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Abstract

This paper examines the growing gap between the theoretical and empirical growth literature and policy needs of the developing economies. Growth literature has focused mainly on long term growth outcomes, but policy makers of the developing economies need rapid improvements in the short to medium term growth rates; see Pritchett (2006). In this paper we argue that this gap can be reduced by distinguishing between the short to medium term dynamic effects of policies from their long run equilibrium effects. With data from Singapore, Malaysia and Thailand, we show that an extended version of the Solow (1956) model is well suited for this purpose. We find that the short to medium term growth effects of the investment ratio are quite significant and they may persist for up to 10 years.

JEL: O11

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

1. Introduction

The empirical literature on economic growth is based on either the Solow (1956) exogenous growth model or variants of the endogenous growth models of Uzawa (1968), Romer (1986,1990), Lucas (1988) and Barro (1990).[1] The econometric techniques used range from country specific time series methods to three types of cross country techniques. The latter are of 3 types viz., pure cross section methods, panel data methods ignoring the time series properties of variables and panel data methods incorporating time series properties of variables. These econometric techniques have been used to estimate both exogenous and endogenous growth models for the developed and developing nations.

However, Pritchett (2006) has recently observed that despite the progress made in the growth literature, that there is an increasing gap between academic interests and the needs of policy practitioners of the developing countries. According to him, nearly everything about the first-generation of 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 nations, whose primary interest is in restoring short-to medium-term growth and accelerating technological catch-up by adopting already known innovations. The aim of this paper is to addresses and provide some guidelines to narrow this gap.[2] We take the view that the potential of the Solow model to narrow this gap is inadequately explored. This is despite the prevalent view that the Solow (1956) model does not have significant policy

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[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*).

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

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 developments in the growth literature and the needs and constraints of policy makers of the developing countries. Section 3 reviews the potential of the Solow model and its extensions to meet some of these needs. Section 4 presents empirical results to show this potential. Section 5 briefly examines an empirical endogenous growth model and its use for policy. Section 6 concludes.

2. Growth Literature and the Needs of Policy Makers

Policy makers of the developing countries (policy makers from now) wish to know the likely consequences of public sector actions over their *relevant time horizons*; Pritchett (2006). However, these time horizons are perceived differently by policy makers and academic economists. For the politicians and policy advisors in the developing nations these time horizons are generally short, spanning over one or two terms in office. During an elections, politicians wish to highlight key economic achievements. Achieving high growth rates is an important policy objective. In contrast, much of the endogenous growth literature investigates the long run determinants of growth spanning over decades. Consequently, it is necessary to distinguish between policies that can effectively be implemented in the short to medium run from those that need decades to be effective. Existing growth literature, by and large, has ignored this distinction because, as noted by Hicks (1965), developments in growth theory do not have much relevance for the developing economies. However, as stated earlier, the potential of the Solow (1986) model and its extended variants, e.g., by Mankiw, Romer and Weil (1992, MRW hereafter), are inadequately explored. For example, the Solow model can be used to analyse the short, medium and long run effects of changes in the investment rate on the level of income and short to medium term growth effects. These short to medium term

[3] Quoted by Pritchett (2006).

transitory growth effects are of interest to the policy makers of developing nations because raising the investment rate is a relatively simple policy option to implement compared to implementing institutional reforms etc., which are difficult to implement and need a long term to be effective. Raising investment rates is also an attractive policy option. De Long and Summers (1991), Levine and Renelt (1992) and Sala-i-Martin (1997) have shown, with cross country data, that the investment rate has long term growth effects. More recently, Greiner, Semmler and Gong (2005), using country specific time series data, have shown that the investment rate 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. Therefore, we shall examine in this paper the dynamics of the growth effects of investment rate.

There are also some neglected areas which may have widened the gap between growth literature and wishes of policy makers of the developing countries. Technocrat policy makers need simpler and less ambiguous 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 growth during long transition periods of the economy between two steady states. Endogenous growth models are primarily interested in the long run growth effects of policies and therefore neglect the dynamics because pure cross section methods are used in many empirical studies. Furthermore, the parameters of endogenous models have a complex non-linear structure and are hard to estimate with country specific time series data. The cross section and panel data based empirical studies use *ad hoc* reduced form growth equations and avoid the estimation of structural parameters. These *ad hoc* growth equations are also estimated with arbitrarily selected explanatory variables. 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.” Durlauf, Johnson, and Temple (2005) have noted that the arbitrary selection of explanatory variables has increased the number of potential growth improving variables to as many as 145. Often these growth enhancing variables are also correlated making it hard to estimate their individual growth effects. The issue of model selection is further complicated because different authors choose different empirical proxies for variables even when the same growth theory is used.[4]

There is also disagreement on the relative merits of the estimation techniques. Much of the empirical work is dominated by 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 involving time series methods (unit roots and cointegration) have also become popular. In these cross country studies, the annual growth rate or their panel averages are used as the dependent variable. 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 bias in the estimated coefficients. We conjecture that the growth effects of variables will be overestimated because the *SSGR* proxied by averages over short panels has both the short and long run components. 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 steady state conditions.

Cross country studies examine which set of variables can best explain the large variations in per capita income or their growth rates across countries despite the limitations noted above, and the standard criticism that cross country studies make the tenuous assumption that one size fits all. However, they have some important policy implications. Cross country methods are important when country specific data on growth enhancing variables are not available for longer periods. If such data were available, the variances of the variables are small compared to their variance in cross country data. Therefore, cross country studies are useful for identifying the more important (fundamental) determinants of growth. Commenting on the diversity in cross country studies, Bosworth and Collins (2003) state that empirical growth

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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 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.

literature is filled with conflicting claims and strong disagreements on econometric methodology, substantive conclusions on the predictors, determinants of cross country growth differences and appropriate ways to measure potential growth determinants. Through careful attention to variable selection and measurement, it is possible to develop a coherent perspective on cross country growth determinants and thereby bring some clarity to empirical growth studies. In spite of these complications Durlauf, Kourtellos, and Tan (2005) summarise the findings of 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. These are broadly consistent with Frankel (2003) who note that three big theories that seem to have emerged from cross country studies on growth are based on climate, openness, and institutions.

However, these findings do not meet the immediate needs of the politicians and policy makers in the developing countries. They need policies for quick improvement in per capita incomes and growth rate. Among the above fundamental factors of Durlauf et. al., (3) to (5) are virtually impossible to change over the short and medium term although their adverse effects can be somewhat mitigated. Since these fundamental growth variables are non-pragmatic policy options, it is left to international aid and credit granting agencies to convince or even force the developing nations to implement these long run reforms to improve the economic, legal and political environment.[5]

Country specific time series studies to identify such fundamental determinants of growth are mostly encouraged by the findings of cross country studies and the availability of long enough time series data. Country specific studies are more appropriate for country specific growth policies. Greiner, Semmler and Gong (2005) strongly defend this approach to cross country studies. The “one size fits all” criticism against cross country studies has also received support from Levine and Zervos (1998) and Durlauf, Kourtellos, and Tan (2008). Levine and Zervos are critical of

[5] These are known as the conditionality of the international aid giving agencies. Interestingly Frankel (2003) also argued that the most important determinants of growth appear to be factors that cannot be changed substantially in the short run.

estimating regressions with a sample of a large number of countries with diverse economic structures and interpreting the coefficients of policy variables as their growth elasticise. Durlauf et. al., find evidence of parameter heterogeneity in the aggregate production functions of cross country studies. Similarly Luintel, Khan, Arestis and Theodoridis (2008) note 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 such as the investment ratio, trade openness, education, budget deficits, public investment in infrastructure, aid 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 changed quickly by policy makers compared to reforming institutions. However, as noted earlier, the specifications used by many country specific studies are as *ad hoc* as in cross country studies. They do not make clear whether their specifications are based on or how they have derived their specifications from the theoretical growth models. Furthermore, it is also not obvious whether the estimated relationship is a production function or a growth equation. 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. None of them seem to have analysed the dynamic growth effects of policy variables such as the investment rate. It is hard, therefore, to rely on the results of these *ad hoc* studies for developing growth policies.[6]

Despite the aforesaid weaknesses in the empirical literature, debates on growth economics and econometrics are useful for reaching some broad agreements on model selection, estimation methods and identifying fundamental growth factors. It is also important to examine the dynamic growth effects of policy variables wherever possible because the short and long run growth effects may differ. In this context it is of interest to note that Greiner et. al. (2005), using time series data for the OECD countries and specifications based on various endogenous models, find that in the early stages of development, investment with a potential for externalities are

[6] 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.

important for growth. Human capital formation and expenditure on research and development (R&D) are important in the later stages of development. The first finding is important for the developing countries and requires attention. Against this backdrop we next examine the use of the existing growth literature for the needs of the developing countries.

3. Useful Models and Technique for Policy

Policy makers—politico and technocrat—are interested in models and techniques to generate the dynamic effects of policies on the level and growth of income. A related issue is whether a policy has only a temporary or permanent growth effect and if temporary, how long such effects may last. An example would be a policy to increase the investment rate 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 policy maker, a policy that is quick to implement and increase the growth rate—irrespective of whether it is transitory or permanent—is a more attractive policy than institutional reforms that may change the long standing traditional values of a country. Although institutional reforms have lasting growth effects, they may need decades to be effective. For this purpose endogenous models are appropriate but it is hard to estimate them with country specific data because of the lack of reliable measures of reform, data availability for a long enough period and their nonlinear parametric structure. Because of these difficulties it hard to estimate endogenous models to analyse even the effects of the investment ratio with country specific data. Therefore, often calibration methods are used to simulate the growth effects of policies in these models; see Albelo and Manresa (2005). In contrast, the Solow model, when extended, is simpler to estimate and simulate to understand the dynamics of growth. Apart from this it is difficult to state that one of these models is better than the other although there are some strong views against the merits of endogenous models.[7]

[7] Mankiw, Romer and Weil (1992) have argued that the Solow model can explain the observed facts better than the endogenous models. Jones (1995) argues 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

The Solow model has been used to test the convergence hypothesis. Its ability to explain the dynamics of growth with country specific time series data has not received 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 income across countries with diverse structures. The majority of the empirical studies on convergence, which have used data from both the developed and developing countries, do not support convergence and imply that the Solow model is inadequate for explaining differences in incomes. This in turn has partly induced interest in endogenous growth models as alternatives. But the more important reason for the development of 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 inadequate. Although testing the convergence hypothesis has some methodological merits, policy makers of the developing countries are least interested in knowing whether per capita incomes in their countries will converge, in about 200 years, to the level of per capita income in the USA.

Subsequent extensions to the Solow model by MRW (1992) have shown that the Solow model, if augmented with human capital, can satisfactorily explain cross country differences in the level of income. In particular, their results show that the steady state levels of income differ across countries and incomes converge to country specific steady state levels. 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 MRW 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 level of income across countries compared to 60% with the standard Cobb-Douglas production function in 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 steady state income.

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modest flow of normal science. This is not a bad thing.” See also Parente (2001) for other criticisms of endogenous models.

Third, the augmented Solow model predicts that per capita income converges to the country specific steady state level of income. 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 increase income and growth within a short space of time.

3.1 The Solow Model for Policy

Senhadji (2000) is the earliest to use the framework of MRW with country specific time series data. He has estimated an augmented production function using time series methods for 88 countries for the period 1960-1994. His specification of the augmented production function, with Harrod neutral technology, can be expressed as:[8]

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

where A is the stock of knowledge, Y is income , K is capital, L is employment and H is a measure of human capital as in MRW. Equation (1) can be expressed in skill adjusted per worker terms as follows:

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

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

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

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[8] The Mankiw, Romer and Weil production function for cross country specification is: $Y_t = L_t^{1-\alpha-\beta} K_t^{\alpha} H_t^{\beta}$ and the implied specification for 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 $\bar{y}^{*}(=Y/AHL)$ is the steady state level of income per skill adjusted worker, s = the ratio of investment to income, d = depreciation rate of capital, g = the rate of technical progress 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 using (3). However, two methods can be used to understand the dynamics of growth between these steady states. Firstly, the much neglected 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 $\lambda=(1-\alpha)(d+g+n)$. 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 MRW in equation (13) which is:

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

where $y_t^* =$ the steady state per worker income in period t, which can be computed with a variant of (3) because of the presence of human capital as an additional input. $y_t =$ actual level of income per worker. λ can be estimated or computed as $\lambda=(1-\alpha-\beta)(d+g+n)$, 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 MRW's solution to 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 estimates only the production function given by equation (2). He does not estimate steady state income using equation (3) or compute the transitional dynamics of growth using equation (4) or (6). However, he uses the estimates of country specific αs to conduct growth accounting exercises to decompose the contributions of factor accumulation ($\alpha\,\Delta\ln(k^{\sim})$) and technical progress (*TFP*) ($\Delta\ln(y^{\sim}) - \alpha\Delta\ln(k^{\sim})$) to growth. In the sample of developing countries the contribution of *TFP* to growth is negligible or even negative. Next, he regresses the estimated *TFP* on some potential determinants and initial conditions, life expectancy, external shocks (proxied by the terms of trade shocks), macroeconomic conditions (proxied with 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 by the ratio of war casualties to the population).[9] His major findings are: (1) the contribution of *TFP* to growth is generally small in many developing countries;[10] (2) there is support for conditional convergence, validating the applicability of the augmented Solow model for a large number of countries 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 policy making in the developing countries. From the short to medium term perspective, policies with a potential to increase *TFP* are: reductions in the share of public consumption, lower real exchange rate, increases in the ratio of reserves to imports through export promotion and trade

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[9] 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.

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

liberalisation policies and reduction in external debt. Many of these policies have been successfully implemented by the East Asian countries, and subsequently by China and India. All these countries have experienced high growth rates. Whether these high growth rates in the Asian countries are temporary or permanent is an interesting issue but they seem to have persisted for a number of years. Policies requiring 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 in the short to medium term.

In order to rapidly improve the level of income and transitional growth rate, an attractive short to medium term policy is to increase in the ratio of investment to GDP. However, Senhadji does not examine this. The potential level and growth effects of the investment ratio can be computed using equations (3) and (4). Simulations using equation (4) to understand the dynamics of growth can be implemented with Excel or any 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 ratio is (s) = 0.15. The steady state per worker income (when $s = 0.15$) is set to 1000.[11] 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 s is $\alpha(1-\alpha)^{-1} = 0.67$ and s increases by 18.2%.

What are the dynamics of the increase in income between these two steady states? Our simulations shows that the rate of growth of actual income increases from 1% to 5.2% after one period. It continues to grow by 3% even after 10 periods before converging to the original *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 investment rate increases the transitional growth rate for 25 to 30 years. An increase in the investment ratio by 3 percentage points, from 15 to 18 percent, is

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

not a difficult target to achieve in the short to medium terms for many developing countries.[12]

3.2. Solow Model for Policy: Alternative Methods

The above simulation of dynamic growth effects are analytical and may not hold in practice for 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 weak 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 be learning by doing because investment in new and improved machinery requires new skills and training for 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 using time series data. However, the Solow model can also be extended empirically to capture some externalities and 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 rather than the three step method of Senhadji.[13] To illustrate we use the standard textbook model of Solow with 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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[12] We did not simulate with the MRW equation (6) because there are three inputs in their production function.

[13] 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 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 the investment rate (*s*) and the rate of technical progress (g) are determined exogenously. Endogenous growth models relax these assumptions, where optimising households and firms make saving and investment decisions and the rate of technical progress depends on the externalities created by variables such as investment, education, trade openness, R&D expenditure and the quality of institutions etc. Some of these externalities such as 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, firms and the policy incentives.

However, the Solow model can also be extended by making the stock of knowledge to depend, besides time, on some variables, Z_i, identified to be growth enhancing by some endogenous models. This is similar to the procedure in some endogenous growth models in which there is an equation for the growth of knowledge. We shall examine in Section 5 one such endogenous model where externalities due to investment are incorporated. To extend the Solow model we assume that *g* in (9) is a function of the *Z* variables, so that:

$$A_t = A_0 e^{(g_0 + g_i Z_{it})t} \quad i = 1.....n \qquad (10)$$

The advantage of this extension is that it is relatively easy to estimate and examine the significance of permanent growth effects of Z_i with country specific time series data. In equation (10) the rate of growth of technical progress is: $g = g_0 + \sum g_i Z_i \quad i = 1...n$, where g_0 captures the effects of the neglected but trended variables. Thus the long run growth rate depends, besides trend, on the level of the Z_i variables, as in the endogenous models. The coefficients $g_i \quad i = 0...n$, should be significant if the Z_i variables, the trended and excluded variables have externalities.[14]

In practice it is not possible to include more than a handful of crucial variables as Z_i in country specific time series studies due to limited sample sizes and possible multicolinearity among these variables. The growth enhancing variables we use are: trade openness measured as the ratio of exports plus imports to GDP (*TRAT)*, the share of government expenditure to GDP (*GRAT*), ratio of investment to GDP (*IRAT*) and human capital (*HK).* Data for Singapore, Malaysia and Thailand from 1970 to 2004 are used.[15] All these variables are considered to be important for the high

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[14] 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 much better.

[15] The sources of data are: UN database is used for output, investment, government expenditure, 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. Capital

growth rates experienced by these East Asian countries. *HK* is included because some endogenous models based on the canonical Romer (1986) model argue that investment alone 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 endogenous models that growth rates do not increase with increases in levels of expenditure on R&D etc. Among our variables the *IRAT* cannot increase indefinitely and *GRA*T cannot increase or decrease forever. Our empirical results show that the permanent growth effects of these variables are 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, we also find that the growth effect of *TRAT* is nonlinear in Singapore and seems to converge to an upper limit. But, there is no strong support for this in Malaysia and Thailand. 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 equation (10). We shall use the Hendry (2000) general to specific approach (*GETS*) for estimation of (10). Hendry (2000), Hendry and Krolzig (2005) and Rao, Singh and Kumar (2009) explain the advantages of *GETS* over other time series methods. Furthermore, *GETS* seems to be the only method where the cointegrating equation can be estimated with constraints on the coefficients and the cointegration equation and the dynamics are estimated in one step. 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 on 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:[16]

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stock is estimated with the perpetual inventory method with data on capital formation from the UN Database.

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

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

4. Empirical Results

All the variables are tested for unit roots using the *ADF* and the generalised Elliot, Rothenberg and Stock (1992, ERS) *DFGLS* 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 authors. Strictly speaking a time series interpretation for *GETS* is not necessary because *GETS* formulations can be estimated with the classical methods; see Rao, Singh and Kumar (2009). For this reason we shall not use the Ericsson and McKinnon (2002) test for cointegration of the *GETS* equations. Estimates of (11), using the nonlinear two stage instrumental variable method (*2SLSIV*), for Singapore are given in Table-1 and for Malaysia and Thailand in Table-2. *2SLSIV* is used to minimise the endogenous variable bias because contemporary changes in the variables are retained in some equations. The choice of instrumental variables is controversial and as Frankel (2003) observes, in the context of cross country studies, the quality of instrumental variables is largely in the eye of the beholder. However, this observation is less applicable to time series studies. We have selected the lagged values of the variables as instruments and applied a Sargan test to validate these instruments. Estimates for equations (6) and (10) for Singapore are reported in columns1 and 2 of Table-1 - equation (I) and equation (II) respectively. Equations (III) and (IV) are estimates of variants of (II). All these equations are well specified but equation (IV) with the nonlinear effects for *TRAT* appears to be the best.

In equation (I) all the estimated coefficients are significant at the 5% or 10% levels. The χ^2 tests on the residuals show that there is no serial correlation or misspecification. The residuals are normally distributed and the Sargan test indicates that the choice of instruments is appropriate. However, its $\bar{R}^2 = 0.22$ is low. The estimate of the share of profits α is 0.211, somewhat lower than its stylised value of one third. The coefficient on the trend variable indicates that *TFP* is almost 4% per year in Singapore.

Estimates of our extended production function in (II) explain 63% of the variation in the dependent variable compared to 22% in (I). The χ^2 statistics on the residuals are as good as in equation (I). The estimate on the share of profits is significant and close to the stylised value of one third. However, the coefficient on the trend variable is insignificant and the coefficient on *HK* is significant only at the 10% level. All other coefficients are significant at the 5% level and have the expected signs. The insignificance of the trend term is not unexpected because *TRAT*, *GRAT*, *IRAT* and *HK* seem to adequately explain *TFP*.

The estimates for equation (III) are the constrained version of (II). The coefficients on *IRAT* and *HK* are constrained to be equal. These two coefficients are very close to one another in equation (II). The Wald test does not reject the null hypothesis that these two coefficients are equal and also that the coefficient on the trend variable is zero. Therefore, (III) is a reestimate of (II) with these two constraints. There is a slight improvement in the $\bar{R}^2$ due a small increase in the degrees of freedom. All the summary statistics and estimates are similar 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 a 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.

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 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.

Equation (IV) is a reestimate of (III) to examine if the effects of *TRAT* are nonlinear and converge to a maximum. The $\bar{R}^2$ of this equation is marginally higher than (III) and all of the 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 close to 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 1970s decade is 1.40% and it increases to 2.12% by the end of the 1980s decade. This has further increased to an average of 2.60% in the decade of the 1990s and slows down slightly to an average of 2.5% during 2000-2004. These are shown 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 due to the nonlinearity. But *TRAT* has also some transitory short run growth effects because the coefficient on $\Delta TRAT$ is positive and significant.

An increase in *IRAT* has only small long run but larger transitory short run growth effects through its effects on $\Delta \ln k$. This can be explained as follows. The mean *IRAT* during 2000-2004 is 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 percent points implying that if the economy is growing at a *SSGR* of 2.5%, 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.[17] These computations do not make clear the dynamics of

[17] 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. It is also assume that employment is constant during the 2 periods. The above can be expressed as:

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.

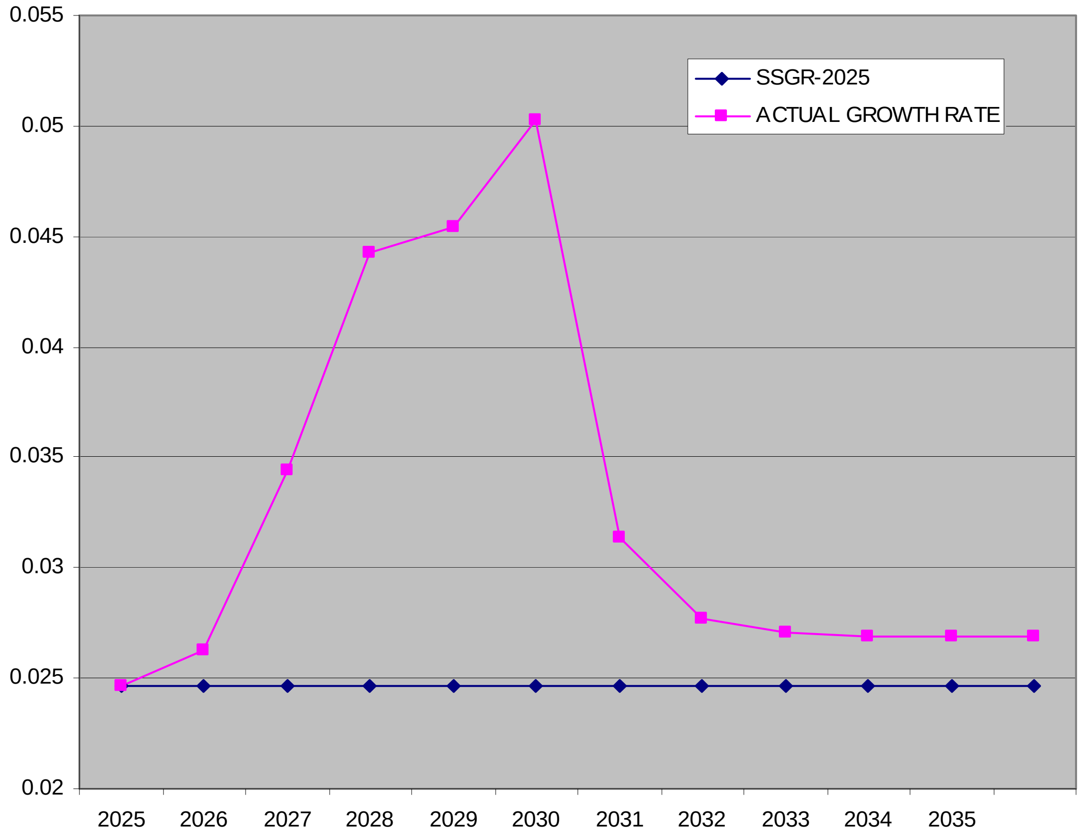
The time profile of the dynamics of the growth rate can be estimated by simulating equation (IV). We perform this dynamic simulation exercise with some simplifications. Instead of assuming that *IRAT* increases suddenly by 11 points in one year, we assumed that this increase is gradual over 4 years. 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 until 2035 is 3.34% per year and the new *SSGR* after 25 periods is 2.69%. Thus the permanent increase in the *SSGR* is 0.22 percentage points. However, the actual growth rate significantly exceeds the *SSGR* of 2.47% for about 11 years before it reaches its new *SSGR* of 2.69%. It reaches a maximum of 5% after 5 periods in 2025. The time profile of the dynamics of the growth rate is illustrated in Figure-1. These transitional growth effects, measured as the difference between the actual growth rate and the initial *SSGR*, are country specific and may differ between countries. For example in a country at its early stage of development, *IRAT* may have larger external effects and therefore the transitional growth effects may be larger. On the other hand these effects will be smaller if investments are made inefficiently.

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

The average value during 2000-2004 of capital to output 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 a 0.056 point increase in short run growth.

Figure-1

Dynamics of Actual Growth Rate



Selected estimates of equations for Malaysia and Thailand are reported in Table-2. The specifications estimated for these two countries are variants of the specification in column 2 of Table-1 for Singapore. Equations (I), (II) and (III) are for Malaysia and (IV) is for Thailand. Equation (I) 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 Δ*IRAT*. Equation (II) is a constrained estimate of (I) with the constraints that the coefficients of the trend term, *GRAT* and *HK* are zero. The Wald test does not reject these constraints and this has improved the significance of the remaining coefficients. All the coefficients are significant now at the 5% or the 10% levels and the estimated share of profits is closer to the stylised value of one third. In equation (III) *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 (II).

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 trend coefficient 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 (IV) 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 trend coefficient is higher because these are trended variables. This equation implies that *GRAT* seems to have strong negative effects on growth of Thailand compared to Singapore and Malaysia.

The sample period and decade averages of the *SSGRs* for these two countries and also for Singapore are given for comparison in Table-3. In both Malaysia and Thailand the *SSGRs* for the entire sample period are lower, at about 1% and 1.5% respectively, than 2% for Singapore. However, the sub-sample period comparisons show some improvement in Malaysia and some deterioration in Thailand. In Malaysia there has been a small improvement in the *SSGR* until the end of the 1990s and has stabilised in 2000-2004 at 1.5%. In Thailand the *SSGR* during the 1970s is 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 affected Thailand and subsequent political instability.

Table-2

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

	I Malaysia	II Malaysia	III Malaysia	IV 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 [0.106]	16.160 [0.135]	16.259 [0.132]	11.294 [0.256]
SEE	0.020	0.019	0.019	0.017
$\chi^2(sc)$	0.712 [0.399]	0.798 [0.372]	0.748 [0.387]	2.720 [0.099]
$\chi^2(ff)$	0.255 [0.613]	1.708 [0.191]	1.729 [0.189]	0.276 [0.599]
$\chi^2(n)$	.465 [0.792]	1.754 [0.416]	1.699 [0.427]	1.954 [0.376]

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

Table-3

Estimates of *SSGRs* and Actual Mean Growth Rates

	SGP	MYS	THA
1970-79 [Actual Growth]	1.40 [5.35]	0 .8 [5.93]	1.46 [3.54]
1980-89 [Actual Growth]	2.12 [4.31]	1.00 [2.24]	1.20 [3.79]
1990-99 [Actual Growth]	2.60 [4.20]	1.50 [3.79]	1.90 [4.01]
2000-04	2.50 [2.52]	1.50 [2.03]	1.50 [3.60]
1970-04 [Actual Growth]	2.14 [4.31]	1.15 [3.64]	1.53 [3.71]
Growth Effect of Change in *IRAT* $\Delta IRAT = 0.11$			
	SGP	MYS	THA
Long run: $\Delta SSGR$	0.2	0.2	0.3
Short run growth effects	5.6	2.5	7.4

Notes: Average actual growth rates are in the square brackets below *SSGRs.*

A comparison of the actual growth rates (shown in the square brackets below the *SSGRs*) with the *SSGR*s indicate that a substantial proportion of the actual growth rate of these countries is due to the transitory dynamic effects of improvements in growth enhancing variables. However, their permanent growth effects are small.[18]

[18] For the entire sample period permanent and transitory growth effects are roughly equal in Singapore at about 50% each. For Malaysia and Thailand the proportion of the transitory growth effects are, respectively, 68.4% and 58.8%. However, by 2000-2004, the proportion of the transitory growth effects seem to have declined significantly in Singapore and Malaysia. Singapore is growing near its *SSGR* and in Malaysia the significance of the transitory growth rate has declined to 25%. However, in Thailand and there is no significant improvement.

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. The *SSGR* will increase from 1.5% to 1.7%. In Thailand the income will grow from an average of 3.6% in 2000-2004 to 11.2% of which 7.4% is the short run effect and 0.3 percentage points is the long run effect. The *SSGR* will increase from 1.5% to 1.8%. A dynamic simulation, similar to Singapore, for these two countries is beyond the scope of the present paper. It is reasonable to expect the dynamic pattern of growth for 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 11 point increase in *IRAT* caused at the most only a 0.3 percentage point increase in the *SSGR* of Thailand. This is significantly less than the 3% effect found by De Long and Summers (1991) based on a cross country approach.[19] They disaggregated *IRAT* and found that only investment in plant and equipment has such high growth effects. In fact the non-equipment investment ratio has a zero or even negative effect on the growth rate. Besides this, as we mention earlier, measuring the rate of growth even with 20 or even more years is not a good proxy for the unobservable long run growth rate and may overestimate the growth effects of variables such as *IRAT*. For example, when we regress 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 1.5 which is 7.5 times more than our estimate for Singapore with our specification.

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 growth rate in Singapore exceeds its *SSGR* of 2.5% by as much as 2% points during 3 periods. Our results imply that increasing the growth rate by increasing the investment rate is an effective growth policy for the short to medium

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

terms. Needless to say policy makers of the developing countries will find this result attractive. But the long run growth effects of *IRAT* are modest and this needs further examination with disaggregated data on investment because they may have different growth effects. For long run growth policies the findings of cross country studies that the fundamental growth determinants are openness, institutions and geography are also worth pursuing.[20]

5. Endogenous Models

As already noted endogenous growth models are of limited use for policy makers of the developing countries because their main purpose is to show theoretically that in a model with optimising agents, endogenous factors can cause sustainable growth of per capita income in the long run. The theoretical arguments of these models are important because they imply that it is possible to improve the growth rate through policies by influencing the decisions of households and firms. In contrast the Solow model has also policy implications for increasing the level of income and growth rate during the transition period. Furthermore, Senhadji (2000) has illustrated how the Solow (1956 and 1957) model can be used to identify key factors to improving the long run growth rate. Our extension to the Solow model is similar to his approach and it is relatively easy to estimate. Against this backdrop we briefly examine some problems in estimating a well specified endogenous growth model and its use 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) shows how externalities due to investment lead to a sustainable positive growth of income. Greiner and Semmler (2002) were 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

[20] On the controversy about these fundamental determinants of long run growth see Frankel (2003) which are more tempered than some critical views expressed by others in their comments on Bosworth and Collins (2003). Openness also offers opportunities for learning by doing and may have large permanent growth effects.

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, the rate of social return will be higher than the competitive private return. The stronger are these 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 financing 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 in a similar manner to show that the long run growth rate can be increased through policies to increase the levels of other growth improving variables such as education, health, R&D activity, institutional reforms to improve legal, political and economic environment 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 potential candidate in the empirical studies on growth. This explains why Durlauf, Johnson, and Temple (2005) have found that many different growth improving variables are selected in the empirical models. The concerns of Easterly, Levine and Roodman (2004) on the use of arbitrary specifications and lack of reference to any theoretical model are true because it is hard to estimate structural theoretical endogenous models. Theoretical endogenous models, in principle, help to compute the gap between the competitive and socially optimal returns of a potentially growth enhancing variable such as investment. The relationship between the long run growth rate and the level of the growth improving variable can also be derived and these results may be used by policy makers if it is easy to estimate fully specified endogenous models. But as we shall see, there are difficulties in estimating these models.

The competitive solution of an endogenous model depends in a complex manner on the parameters of the intertemporal utility and production functions besides the equilibrium conditions and constraints in the optimisation model. Consider the following results from a model of the Greiner and Semmler (2002). Their specifications of the inter-temporal Cobb-Douglas production (Y), the CRRA consumption (C) function 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.

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

$$U_t = \frac{C_t^{1-\xi}}{1-\xi} + \frac{C_t^{1-\xi}}{(1-\xi)((1+\rho)} \; \dots \qquad (13)$$

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

$$\dot{K} = I - \delta K \qquad (16)$$

where $u =$ time spent on work, $L =$ labour, held constant and normalised as unity, $\xi =$ is the risk averse coefficient in the CRRA utility function in which the inverse yields the elasticity of intertemporal substitution, $\rho =$ time preference rate, $\delta =$ depreciation rate of K and $\eta =$ depreciation rate of A. A dot on the variable indicates its rate of change. Note that the production function is transformed into per worker terms although Greiner and Semmler do not change their notation. The solution to the model is as follows:

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

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

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

where the asterisk for u indicates that it is given and a constant. There are some problems in estimating these structural equations in (17) to (19).There are not enough restrictions to identify all the parameters. Further, data on the unobservable stock of knowledge A has to be estimated with the perpetual inventory method as 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 is useful but the important parameter concerning the scale effects of investment, $(\varphi(u^{*}))$, is assumed 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 as part of 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 limitations Albelo and Manresa (2005) have used calibration methods by making plausible assumptions about all the parameters in their model. They use this model to show that if 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 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. Nevertheless, endogenous models are useful to identify a few fundamental determinants of long run growth and to prudently select some of these variable for estimation with our extended Solow model.

[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.

5. Conclusions

This study examines the 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 long term growth effects, policy makers of the developing countries wish to know the short and medium term consequences of policies on the growth rate. It is suggested, therefore, there is a need to distinguish between the short and long rum effects of policies. We have shown that the Solow (1956) model can be extended and used to examine the dynamic growth effects of policies both in the short and long run. We estimate the extended Solow model with data from Singapore, Malaysia and Thailand to estimate the growth effects of variables such as the investment ratio, trade openness, the ratio of government expenditure to GDP and human capital. We specifically examine the effects of the investment ratio and find that it has significant short run growth effects and they persist for about 10 years in Singapore. These short run effects, though transient, are much larger than the long run effects. Because this distinction cannot be identified in cross country empirical studies, these studies seem to have overestimated the long run growth effects of variables such as the investment ratio. A finding that is of interest to the East Asian countries is that their high growth rates seem to be due to the relatively large transitory growth effects of variables like the investment ratio. Their long run growth rates or the *SSGRs* seem to be modest. Our finding that the long run growth effects of investment ratio are small is consistent with the general view (based on cross country studies) that there may be a few more fundamental variables that may have larger effects on the long run growth. For example Acemoglu, Johnson, Robinson and Thaicharoen (2003) find that institutions are more powerful than macro economic policies in explaining long run growth. Nevertheless, our paper suggests that macro policies are likely to be useful in increasing the growth rates in the short to medium term. Such policies are attractive and meet the immediate needs of policy makers of the developing countries. Further, these policies, if successful, offer opportunities to implement the more difficult long run growth policies such as institutional reforms.

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 used in empirical studies. However, our framework can be easily extended to include additional variables subject to the availability of data. In particular, the inclusion of variables that proxy the quality of institutions may reduce the significance of the variables we have selected. But it is likely that the variance in the institutional variables will be small in country specific time series data compared to cross country data.[22] 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 time series econometrics and used *GETS* with the classical methods of estimation. Nevertheless, the t-ratios of the adjustment coefficient λ of the preferred equations for Singapore and Malaysia exceed the critical values of Ericsson and McKinnon (2002) for cointegration. The equation for Thailand fails this test.

Despite 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 economies. Hopefully other investigators will further narrow the gap between the academic nature of growth research and the needs of policy makers in the developing economies.

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[22] Furthermore, changes in the institutional structure are usually sudden after a war, an upheaval and at the time of independence of a country; see Frankel (2003).

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