singapore, Malaysia and Thailand from 1970 to 2004 are used.[17] All these variables are considered to be important for the high growth rates of these East Asian countries. *HK* is included because some endogenous models based on the canonical Romer (1986) model have argued that investment by itself and without education (i.e., human capital formation) may not have significant externalities; see Greiner and Semmler (2002). Our selected growth improving variables may also meet Jones' criticisms of the endogenous models that growth rates did not increase with the increases in the levels of the growth improving variables like expenditure on R&D etc. Among our variables *IRAT* cannot increase indefinitely or *GRA*T cannot increase or decrease forever. Our empirical results show that the growth effects of these variables is much smaller than those found in some cross country studies implying that ever increasing growth rates are most unlikely when the levels of these variables change in favourable directions. Furthermore, in our empirical results we also fund that the growth effect of *TRAT* is nonlinear in Singapore and converges to an upper limit. But, there is no strong support for this in Malaysia and Thailand. In fact in Thailand *TRAT* seems to have only minor short run growth effects.

At the outset it should be noted that what can be estimated in the Solow model is the production function in (6) or with our modification in (10). The London School of Economics and Hendry general to specific approach (*GETS*) is used for estimation. Rao, Singh and Kumar (2008) explain the advantages of *GETS* over other time series methods. Furthermore, *GETS* is the only method where the cointegrating equation can be estimated with constraints on the coefficients. Additional growth enhancing variables can be added if enough data are available. Generally some of these growth improving variables are highly trended and the coefficient of time (a_1 in the equation below) may capture some effects of these omitted variables. The implied *GETS* specification of the modified production function in (10) is as follows:[18]

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[17] The sources of data are: UN database is used for output, investment, government expenditure and exports and imports, World Development Indicators for employment, and Bosworth and Collins (2003) for education and human capital. Their data up to 2000 is extrapolated to 2004 by the authors.

[18] Many empirical works based on the Solow model mistake that the estimated equation is a growth equation because the dependent variable is the rate of change of output. What actually estimated in this equation are the long run parameters of the production function.

$$\Delta \ln y_t = -\lambda \begin{pmatrix} \ln y_{t-1} - (a_0 + (a_1 + a_2 TRAT_{t-1} + a_3 GRAT_{t-1} \\ + a_4 IRAT_{t-1} + a_5 HK_{t-1})T + \alpha \ln k_{t-1} \end{pmatrix}$$
$$+ \sum_{i=0}^{n1} \gamma_i \Delta \ln k_{t-i} + \sum_{i=0}^{n2} \kappa_i \Delta TRAT_{t-i} + \sum_{i=0}^{n3} \omega_i \Delta GRAT_{t-i}$$
$$+ \sum_{i=0}^{n4} v_i \Delta IRAT_{t-i} + \sum_{i=0}^{n5} \tau_i \Delta HK_{t-i} + \sum_{i=1}^{n6} \eta_i \Delta \ln y_{t-i} \qquad (11)$$

4. Empirical Results

All the variables are tested for unit roots with the *ADF* and the generalised *ADF* tests and found to be *I(1)* in levels and *I(0)* in their first differences. These results are not reported to conserve space and may be obtained from the author. Strictly speaking a time series interpretation for *GETS* is not necessary because *GETS* formulations need only the classical methods for estimation; see Rao, Singh and Kumar (2008). For this reason we shall not strictly use the Ericsson and McKinnon (2002) test for cointegration in the *GETS* equations. Estimates of (11), with the nonlinear two stage instrumental variables method (*2SLSIV*), for Singapore are given in Table-1 and for Malaysia and Thailand in Table-2. *2SLSIV* is used to minimise any endogenous variable bias because contemporary changes in the variables are retained in some equations. Estimates with the standard specification of the production function in (6) and with the extended function in (10) for Singapore are given as equations (I) and (II) in columns1 and 2 of Table-1. Equations (III) and (IV) are estimates of the variants of (II). All these equations are well determined but equation (IV) with the nonlinear effects for *TRAT* seems to be the best.

In equation (I) all the estimated coefficients are significant at the 5% level. The χ^2 tests on its residuals show that there is no serial correlation and misspecification. The residuals are normally distributed and the Sargan test indicates that our choice of instrumental variables is appropriate. However, the $\bar{R}^2 = 0.22$ is low. The estimate of the share of profits α at 0.211 is reasonable although somewhat lower than its stylised value of one third. The coefficient of trend indicates that *TFP* is almost 4% per year.

TABLE-1
Results for Singapore
Dependent variable $\Delta \ln y$
NL2SLS-IV Estimates, 1974-2004

	I	II	III	IV
λ	1.299 (4.206)**	1.127 (5.263)**	1.134 (6.107)**	1.153 (5.298)**
T	0.039 (35.21)**	0.003 (0.293)	-	0.014 (1.864)*
$TRAT_{t-1}$	-	0.005 (3.568)**	0.005 (4.202)**	-
$TRAT_{t-1}^{-1}$	-	-	-	-0.019 (-5.433)**
$GRAT_{t-1}$	-	-0.064 (-3.306)**	-0.056 (-7.180)**	-0.048 (-2.509)**
$IRAT_{t-1}$	-	0.011 (3.481)**	0.012 (5.494)**	0.015 (4.993)**
HK_{t-1}	-	0.011 (1.607)*	0.012 (5.494)**	0.015 (4.993)**
$\ln k_{t-1}$	0.211 (4.471)**	0.296 (7.088)**	0.302 (12.360)**	0.298 (9.708)**
DYNAMICS				
$\Delta TRAT_t$		0.158 (3.741)**	0.167 (5.775)**	0.176 (3.678)**
$\Delta \ln k_t$	2.683 (2.187)*	0.651 (3.821)**	0.621 (4.483)**	0.524 (3.493)**
$\Delta \ln y_{t-1}$	0.338 (2.367)*	-	-	
$\bar{R}^2$	0.22	0.626	0.643	0.685
Sargan's χ^2	1.562 [.458]	2.501 [.981]	2.721 [.994]	3.387 [.971]
SEE	0.029	0.021	0.020	0.019
$\chi^2(sc)$	0.656 [.418]	0.173 [.173]	0.269 [.603]	0.046 [.830]
$\chi^2(ff)$	0.112 [.738]	0.699 [.699]	0.651 [.420]	2.315 [.128]
$\chi^2(n)$	3.71 [3.71]	1.586 [1.586]	1.624 [.444]	.896 [.639]

Notes: Absolute t-ratios (White-adjusted) are in the parentheses below the coefficients; 5% and 10% significance are denoted with ** and * respectively; p-values are in the square brackets for the χ^2 tests; constrained estimates are denoted with (c).

Estimates with our extended production function in (II) explain 63% variation in the dependent variable compared to 22% in (I). χ^2 tests on its residuals are as good as in equation (I). Estimate of the share of profits is significant and close to its stylised value. However, the coefficient of trend is insignificant and the coefficient of *HK* is significant only at a slightly higher level of 12%. All other coefficients are significant and have the expected values. The insignificance of trend is not unexpected because *TRAT*, *GRAT, IRAT* and *HK* seem to have adequately explained growth in *TFP*.

Estimates in equation (III) are the constrained version of (II). It can be seen that in (II) the coefficients of *IRAT* and *HK* are very close. The Wald test could not reject the null that these coefficients are equal and also that the coefficient of trend is zero. Therefore, (III) is a reestimate of (II) with these two constraints. There is a slight improvement in its $\bar{R}^2$ due a small increase in the degrees of freedom. All of its summary statistics and estimates are close to (II). This equation implies that increases in the investment ratio and human capital have similar effects on the long run rate of growth. In comparison the long run growth effects of *TRAT* seem to be small whereas *GRAT* has strong long run negative growth effect. In the absence of other variables to capture the effects of good economic policies, *GRAT* may be viewed as a proxy for good macroeconomic policies. Furthermore, investment $(\Delta \ln k_t)$ and changes in *TRAT* have also strong short run growth effects.

Equation (IV) is a reestimate of (III) to test if the effects of *TRAT* are nonlinear and converge to a maximum. *TRAT* is entered in its inverse with an intercept. The $\bar{R}^2$ of this equation is marginally higher than (III) and all of its summary statics are good. The estimated coefficients are all significant at the 5% level except the intercept for *TRAT* which is significant at the 10% level. This equation implies that the growth effects of *TRAT* eventually converge to about 1.4% as *TRAT* increases. The estimate of the profit share is near one third as in (II) and (III). Estimates of all other coefficients are similar to (III). Since this equation has the highest $\bar{R}^2$ and the estimates of the coefficients are similar to equations (II) and (III), this is our preferred equation.

For illustrating the policy use of equation (IV) we have computed the *SSGRs* for various decades with the actual values of the variables. The average *SSGR* during the decade of 1970s is 1.40% and it has increased to 2.12% by the end of the decade of 1980s. This has further increased to an average of 2.60% in the decade of the 1990s and slightly moderated since then to an average of 2.5% during 2000-2004. These are shown for comparisons in Table-3. Policy options to increase the *SSGR,* albeit by a small amount, are also clear since it can be changed by changing *TRAT, GRAT, IRAT* and *HK*. However, the potential long run growth effects of *TRAT* are limited because of the nonlinearity in its effects. However, *TRAT* has also some short run growth effects. An increase in *IRAT* has small long run and larger short run growth effects through its effects on $\Delta \ln k$. The mean *IRAT* during 2000-2004 was about 0.24 and the mean ratio of net investment to capital is 0.03. The mean capital to output ratio is 3.4, which seems to be a bit high but adequate for illustrating the policy implications. If *IRAT* is increased by 11% points to 0.35, which is slightly less than the average of 0.39 during the decade of the 1990s, what are the short and long run growth implications? The long run growth effect is easy to compute and this is 0.2%. In other words the *SSGR* of 2.5% increases to 2.7%. The short run growth effect of the change in *IRAT* is about 5.6 percentage points implying that if the economy is growing at its *SSGR* of 2.5%, the actual growth will increase immediately to 8.3%, of which 2.7% is due to the long run effect and 5.6% due to the transitory short run effects.[19] These computations do not make clear the transitory growth effects of an increase in *IRAT*. For this purpose it is necessary to simulate equation (IV) by assuming some initial values for the variables e.g., their average values during 2000-2004.

The time profile of the dynamics of the growth rate can be estimated by simulating equation (IV). We have performed the dynamic simulation exercise with this equation. Some simplifications are made in our simulation. Instead of assuming that

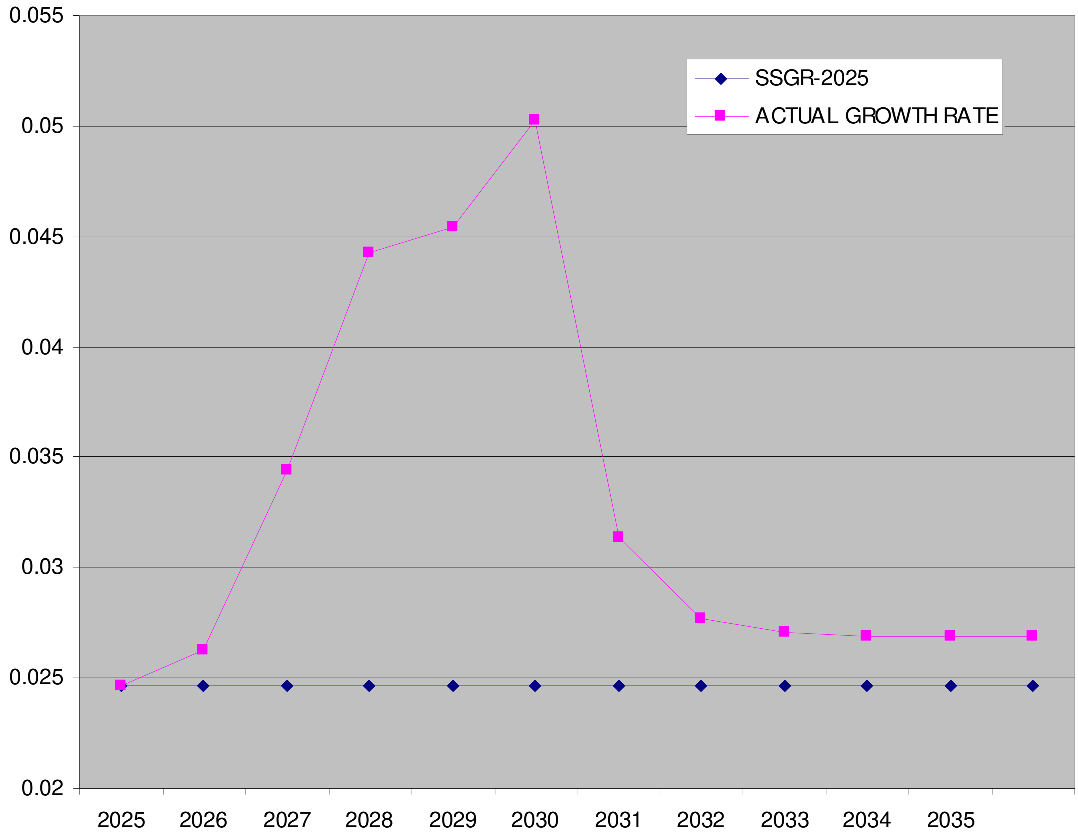
[19] The short run growth effects are computed as follows. $\Delta \ln k = dk / k = I(1+d)/K$, where $d =$ is depreciation rate which is assumed to be 0.04 in the estimates of K. It is also assume that employment is constant during the 2 periods. The above can be expressed as:

$$\Delta \ln k = dk / k = I(1+d)/K$$
$$= \frac{IRAT \times Y(1+d)}{K}$$
$$= a \times IRAT.$$

The average value during 2000-2004 of capital to out ratio is 3.4 and therefore $a = 0.306$. The average *IRAT* is 0.24 implying that when *IRAT* is 0.35, the value of $\Delta \ln k = 0.073$. This causes 0.056 points increase in the short run growth.

Figure-1

Dynamics of Actual Growth Rate



IRAT increases by 11 points in one year we assumed that this increase is gradual over a 4 period. In the first period the increase is 1 percentage point. In the second and third periods this is 3 percentage points and in the fourth year 4 percentage points. For 25 periods the values of the variables are set at their mean values during 2000-2004 and *IRAT* is assumed to increase from 0.24 to 0.35 over 4 years. The *SSGR* is computed as 2.47% for the initial 25 periods. *IRAT* is then assumed to increase in the aforesaid manner during 2005-2008. The average (actual) growth rate till 2035 is 3.34% per year and the new *SSGR* is 2.69%. Thus the permanent increase in the *SSGR* is 0.22 percentage points. However, the actual growth rate has significantly exceeded the *SSGR* of 2.47% for about 11 years before it reached its new *SSGR* of 2.69%. It reached a maximum of 5% after 5 periods in 2025. The dynamics of the growth rate is given in Figure-1. These transitional growth effects are country specific and may differ between countries. For example in a country which is in its early stage of development, *IRAT* may have larger external effects and therefore these transitional growth effects may be larger. On the other hand these effects may be smaller if investments are made inefficiently.

Selected estimates for Malaysia and Thailand are in Table-2. The specifications estimated for these two countries are variants of the specification in column 2 of Table-1 for Singapore. Equations (V), (VI) and (VII) are for Malaysia and (VIII) is for Thailand. Equation (V) is similar to (II) for Singapore. Although the summary statistics of this equation are good, a number of coefficients are insignificant. The only significant coefficients are the adjustment parameter (λ), *IRAT* and $\Delta IRAT$. Equation (VI) is a constrained estimate of (V) with the constraints that the coefficients of trend, *GRAT* and *HK* are zero. The Wald test did not reject these constraints and they have improved the significance of the estimated coefficients. All the coefficients are significant at the 5% or the 10% levels and the estimated share of profits is closer to the stylised value of one third. In equation (VII) *IRAT* and *HK* are specified in multiplicative form to examine if human capital formation improves the effects of *IRAT*. The significance of the coefficient of this composite variable has improved compared to the coefficient of *IRAT* in equation (VI). Furthermore, there is also a marginal improvement in the $\bar{R}^2$ and this is our preferred equation for Malaysia.

We faced some difficulties in estimating the equations for Thailand. When the specification in equation (II) in Table-1 for Singapore is estimated for Thailand, the coefficient of trend was implausibly high at 14%. The coefficient of *IRAT* was insignificant and that of *HK* was negative. After considerable modifications we obtained reasonable estimates when the coefficients of *TRAT* and *HK* were constrained to be zero and these estimates are reported in equation (VIII) of Table-2. All the coefficients are significant at the 5% level except that of $\Delta GRAT$ which is significant at 12% level. The tests on the residuals indicate that this equation is well determined. The estimated profit share is slightly higher than one third but not significantly different from this value. Because we have dropped *TRAT* and *HK* the coefficient trend seems to be higher because these are trended variables. This equation implies that *GRAT* seems to have strong negative effects on growth compared to in the other two countries.

Table-2

Results for Malaysia and Thailand
Dependent variable $\Delta \ln y$
NL2SLS-IV Estimates, 1974-2004

	V Malaysia	VI Malaysia	VII Malaysia	VIII Thailand
λ	0.874 (1.824)*	0.648 (6.106)**	0.656 (6.069)**	0.739 (2.484)**
T	-0.057 (-0.654)	-	-	0.028 (4.399)**
$TRAT_{t-1}$	0.005 (0.897)	0.001 (5.669)**	0.006 (6.063)**	
$GRAT_{t-1}$	0.004 (0.198)	-	-	-0.186 (-7.645)**
$IRAT_{t-1}$	0.021 (2.757)**	0.014 (1.848)*	-	0.022 (5.679)**
HK_{t-1}	0.032 (0.538)	-	-	
$IRAT_{t-1}$ * HK_{t-1}	-	-	0.010 (2.038)*	-
$\ln k_{t-1}$	0.445 (1.617)	0.268 (1.994)*	0.277 (3.732)**	0.368 (4.011)**
DYNAMICS				
$\Delta TRAT_t$	-	-	-	-
$\Delta GRAT_t$	-0.570 (-0.584)	-1.007 (-1.914)*	-0.999 (-1.921)*	-1.526 (-1.599)
$\Delta IRAT_t$	0.588 (2.205)*	0.377 (4.143)**	0.369 (4.579)**	0.821 (4.704)**
$\Delta \ln k_t$	0.557 (1.128)	0.685 (1.994)*	0.721 (2.304)*	-
DUM97-98	-	-	-	-0.054 (-2.343)
$\bar{R}^2$	0.740	0.776	0.777	0.845
Sargan's χ^2	13.177 [.106]	16.160 [.135]	16.259 [.132]	11.294 [.256]
SEE	0.020	0.019	0.019	0.017
$\chi^2(sc)$	.712 [.399]	.798 [.372]	.748 [.387]	2.720 [.099]
$\chi^2(ff)$	.255 [.613]	1.708 [.191]	1.729 [.189]	.276 [.599]
$\chi^2(n)$	.465 [.792]	1.754 [.416]	1.699 [.427]	1.954 [.376]

Notes: Absolute *t*-ratios (White-adjusted) are in the parentheses below the coefficients; 5% and 10% significance are denoted with * and ** respectively; *p*-values are in the square brackets for the χ^2 tests; constrained estimates are denoted with (c). DUM97-98 is a dummy variable for the East Asian Financial crisis.

The decade averages of the *SSGRs* for these two countries and also for Singapore are given in Table-3. In both Malaysia and Thailand the *SSGRs* are lower than in Singapore. In Malaysia there has been a small improvement in the *SSGR* till the end of the 1990s and it has stabilised during 2000-2004 at 1.5%. In Thailand the *SSGR* during the 1970 was marginally higher than in Singapore at 1.5%. This has declined to 1.2% in the 1980s and then improved to 1.9% during the 1990s. During 2000-2004 this has declined to 1.5%, perhaps mainly due to the East Asian financial crisis in the late 1990s which has hit hard this country and subsequent political instability.

Table-3

Estimates of the *SSGRs*

	SGP	MYS	THA
1970-79	1.40%	0 .8%	1.50%
1980-89	2.12	1.00%	1.20%
1990-99	2.60%	1.50%	1.90%
2000-04	2.50%	1.50%	1.50%
Growth Effect of $\Delta IRAT = 0.11$			
Long run: $\Delta SSGR$	0.2	0.2	0.3
Short run growth effects	5.6	2.5	7.4

What are the growth effects of a 11 point increase in *IRAT?* In Malaysia the short run rate of growth will increase from an average of 2% during 2000-2004 to 4.7% of which 2.5% is the short run effect and 0.2 percentage points is due to the long run effect. Its *SSGR* will increase from 1.5% to 1.7%. In Thailand growth of income will increase from an average of 3.6% during 2000-2004 to 11.2% of which 7.4% is the short run effect and 0.3 percentage points is the long run effect. Its *SSGR* will increase from 1.5% to 1.8%. A dynamic simulation for these two countries is beyond the scope of the present paper. It is reasonable to expect that the dynamic pattern of growth in these two countries will be similar to Singapore.

Our empirical results with the extended Solow model have shown that the long run growth effects of increasing the investment ratio are small. About a ten point increase in *IRAT* caused at the most only 0.3 percentage points increase in the *SSGR* of

Thailand. This is significantly less than 3% effect found by DE Long and Summers (1991) based on the cross country approach.[20] However, these authors have disaggregated *IRAT* and found that only investment in plant and equipment has such high growth effects. In fact non-equipment investment ratio has zero or even negative effects on the growth rate. Besides this, as we have noted earlier, measuring the rate of growth even with 20 or even more years of average growth rate is not a good proxy for the unobservable long run growth rate and may overestimate the growth effects of variables like *IRAT*. For example, when we have regressed the annual rate of growth of output of Singapore on the current and lagged values of the levels of *TRAT*, *GRAT, HK* and *IRAT* the sum of the coefficients of *IRAT* is 0.15 which is 7.5 times more than our estimate for Singapore.

However, *IRAT* has significant growth effects in the short run and they are likely to persist for about ten years. This distinction between the short and long run effects of *IRAT* cannot be captured in the cross country regressions. During this transition period, the average rate of growth can be higher at least by 1% than the *SSGR*. In Singapore, this transitional growth rate has exceeded its *SSGR* of 2.5% by as much as 2% points during 3 periods. The implication of these results is that increasing the growth rate by increasing the investment rate is an effective growth policy for the short to medium terms. Needless to say policy makers of the developing countries will find this result attractive for growth policies. However, the long run growth effects of *IRAT* are modest and this needs further examination with disaggregated data on investment.

5. Endogenous Models

As already noted endogenous growth models are of limited use for policy makers of the developing countries because the main purpose of these models is to show theoretically how in a model with optimising agents endogenous factors can cause sustainable growth of per capita income in the long run. Their theoretical arguments are important because it is possible to improve the growth rate through policies by

[20] In another cross country study by Levine and Renelt (1992) the growth effects of aggregate investment ratio are much higher and somewhat implausible.

influencing the decisions of households and firms. In contrast the basic exogenous model of Solow does not explain this persistent growth and has no policy implications for long run growth. However, as we have argued, the Solow model has some policy implications to increase the level of income and its growth rate during the long transition period. Furthermore, Senhadji (2000) has illustrated how Solow (1956 and 1957) models can be used to identify key factors to improve the long run growth rate. Our extension to the Solow model is similar to his approach and it is relatively easy to estimate the extended Solow model. With this backdrop we shall briefly examine the use of endogenous models for policy.

A brief outline of a canonical endogenous model would be useful here. The benchmark model, with optimising agents, is the conventional Ramsey (1928) growth model with zero (or even negative) per capita long run growth. Romer (1986) showed how if investment with externalities takes place, there will be a sustainable positive growth of income. Since saving and investment decisions are made by households and firms, the Romer model is an endogenous growth model. Greiner and Semmler (2002) is perhaps the earliest to estimate an extended version of the Romer model with time series data for Japan and Germany for the period 1950-1992. Their model can be described as follows. In a competitive economy saving and investment decisions are made by optimising households and firms. Equilibrium occurs when factor prices equal marginal products. However, if investment has positive economy wide externalities, its rate of social return will be higher than the competitive private return. The stronger are the externalities the wider is the gap between these two returns. Therefore, competitive levels of saving and investment will be less than their socially optimum levels and the government can increase social welfare through appropriate policies e.g., by subsidising investment. Another aspect examined by the endogenous literature is how to finance the additional government expenditure without increasing the budget deficit. The general answer is that it should be financed by imposing lump-sum taxes. This framework can be extended similarly to show that the long run growth rate can be increased through policies to increase the levels of other growth improving variables like education, health, R&D activity, legal, political and economic environment through institutional reforms and liberalisation policies etc. However, there is no generalised endogenous model where the growth effects of many such variable are derived. Often the theoretical models use one or two growth enhancing variables; see footnote 1. Therefore, any variable that is believed to create significant externalities is included as a candidate in the empirical work on growth. This explains why Durlauf, Johnson, and Temple (2005) have found that too many growth improving variables are identified in the empirical models. The concerns of Easterly, Levine and Roodman (2004) on the use of arbitrary specifications and lack of any reference to any theoretical model is also justified because it is hard to estimate the actual structural equations of the theoretical endogenous models. The theoretical endogenous models in principle help to compute the gap between the competitive and socially optimal levels of a potentially growth enhancing variable like investment. The relationship between the long run growth rate and the level of the growth improving variable can also be derived. This may be of use to the policy makers if it is easy to estimate these models. But as we shall see, there some difficulties in estimating these models at present.

The competitive solution of an endogenous model depends in a complex manner on the parameters of the inter temporal utility and production functions besides the equilibrium conditions and constraints of the optimisation model. Consider the following results from the model of the Greiner and Semmler (2002). First, the specifications of the inter-temporal Cobb-Douglas production (Y) and CRRA consumption (C) functions and the rate of growth of the stock of knowledge (A) are as follows. Time subscripts are ignored for convenience except for the consumption function.

$$Y = (uAL)^{\alpha} K^{1-\alpha} = (uA)^{\alpha} K^{1-\alpha} \tag{12}$$

$$U_t = \frac{C_t^{1-\xi}}{1-\xi} + \frac{C_t^{1-\xi}}{(1-\xi)((1+\rho)} \ \text{K} \tag{13}$$

$$\dot{A} = \varphi(u) I - \eta A \qquad \varphi'(u) < 0 \tag{15}$$

$$\dot{K} = I - \delta K \tag{16}$$

where $u =$ time spent on work (normalised as unity), $\xi =$ is the risk averse coefficient in the CRRA utility function whose inverse gives the elasticity of inter-temporal substitution, $\rho =$ time preference rate, $\delta =$ depreciation rate of K and $\eta =$ depreciation rate of A. A dot on the variable for its rate of change. Note that the production function is transformed into per worker terms although Greiner and Semmler did not change their notation. The solution to the model is as follows.

$$\frac{dC}{C} = -\frac{\rho+\delta}{\xi} + \frac{(1-\alpha)\left((u^*)A\right)^{\alpha} K^{-\alpha}}{\xi} \tag{17}$$

$$\frac{dK}{K} = -\delta - \frac{C}{K} + \left((u^*)\frac{A}{K}\right)^{\alpha} \tag{18}$$

$$\frac{dA}{A} = -\eta + \varphi(u^*)\left((u^*)^{\alpha}\left(\frac{K}{A}\right)^{1-\alpha} - \frac{C}{A}\right) \tag{19}$$

There are some problems in estimating these structural equations (17) to (19).There are not enough restrictions to identify all the parameters. Further, data on the unobservable stock of knowledge A are to be estimated with the perpetual inventory method just like K is estimated with data on I and with some plausible assumption about $\varphi(u^*)$. Greiner and Semmler make a simplification by subtracting equation (18) from (17), with the assumption that $(1/\xi)=1,\ \varphi(u^*)=0.4,\ u=0.86, \eta=0.06$ to get:[21]

$$\frac{dc}{c} = -\rho + (1-\alpha)\left(\frac{uA}{K}\right)^{\alpha} - \frac{I}{K} \tag{19}$$

$$\therefore \left(\frac{dc}{c} + \frac{I}{K}\right) = \mathrm{b}_1 + b_2\left(\frac{uA}{K}\right)^{1-b_2} \tag{20}$$

Estimates of equation (20) for Germany for the period 1950-1992 give $b_1 = -0.096$ and $b_2 = 0.37$ and both are significant. No doubt this exercise has some use but the important parameter concerning the scale effects of investment is assumed $(\varphi(u^*))$ and not estimated. Further estimates of (20) are only useful to estimate the time preference rate ρ and the share of profits $(1-\alpha)$ and nothing more. These parameters can also be estimated by estimating the consumption and production functions and there is no particular merit in estimating them with an endogenous growth model. Nevertheless, the theoretical results show that if investment has no externalities i.e., $\varphi(u^*)=0$, it cannot sustain a positive growth rate. Perhaps because of these estimation

[21] The assumption that the elasticity of inter-temporal substitution of consumption $(1/\xi)=1$ implies that the utility function is the simpler Cobb-Douglas type.

limitations Albelo and Manresa (2005) have used calibration methods by making plausible assumptions about all the parameters in their model. They have used their model is to show that when externalities due to investment are of two types viz., economy wide and firm specific, under some conditions growth and investment may be negatively correlated. This is contrary to the findings in the cross country studies and also our results with the extended Solow model. Given these difficulties it is hard to disagree with Solow (2000) that "The second wave of runaway interest in growth theory—the endogenous growth literature…. appears to be dwindling to a modest flow of normal science."

5. Conclusions

This study has examined an influential view that there is a large gap between the needs of policy makers of the developing countries and the existing theoretical and empirical growth literature. While growth theory and empirical work have focused on the long term growth effects, policy makers of the developing countries wish to know the short and medium term consequences of policy on the growth. It is suggested, therefore, there is a need to distinguish between the short and long rum effects of policies. We have shown that how the Solow (1956) model can be extended and used to examine the dynamic growth effects of policies both in the short and long runs. We estimated the extended Solow model with data from Singapore, Malaysia and Thailand to examine the effects of certain policy measures viz., the investment ratio, trade openness, the ratio of government expenditure to GDP and human capital formation. We concentrated on the effects of the investment ratio and found that it has significant short run growth effects which persist for about 10 years. These short run effects, though transient, are much larger than the long run effects. Because this distinction is not possible in cross country empirical work, in general they may have overestimated the long run growth effects of variables like the investment ratio.

There are some limitations in our paper. Firstly, our empirical results should be interpreted with caution because we have selected only four key growth enhancing variables in comparison to more than a hundred such potential variables examined by the empirical works. However, our framework can be easily extended to include additional variables subject to the availability of data. Secondly, we have selected only Singapore to conduct the dynamic simulation exercise. It is desirable to perform this with data from other countries. However, this simulation exercise is demanding and our example may encourage others to fill this gap. Thirdly, we have neglected the time series econometrics and used *GETS* and classical methods of estimation. Nevertheless, the t-ratios of the preferred equations for Singapore and Malaysia exceed the critical values of Ericsson and McKinnon (2002) for cointegration. The equation for Thailand, however, fails this test.

In spite of these limitations we believe that our framework is well suited to meet the short and medium term needs of the policy makers of the developing countries. Hopefully other investigators will further narrow the gap between the academic nature of growth research and the needs of policy makers in both the developing and developed countries.

References

Albelo C and Manressa A (2005). Internal Learning by Doing and Economic Growth. Journal of Economic Development 30: 1-23

Barro R (1990). Government Spending in a Simple Model of Endogenous Growth. Journal of Political Economy 98: S103-S125

Cooley T, Greenwood J and Yorukoglu M (1997). The Replacement Problem. Journal of Monetary Economics 40: 457-499

DeLong B and Summers L (1991). Equipment Investment and Economic Growth. Quarterly Journal of Economics 106: 445-502

Durlauf S, Kourtellos A and Tan C (2008). Are Any Growth Theories Robust? Economic Journal 118: 329-346

Durlauf S, Johnson P and Temple J (2005). Growth Econometrics: Handbook of Economic Growth in Aghion P and Durlauf S (eds.) Volume 1 Chpter 8. pp555-677

Easterly W, Levine R and Roodman D (2004). New Data, New Doubts: Revisiting Aid Policies and Growth: Centre for Global Development Working Paper No: 26

Ericsson, N., and MacKinnon, J. (2002). Distributions of Error Correction Tests for Cointegration, Econometrics Journal 5: 285

Greenwood J and Krusell P (1997). Growth Accounting with Investment Specific Technological Progress: A Discussion of Two Approaches, Journal of Monetary Economics 54: 1300-1310

Greiner A, Semmler W and Gong G (2005). The Forces of Economic Growth – A Time Series Perspective: Princeton University Press, Princeton

Griener A and Semmler W (2002). Externalities of Investment, Education and Economic Growth. Economic Modelling 19: 709-724

Hendry D (2000). Econometrics Techniques: General Discussion in Backhouse R and Salanti A (eds.) Macroeconomics and the Real World. Oxford University Press. Oxford

Hendry D and Krolzig H (2001) The Properties of Automatic GETS Modelling. Economic Journal 115: C32-C61

Hicks J (1965). Capital and Growth. Oxford.

Jones C (1995). R&D Based Models for Economic Growth. Journal of Political Economy 103: 759-784

Levine R and Renelt D (1992). A Sensitivity Analysis of Cross Country Growth Regressions. American Economic Review LXXXII: 942-963

Lucas R (1988). On the Mechanics of Economic Development. Journal of Monetary Economics 22: 3-42

Luintel K, Khan M, Arestis P and Theodoridis K (2008). Financial Structure and Economic Growth. Journal of Development Economics 86: 181-200

Mankiw N G, Romer D and Weil D (1992). A Contribution to the Empirics of Economic Growth. Quarterly Journal of Economics 2: 407-437.

Parente (2001). The Failure of Endogenous Growth. Knowledge, Technology and Policy 13: 49-58

Pritchett L (2006). The Quest Continues. Finance and Development 43.1

Ramsey F P (1928). A Mathematical Theory of Saving, Economic Journal, 38: 543-59

Rao, B. B. (2006). Investment Ratio and Growth, ICFAI Journal of Applied Economics 3: 68-72.

Rao, B. B., Singh, R. and Kumar, S. (2008) Do We Need Time Series Econometrics? forthcoming, Applied Economics Letters

Romer M (1986). Increasing Returns and Long Run Growth. Journal of Political Economy 94: 1002-1037

Romer P (1990). Endogenous Technological Change. Journal of Political Economy 98: S71-S102

Sala-i-Martin X (1997). I Just Ran Two Million Regressions. American Economic Review 87: 178-183

Sato R (1963). Fiscal Policy in a Neo-Classical Growth Model: An Analysis of Time Required for Equilibrium Adjustment. Review of Economic Studies 30: 16-23

Senhadji A (2000). Sources of Economic Growth: An Extensive Growth Accounting Exercise. IMF Staff Papers 47:

Solow R (1956). A Contribution to the Theory of Economic Growth. Quarterly Journal of Economics 70: 65-94
Solow R (2000). Toward a Macroeconomics of the Medium Run. Journal of Economic Perspectives 14: 151-158
Uzawa H (1968). Market Allocation and Optimum Growth. Australian Economic Papers 17: 17-27