Estimates of the Steady State Growth Rates for Selected Asian Countries with an Extended Solow Model

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Abstract

This paper develops an extended version of the Solow (1956) growth model in which total factor productivity is assumed a function of two important externalities viz., learning by doing and openness to trade. Using this framework we show that these externalities have played an important role to improve the long run growth rats of six Asian countries viz., Singapore, Malaysia, Thailand, Hong Kong, Korea and the Philippines. A few broad policies to improve their long run growth rates are suggested.

JEL Classification: N1, O1, O4, O11

Keywords: Solow Growth Model, Endogenous Growth, Learning by Doing, Trade Openness, Steady State Growth Rate, Newly Developing Asian Countries.

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> "In a world full of countries desperately trying to get richer, the winners become influential models for the rest. But exactly what is it that accounts for their success? This isn't merely an abstract academic debate. The consensus tends to get built into the policies of dozens of ambitious countries, affecting patterns of world trade and much else." *Washington Post,* quoted by Sarel (1995).

1 Introduction

Endogenous growth models (ENGMs) are useful for answering two important policy questions: What are some potential factors on which the long run or the steady state growth rate (SSGR hereafter) may depend and whether the SSGR can be improved through policy. From a policy perspective, therefore, ENGMs are more attractive than the Solow (1956) model in which SSGR equals total factor productivity (TFP) and TFP is assumed to be exogenous and trend dependent. Although there is a large volume of cross-country empirical work with ENGMs to gain insights into growth policies, empirical work with country specific time series data is limited and use *ad hoc* specifications. Even in the cross section empirical works these specification weaknesses are common. Often they regress the annual growth rate of output on a few selected variables which the investigators believe to be important. The scope for an arbitrary selection of these growth enhancing variables is large because, as noted by Hoover and Perez (2004), the list of these growth improving variables, in the empirical work with the ENGMs, is more than 80. Easterly, Levine and Roodman (2004, p.774), commenting on the *ad hoc* nature of specifications in the empirical growth literature, have observed that

> "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."

Besides this, there is also another hither to neglected weakness. It is hard to accept that the dependent variable i.e., SSGR, which many empirical works aim and claim to explain, can satisfactorily be proxied with the annual growth rate of output or even with its averages over short panels of 3 to 5 years. Conceptually SSGR is similar in importance to country specific estimates of the natural rate of unemployment. Both are long run variables and unobservable. They have to be derived from the estimates of appropriate non-steady state models after imposing the steady state conditions.

Since estimates of country specific SSGRs and their determinants are important for growth policies, this paper develops a framework and estimates SSGRs for six newly industrializing Asian countries. Although in principle it is possible to estimate country specific SSGRs with an ENGM, the econometric problems in estimating a set of non-linear dynamic equations are considerable. To overcome some of these econometric problems Greiner, Semler and Gong (2004) have discarded the scale effect in ENGMs, which is an important property of these models.[1] Some studies, instead of estimating the structural parameters of the ENGMs, have used plausible *a priori* values for them to compute the effects of policies on SSGR with the calibration methods; for recent examples see Albelo and Manresa (2005) and Sequeira (2008).

In this paper we develop a simpler and alternative framework to estimate SSGRs. Our approach, based on an extension to the exogenous growth model of Solow (1956), can be justified on two grounds. Firstly, there is no clear cut evidence that the more demanding ENGMs can explain observed facts better than the simpler Solow model.[2] Secondly, our method is attractive to many applied economists to get quick insights into policies to improve the long run growth rate. It is relatively simple to estimate especially with the country specific time series data.

The structure of this paper is as follows. Section 2 discusses our extensions to the Solow model and develops our specifications. Empirical results and estimates of the SSGR are discussed and presented first for Singapore in Section 3 because the cointegration test results

[1] To the best of our knowledge Greiner et.al (2004) is the only systematic empirical work on various ENGMs. This work also discusses some important methodological issues concerning the relative merits of country specific time series studies over cross-country studies. See also Greiner (2008).

[2] Jones (1995) is the earliest to examine how well ENGMs can explain some observed facts with country specific time series data. He has estimated VAR equations for the USA and the OECD countries and found that there is no evidence that the rate of growth of output increased proportionately with increases in the expenditure on some growth improving factors like R&D and investment ratios etc. Subsequently Kocherlakota and Kei-Mu Yi (1996) have used US data and found that only investment on non-military equipment and non-military structural investment have had small effects on the long-run growth rate. Chao-Hsi Huang (2002) has applied the Kocherlakota and Kei-Mu Yi approach to 11 Asian countries and found no support for ENGMs. More recently Lau (2008) has used an indirect method to test the validity of ENGMs. He examined whether temporary or permanent changes to investment ratio have any permanent effects on output (and by implication its growth rate) in four industrialized countries viz., France, Italy, Japan and the UK. His results are unfavorable to ENGMs.

are very robust for this country. To conserve space, insights from analyzing the Singapore data are used in Section 4 to estimate and derive SSGRs for 5 other Asian countries viz., Malaysia, Hong Kong, Korea, the Philippines and Thailand. Section 5 presents estimates of SSGRs with alternative assumptions about the share of profits and examines the sensitivity of the earlier results. Finally, Section 6 concludes.

2 Specification

Our extension to the Solow (1956) model assumes that total factor productivity (TFP) depends on two important externalities which considerably simplifies estimation. These externalities are *manna from heaven* type and do not need additional investments by firms. Similar externalities are also discussed by Rebelo (1991) and Romer (1986). Two examples of these externalities are learning by doing (LBD) of Arrow (1962) and openness of trade (TRADE).[3]

LBD and TRADE are especially important for the newly industrializing countries because they can increase TFP (therefore SSGR in the Solow model) by increasing assimilation of existing technologies from the industrialized countries without the need to incur by firms additional R&D expenditure. In much of the controversy on the East Asia growth miracle–started by the seminal work of Young (1995), known also as the assimilation versus accumulation controversy–the potential assimilation effects through the accumulation of capital have been ignored.[4] Accumulation of capital is likely to have significant effects on TFP and SSGR through LBD.

An important feature of our approach is that while at the firm level there are constant returns to scale, at the aggregate level there may be increasing returns. This preserves the assumption of perfect competition in the product markets. Let the Cobb-Douglas production function with constant returns for a *representative* firm i and with the assumption that TFP at the firm level depends on the aggregate

[3]In Baily's (2001) interview of Romer, for the Reason magazine, he stresses the importance of some *manna from heaven* externalities by citing the example of how the same size lids for coffee cups has saved significant time.

[4]Frankel (1997) and Sarel (1995) summarized this controversy with a list of potential determinants of TFP. High ratios of exports and investment are considered to be important, but there is no quantitative evidence on their significance. Sarel also discussed reverse causality, i.e., high growth rates causing high ratios of exports and investment, but without resolving this issue. At the end of this prolonged debate the quantitative significance of various factors that caused the East Asian Growth Miracle remain unresolved.

capital stock be:

$$Y_{it} = K_{it}^{\alpha}(A_{it}L_{it})^{(1-\alpha)}\epsilon_{it} \quad (1)$$
$$A_{it} = B_t K_t^{\phi} \qquad \text{where } \phi \geq 0 \quad (2)$$

where Y is output, K is capital, L is employment and ϵ is an error term such that $ln(\epsilon_i) \sim N(0, \sigma^2)$. B here stands for the stock of knowledge which depends on autonomous factors. Therefore, ΔlnB is the rate of growth of autonomous TFP. B can be assumed to be constant ($\Delta lnB = 0$) or to grow at a constant autonomous rate of g i.e.,

$$B_t = B_0 e^{gt} \quad (3)$$

where B_0 is the initial stock of knowledge. ΔlnB thus captures the effects of other missing and trended variables affecting A and similar to A in the Solow (1956) model. Substituting (3) for A in (2) gives, through aggregation, the aggregate production function.[5]

$$\begin{aligned} Y_t &= K_t^{(\alpha+\phi(1-\alpha))}(B_t L_t)^{(1-\alpha)} \\ &= B_0^{1-\alpha} e^{g_t(1-\alpha)} K_t^{(\alpha+\phi(1-\alpha))} L_t^{(1-\alpha)} \epsilon_t \quad (4) \end{aligned}$$

where $\epsilon = \sqrt[n]{(\Pi_1^n \epsilon_i)}$ and $ln(\epsilon) \sim N(0, \sigma^2)$. In equation (4) when $\phi = 0$ there are constant returns at the aggregate level. Otherwise returns to scale are $\alpha + (1-\alpha)(1+\phi) > 1$.[6]

Alternative assumptions about A are possible. For example, if A depends on other factors with externalities, besides K, such factors can also be included. If trade openness (TRADE) has an externality, which is important for the East Asian countries, A may be specified as:

$$A_t = B_0 K_t^{\phi_1}\ TRADE_t^{\phi_2} \quad (5)$$

or

$$= B_0 e^{(g_1 + g_2 TRADE_t)\times t}\ K_t^{\phi} \quad (6)$$

[5]To estimate the aggregate production function it is necessary to measure the variables as geometric means i.e., $lnY = (1/n)\sum lnY_i$ etc. However, such aggregate data are not available. When the aggregate variables are summations, strictly speaking an aggregate production function exists only if the production function is separable. But neither the CD nor CES production functions are separable. Therefore, the *representative firm* assumption and the assumption that factors of production are perfectly mobile between firms are necessary.

[6]A characteristic of some ENGMs is that capital has constant returns, whereas in our model this assumption is not retained.

In equation (6) TRADE increases permanently the growth rate whereas in (5) it has only permanent level effects.[7] Using the previous procedures, (5) gives the following production function:

$$Y_t = B_0^{1-\alpha} e^{g_t(1-\alpha)} TRADE_t^{[\phi_2(1-\alpha)]}\; K_t^{(\alpha+\phi_1(1-\alpha))}\; L_t^{(1-\alpha)} \tag{7}$$

The production implied by (6) is

$$Y_t \;=\; B_0^{1-\alpha}\Big[e^{(1-\alpha)(g_1+g_2)\;TRADE_t}\Big] K_t^{(\alpha+\phi(1-\alpha))} L_t^{(1-\alpha)} \tag{8}$$

and this is the same as (4) except that g is computed as $(g_1+g_2\,TRADE)$. All the later derivations based on (4) hold for (8). These production functions also show the implied parameter restrictions.

2.1 Steady State Output and Growth Rate

For the derivation of the steady state output and its growth rate i.e., SSGR we shall use (4). There is a steady state solution only when $\phi <$ 1. If $\phi \geq 1$, there is no steady state because there are no diminishing returns to K and ΔK does not become zero, which is the definition of the steady state. Therefore, in the following derivations it is assumed that $\phi < 1$.[8]

Since B is similar to A in the standard Solow (1956) model, dividing Y and K with L and B gives $\tilde{y} = (Y/BL)$ and $\tilde{k} = (K/BL)$. Equation (4) can be expressed as:

$$\begin{aligned} \left(\frac{Y_t}{B_t L_t}\right) &= \left(\frac{K_t}{B_t L_t}\right)^{\alpha} K_t^{\phi(1-\alpha))} \\ \tilde{y}_t &= \tilde{k}_t^{\alpha+\phi(1-\alpha)}\Big(B_t L_t\Big)^{\phi(1-\alpha)} \end{aligned} \tag{9}$$

[7]Sarel (1995, p.14) supports the growth effect in equation (6). According to him

> "Among the many suggested determinants of growth in East Asia, the investment rate and the export orientation, in particular, are held in very high esteem. Frequently, they are called the 'engines of growth', meaning that these activities are considered not only to contribute directly to growth, but also to generate spill-over effects to the rest of the economy.

Furthermore, it is reasonable to say that whether a potential growth improving variable has permanent growth and/or level effects is an empirical issue.

[8]Furthermore, there is no empirical evidence for increasing or constant returns to capital. Greiner et. al. (2004) have to remove such scale effects in their empirical work. Jones (1995) also found that there is no evidence for increasing or constant returns even for knowledge capital (R&D expenditure).

The evolution of capital is also the same as in the Solow (1956) model, i.e.,

$$\frac{\Delta\tilde{k}_t}{\tilde{k}_t} = \frac{s\tilde{y}_t}{\tilde{k}_t} - \delta \tag{10}$$

where δ is the rate of depreciation. In equilibrium $(\Delta\tilde{k}/\tilde{k}) = 0$. Therefore, solving for the equilibrium value of $\tilde{k}$ and substituting into the production function in (9) gives the following steady state output.[9]

$$\tilde{y}^* = \left(\frac{s}{\delta + n + g}\right)^{\frac{\alpha+\phi\,(1-\alpha)}{(1-\alpha)(1-\phi)}} (BL)^{\frac{\phi}{1-\phi}} \tag{11}$$

From equation (11) we can solve for the steady state rate of growth of income per worker, noting that $(\Delta y/y) \equiv (\Delta\tilde{y}/\tilde{y}) + g$, where g is autonomous rate of growth of B.

$$\frac{\Delta y}{y} = \frac{g}{1-\phi} + \frac{\phi\, n}{1-\phi} \tag{12}$$

If $\phi = 0$ i.e., there are no externalities, the above growth rate reduces to the exogenous SSGR of g of the Solow model. The steady state output and growth equations when TFP depends on TRADE, as in equation (6), are the same as above, except that $g = g_1 + g_2 TRADE$. On the other hand if the externality due to TRADE has only level effects, as in equation (5), SSGR is:

$$\frac{g + \phi_1\, n \;+\; \phi_2\, \theta}{(1-\phi_1)} \tag{13}$$

where θ is the rate of growth of TRADE.

Since equations like (12) and (13) are steady state equations, they can be estimated with cross section data with 20 to 30 year average values of the variables which are better proxies of SSGR than annual

[9]Note that when $\phi = 0$ this equation reduces to the standard solution in the Solow model.

$$\tilde{y}^* = \left(\frac{s}{\delta + n + g}\right)^{\frac{\alpha}{1-\alpha}}$$

average rates of growth. Country specific annual time series data are not appropriate for estimating these steady state growth equations because a year long duration is inadequate for the economy to attain its steady state. However, annual time series data can be used to estimate the long run production functions with time series methods. Therefore, the SSGRs in equations (12) and (13) can be computed with the estimated parameters of the production functions.

For estimation purpose it is convenient to rearrange the production functions (4), (7) and (8), respectively, as follows.

$$\begin{aligned} lny_t &= (1-\alpha)lnB_0 + (1-\alpha)gt + [\alpha + \phi(1-\alpha)]lnk_t \\ &\quad +\phi(1-\alpha)lnL_t \qquad (14) \\ lny_t &= (1-\alpha)lnB_0 + (1-\alpha)gt + (1-\alpha)\phi_2 lnTRADE_t \\ &\quad +[\alpha + \phi_1(1-\alpha)]lnk_t \quad + \phi_1(1-\alpha)lnL_t \qquad (15) \\ lny_t &= (1-\alpha)lnB_0 + (1-\alpha)(g_1 + g_2 TRADE_t)t \\ &\quad +[\alpha + \phi(1-\alpha)]lnk_t \ + \phi(1-\alpha)lnL_t \qquad (16) \end{aligned}$$

where $y = (Y/L)$ and $k = (K/L)$.

In our empirical work, however, the specification in equation (16), where TRADE has a permanent growth effect, is found to be the best for all the six countries although for Korea it has been necessary to use a variant of (16) in which TRADE has non-linear effects.

3 Empirical Estimates for Singapore

In Table 1, three alternative estimates of the production function for Singapore are given. Singapore is first selected because the cointegration tests are more robust. Of the three specifications in equations (14), (15) and (16) the specification in (16), where TRADE has permanent growth effects, is found to be the best and gave plausible results. To conserve space, only the estimates of this equation and its variants are reported in Table 1. In Table 2 similar estimates of the specification in (16) are given for Malaysia, Thailand, Hong Kong, the Philippines and Korea. Data from 1970 to 2004 are used for estimation of these six countries. Definitions of the variables and sources of data are in the Appendix. The LSE-Hendry GETS technique, with the non-linear two stage instrumental variable method, is used to minimize endogenous variable bias and also to utilize the parameter restrictions.[10] The Ericsson and McKinnon (2003, EM hereafter) test is used to test for cointegration. All the variables are pre-tested, for Singapore, for unit roots with the ADF test. Except the log of capital per worker (lnk), other variables are found to be $I(1)$ in levels and $I(0)$ in their first differences. We have used two alternative unit root tests viz., KPSS, where the null is that the variable is stationary and the ERS test which has more power against the unit root null. These tests showed that lnk is $I(1)$ in levels and $I(0)$ in its first differences. Unit root tests for the other countries will be discussed in the next section.[11]

First, the standard CD production function, without externalities, is estimated for Singapore and the results are in column (1) of Table 1 as equation (I).[12] The final form with the current and lagged first differences of the variables is selected with the general to specific approach and with PcGETS software of Hendry and Krolzig (2001, 2005). The GETS specifications for the other equations in Table1 and Table 2 are similar and can be easily inferred by changing the error correction part. To conserve space these details are not reported. Equation (I) serves as the baseline equation for comparisons. The estimates of this equation are satisfactory in that all of its coefficients are correctly signed and significant at the 5% level, except Δk_{t-1} (not shown) which is significant at 10%. The summary χ^2 tests show that serial correlation (χ^2_{sc}), functional form misspecification (χ^2_{ff}), and non-normality in the residuals (χ^2_{nn}) are not significant at the 5% level. The Sargan test validates the selected instruments. The coefficient of trend, which is the SSGR in the Solow model, is about 4% and seems a bit high. The share of profits (α) at 0.21 seems a bit low. However, neither estimate is implausible.[13]

Estimates of the specifications in equations (14), without externalities due to TRADE and (15) in which both capital and TRADE

[10]See Rao (2008) and Rao, Singh and Kumar (2008) for the merits of the GETS approach.

[11]Details of these test results can be obtained from the author.

[12]The full GETS specification of this equation with the error correction term (ECM) in the square brackets is as follows:

$$\begin{aligned}\Delta y_t &= -\lambda[lny_{t-1} - (intercept + gt + \alpha k_{t-1})] \\ &\quad +\text{first differences of the variables and their lags.}\end{aligned}$$

whereλ is the speed of adjustment of the error correction process.

[13]The dynamic adjustment part, not reported to conserve space, consists of $\Delta lnk_t, \Delta lnk_{t-1}, \Delta lnL_t$ and Δlny_{t-1}. The instruments used are Intercept, Trend, $lny_{t-1}, \cdots lny_{t-4},\ lnk_{t-1}, \cdots lnk_{t-4},\ lnTRADE_{t-2},\ \Delta lnTRADE_{t-1}$

(level effects only) have externalities were disappointing in that the estimated share of profits (α) turned out to be low (about 0.1) and insignificant. Therefore, a grid search procedure is used for α in the range of 0.2 (as found in the baseline equation (I)) to 0.5. In this search procedure, estimates of equation (16) are found to be more satisfactory. In equations (14) and (15) one or another externality is found to be negative and/or insignificant. Estimates of the specification in equation (16) with the constraint that $\alpha = 0.24$ yielded the best results and are reported in column 2 as equation (II). Finally, since trend is insignificant in equation (II) this equation is re-estimated by constraining that the autonomous growth rate is zero and given as equation (III). The summary statistics of the two equations are good.

A comparison of the $\bar{R}^2$ of the standard Solow equation of about 0.5 with the other 2 equations of about 0.6 shows that these extended equations have an improved fit of 18%.[14] Furthermore, the EM cointegration test showed that the null of **no cointegration** can be rejected at the 5% level for the 2 extended equations. The sample size adjusted 5% absolute critical value (CV) for (II) is 4.269 and its test statistics given by the absolute t-ratios of λ exceed this CV. But the null of no cointegration is easily rejected for equation (I). Therefore, it can be said that the two equations (II) and (III) with externalities are

[14]Formal statistical tests, based on the Z test, showed that there is no significant difference between these correlation coefficients, unless these estimates hold in a sample of about 300. Since our sample size is small, it is not possible to say that the correlation coefficients of the 2 extended equations are significantly higher than equation (I) of the basic Solow model. However, asymptotically they are better.

preferable to the Solow equation in (I).[15]

[15] The estimate of equation (II), is not fully reported in Table-1 to avoid formatting problems. Only the estimates of crucial parameters are reported in Table 1. However, the full estimate of (II) is as follows:

$$\begin{aligned}\Delta lny_t &= \underset{(9.673)}{-0.676}\Big[lny_{t-1} - \Big(\underset{(0.265)}{2.734} - \underset{(5.122)}{0.002}\ T \\ &\quad \underset{(5.121)}{+0.113}\ TRATIO_{t-1}\ T + \underset{(c)}{0.24}\ lnk_{t-1} \\ &\quad \underset{(2.485)}{+0.239}\ (lnl_{t-1} + lnk_{t-1})\Big)\Big] \\ &\quad \underset{(2.996)}{+0.902}\Delta lnk_t + \underset{(3.224)}{0.132}\Delta TRATIO_t\end{aligned}$$

t-ratios are reported below the coefficients in the parentheses and the constrained coefficient estimate is indicated with (c). Estimates of (III), in which the autonomous growth rate is constrained to be zero, are similar with minor changes.

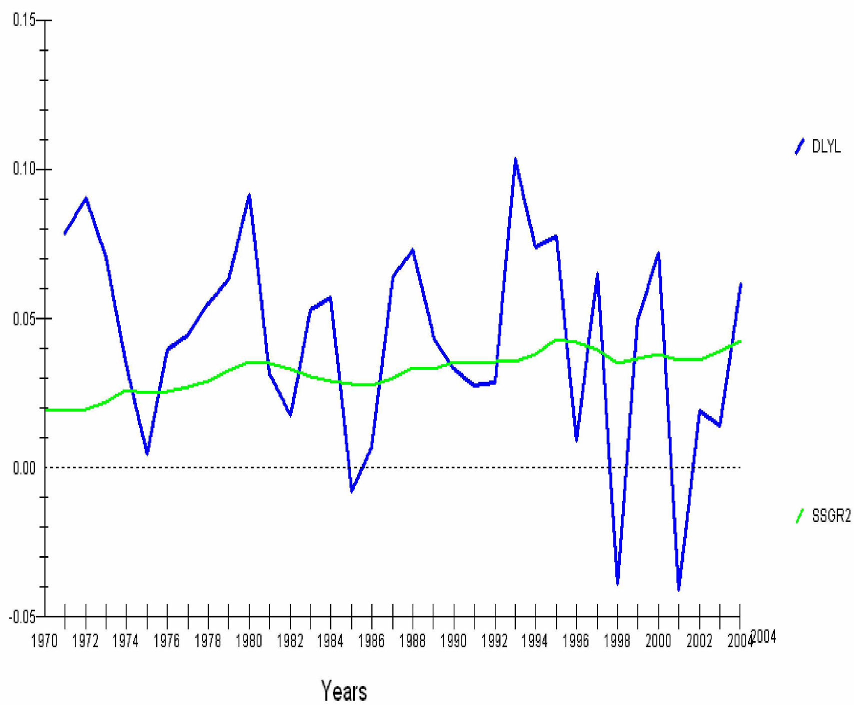
Table 1: Externalities in Singapore

Variable	(I)	(II)	(III)
Const.	7.271	2.734	3.084
	(12.21)*	(1.51)	(2.43)*
Trend	0.039		
	(35.89)*		
λ	-1.044	-0.676	-0.691
	(4.06)*	(9.67)*	(10.06)*
α	0.205	0.240	0.240
	(4.18)*	(c)	(c)
g_1		-0.002	
		(0.27)	
g_2		0.011	0.011
		(5.12)*	(6.89)*
ϕ		0.239	0.220
		(2.48)*	(3.35)*
$\overline{R^2}$	0.508	0.594	0.610
χ^2_{sc}	1.244	1.098	1.059
	(0.27)	(0.30)	(0.30)
χ^2_{ff}	2.473	0.020	0.032
	(0.12)	(0.82)	(0.86)
χ^2_{nn}	0.156	0.388	0.350
	(0.93)	(0.82)	(0.84)
$Sargan\ \chi^2$	1.344	2.615	2.759
	(0.85)	(0.86)	(0.91)

Notes: The t-ratios (White adjusted) are below the coefficients and p-values are below the χ^2 tests statistics. 5% and 10% significance are indicated with * and **, respectively. Constrained estimate is indicated with (c).

Among the 2 equations with externalities the estimate of equation (III) is marginally better because of the improved t-ratios of the coefficients due to a small increase in the degrees of freedom. The estimates of this equation imply that externalities due to openness and LBD are significant for Singapore. SSGR for Singapore is computed with the average values of TRADE and the rate of growth of employment and this is 3.3%; see equation (12) noting that $g = g_1 + g_2 TRADE$. Note that the autonomous growth rate (g_1) is zero. These findings are in contrast to the well known finding of Young (1995) that Singapore's TFP and therefore SSGR were negligible at 0.2% during 1966 to 1990. This may be due to the neglect of externalities by Young (1995) and a larger sample period in our estimates.

Figure 1: Steady State Growth of Singapore



The plot of SSGR for Singapore and the actual rate of growth of per worker output is in Figure 1. The values of SSGR are computed here with the actual values of TRADE and the rate of growth of employment, in contrast to with their average values in the previous paragraph.

It can seen that the SSGR has shown a mild upward trend until the financial crisis during 1996-1997. As Singapore has evolved from an underdeveloped to a newly industrialized country, its SSGR seems to have improved marginally. An OLS equation showed that the trend in SSGR is 0.0006 per year.

The contribution of LBD of 0.8 percentage points to SSGR is 24% of the estimated SSGR. The dominant contribution of 2.5 percentage points which is 76% of the SSGR is due to Singapore's trade openness policy. These findings for Singapore and the findings for the other countries (to be discussed shortly) are summarized in Table 3. Although SSGR is high in Singapore, a policy implication of our model is that there is scope for further improvements by improving LBD through on the job training schemes. A further 25% increase in the effectiveness of LBD programmes could increase Singapore's SSGR by another 0.5% points and this is not an insignificant improvement.

4 Other Asian Countries

We have estimated the specifications in equations (14) to (16) for Malaysia, Thailand, Hong Kong, Philippines and Korea. However, only the specification in (16), used for Singapore (in equations (II) and (III) of Table 1), gave plausible results for these countries. All the variables are tested for unit roots with ADF, KPSS and ERS tests. As for Singapore Δlnk was I(0) only in the KPSS and ERS tests for these 5 countries. ADF test showed that the remaining variables are all I(1) in levels and I(0) in their first differences.

The coefficient of trend, which is the autonomous growth rate, was also insignificant in these 5 countries. Therefore, in Table 2 only the constrained estimates, given in (III) of Table 1, are reported for these 5 countries as equations (IV) to (VIII). The share of profits has to be grid searched again and values around 0.24 gave the best results, except for Korea where the near stylized value of 0.3 gave plausible results. We also faced some convergence problems with the Korean data and eventually obtained good results after introducing non-linear effects for TRADE. In these 5 equations the summary χ^2 test statistics are insignificant and the EM cointegration test rejected the null hypothesis of **no cointegration**. The $\overline{R^2}$s are also satisfactory.

4.1 Malaysia

In equation (IV) for Malaysia the share of profits with grid search is 0.25. The estimates of the other parameters imply a SSGR of 1.5% which is half of Singapore's. The contribution of trade openness to SSGR at 1% points, which is also half of Singapore's, implies that Singapore has benefited more from production technologies and management techniques from its trading partners than Malaysia. Similarly ϕ at 0.13 indicates that the effectiness of LBD on Malaysia's SSGR is about 60% of its effectiveness in Singapore. The ratios of the contributions of trade and LBD to the SSGR, respectively, are 68% to 32%. Therefore, there is scope to improve Malaysia's SSGR through more effective LBD programmes. By increasing TRADE and LBD by 25% SSGR of this country can be improved by another 0.5% points from 1.5% to 2%.

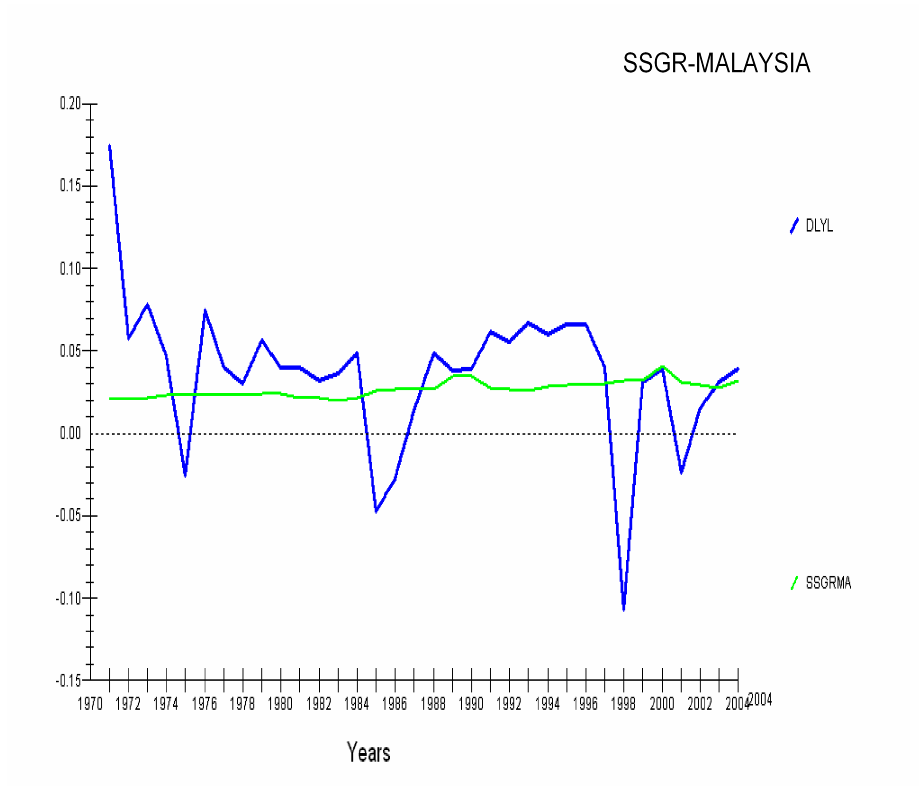
The average rate of growth of output per worker during 1970-2004 and 2000-2004 are, respectively, 3.6% and 2%, implying that currently Malaysia is not far from its SSGR of 1.5%. The plot of the actual rate of growth of output per worker and SSGR (computed with the actual values of TRADE and employment growth) is shown in Figure 2. There is a mild upward trend of 0.0004 in the SSGR which is encouraging for Malysia.

Table 2: Externalities in Other Asian Countries

Variable	(IV)	(V)	(VI)	(VII)	(VIII)
Const.	5.654	2.080	3.403		-4.188
	(10.19)*	(1.99)**	(5.35)*		(9.18)*
λ	-0.760	-0.506	-0.713	-0.371	-0.477
	(12.98)*	(6.42)*	(10.46)*	(3.23)*	(4.77)*
α	0.250	0.240	0.240	0.260	0.300
	(c)	(c)	(c)	(c)	(c)
g_2	0.006	0.012	0.004		0.006
	(10.66)*	(5.11)*	(6.80)*		(3.49)*
ϕ	0.132	0.285	0.292	0.357	0.289
	(6.14)*	(7.48)*	(12.26)*	(102.63)*	(11.16)*
$\overline{R^2}$	0.614	0.620	0.532	0.345	0.522
χ^2_{sc}	1.644	1.898	0.215	0.009	0.019
	(0.20)	(0.17)	(0.64)	(0.93)	(0.91)
χ^2_{ff}	1.719	11.733	0.048	0.151	2.545
	(0.19)	(0.00)*	(0.83)	(0.70)	(0.11)
χ^2_{nn}	0.448	2.916	0.150	0.224	3.762
	(0.80)	(0.23)	(0.93)	(0.89)	(0.15)
$Sargan\ \chi^2$	8.411	11.610	17.246	3.617	6.263
	(0.30)	(0.11)	(0.14)	(0.82)	(0.51)

Notes: The t-ratios for the coefficients and the p-values for the χ^2 tests are in parenthesis. 5% and 10% significance are indicated with * and **, respectively. Constrained estimate is indicated with (c).

Figure 2: Steady State Growth of Malaysia

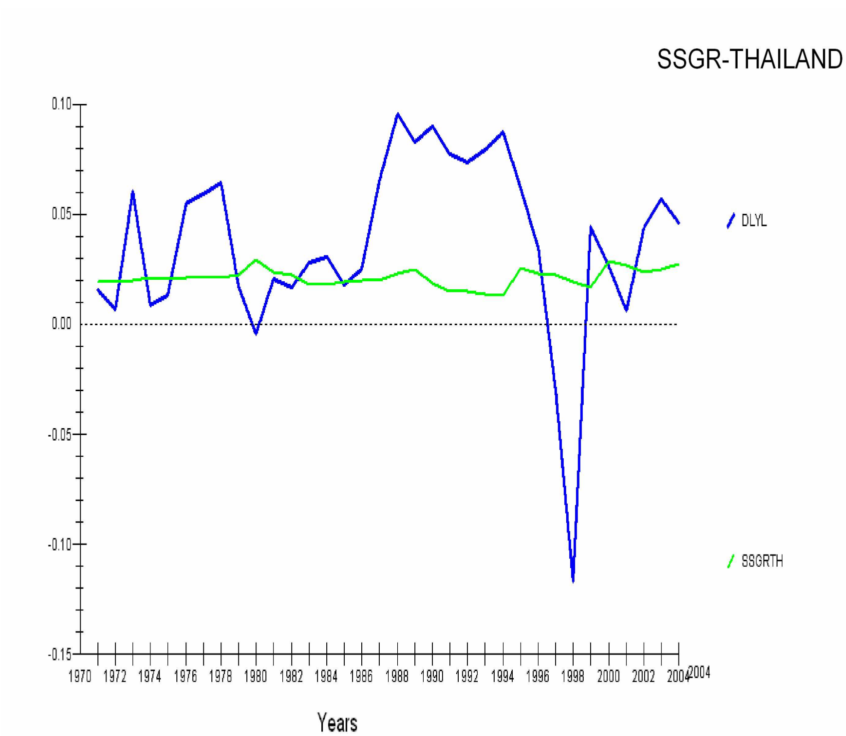


4.2 Thailand

The estimates for Thailand are in equation (V). A profit rate of 0.24 gave the best results. The computed parameters imply a SSGR of 2.3%. The contributions of LBD and TRADE to SSGR seem to be of equal importance, contributing about 1% points each to SSGR. To increase its SSGR by another 0.5 points to 2.8%, Thailand needs to introduce significantly more liberalized trade policies to increase the mean value of TRADE from about 0.7 to above 1.

The average rate of growth of output per worker is high at 3.7% during 1970-2004 and declined only marginally during 2000-2004 to 3.6%. Therefore, this country is growing above its SSGR mainly due to the transitory effects of increased investment ratio. Investment boom in Thailand started in the late 1980s and investment ratio reached near 50% until the Asian financial crisis in 1997-1998. During the investment boom period, the rate of growth of per worker income was as high as 10%. The SSGR for this country, with the actual values of TRADE and employment growth, and the actual rate of growth of per worker income is in Figure 3 and it shows a mild upward trend of about 0.0001.

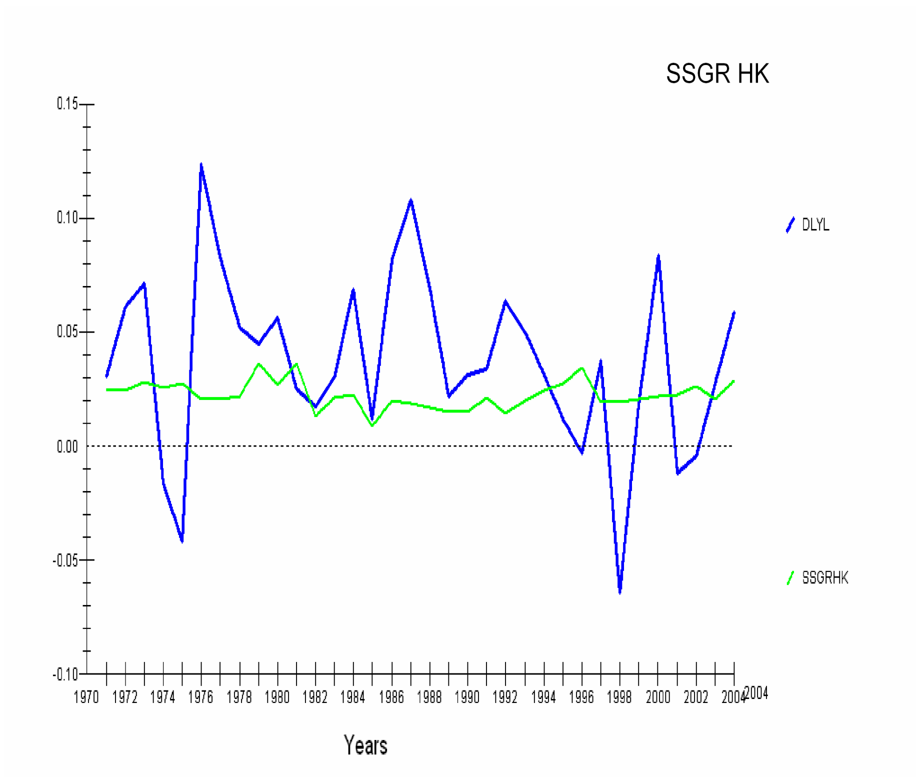
Figure 3: Steady State Growth of Thailand



4.3 Hong Kong

In Hong Kong a profit share of 0.24 worked well and estimates for this country are given in equation (VI) of Table 2. The implied SSGR is 2.4%. It can be seen from these estimates that the effect of TRADE and LBD on the SSGR are about equal. The average rate of growth of output per worker during 1970-2004 and 2000-2004 respectively are 3.7% and 3%,implying that Hong Kong is growing above its steady state growth rate. This may be due to some missing scale effects and/or due to the dynamic, but transient growth effects of the high investment rates in Hong Kong during the pre East Asian financial crisis. The average investment rate has been about 30% with an average annual increase of 0.1%. After the Asian financial crisis, the decline in the investment ratio was more modest compared a decline of 56.5% in Singapore.[16] Since trade openness is the highest in Hong Kong, where the mean value of TRADE is 2.280, its SSGR can be improved perhaps with more effective on the job training programmes to improve LBD. If ϕ can be increase by 25%, Hong Kong's SSGR can be increased to 3%. The SSGR for this country, with actual values of TRADE and employment growth, and the actual rate of growth of per worker income is in Figure 4. However, the SSGR showed a mild downward trend of -0.0001.

Figure 4: Steady State Growth of Hong Kong

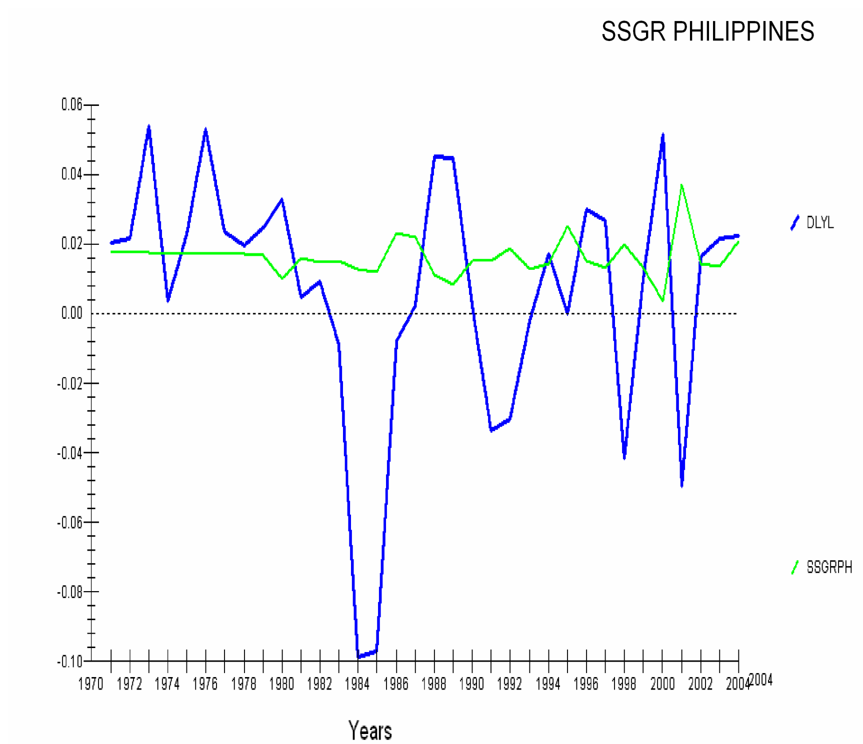


[16]The transient growth effects of changes in the investment ratio are not adequately recognized in empirical discussions. Simulations with the closed form solution of Sato (1963) show that such transient growth effects are significant and may last up to 20 to 25 periods.

4.4 The Philippines

Estimates for the Philippines are in equations (VII) of Table 2. The coefficient of TRADE, as well as the autonomous growth rate, in the specification of equation (16) were insignificant. Therefore (VII) is estimated with the constraints that g_1 and g_2 are zero. A profit share of 0.26 gave good results but the equation just passed the EM cointegration test at the 10% level. The absolute value of the t-ratio of λ of 3.23 just exceeds the absolute 10% CV in the EM test of 3.22.

Figure 5: Steady State Growth of the Philippines



Equation (VII) implies that Philippines' SSGR is 1.6% and it is entirely due to LBD. The average growth rate during 1970-2004 is 0.6% but this has doubled to 1.2% during 2000-2004. Yet this country seems to be growing below its SSGR. Such a low growth rate may be due to some negative externalities, especially due to the on and off political instability in this country. Therefore, we cannot claim that our results for the Philippines have adequately captured all the relevant externalities. Further work is necessary to draw definitive conclusions but it may be said that increased trade liberalization can make the coefficient of TRADE positive and significant. The SSGR for this country, with the actual values of employment growth, and output growth is in Figure 5. Like in Hong Kog there is a downward trend of -0.0002 in the SSGR.

4.5 Korea

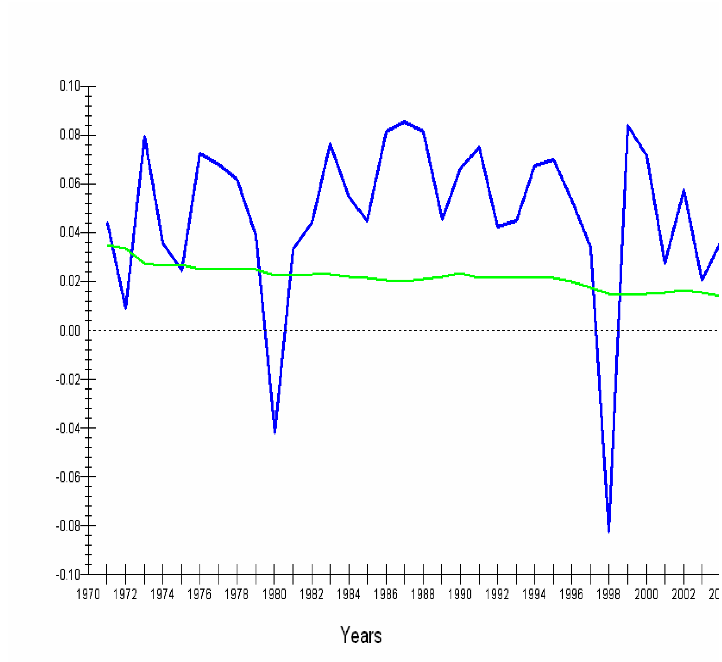
Finally, estimates for Korea are in equation (VIII) of Table 2. A profit share of 0.3 yielded good results and until the non-linear effects of trade were introduced the coefficient of TRADE remained insignificant. The non-linear effect is introduced with the inverse of the TRADE variable and implies that its growth effect on Korea's SSGR decreases as TRADE increases. The 5% level CV for the EM test is -4.269 and the estimated t-ratio of λ is -4.772. Therefore, there is cointegration in this equation. The computed SSGR is 2.24%, which is similar to that of Thailand and a full one percent point less than in Singapore. TRADE is the major contributor with 1.3% points to its SSGR which is about 60% of the computed SSGR. The actual average rate of growth of output at 4.7% is much higher than Korea's SSGR. Except during the late 1990s due to the financial crisis , from which Korea suffered most, Korea grew above its SSGR, due to the high rates of investment.

While Korea's trade openness has been increasing, its contribution to SSGR is declining. TRADE in 1970 was 0.34 and increased slowly to 0.84 by 2004. The decline in its effect on SSGR may be partly due to Korea's increasing reliance on domestic technologies and management practices.[17]

The declining trend in Korea's SSGR is shown in Figure 2 and seems to be due to two reasons. Firstly, as stated above, trade openness may not have played an effective role in the early stages of its development. As Korea became industrialized, protectionist pressures may have sheltered some inefficient domestic industries. Secondly, the SSGR shown in Figure-6 depends on the actual rate of growth of employment and this has declined in Korea from a high of 3.5% during the 1970s to less than 1% by 2000.

[17]There is some evidence that best technologies and management practices are not followed in Korea. There are impediments to exit and enter into industries which are used to insulate inefficient producers from market pressures; see Aw, Chung and Roberts (2003). There is also evidence to show that the mix of consumer goods changed to satisfy the domestic consumers and therefore seem to lack variety. During the early 1970s imports of consumer goods were slightly more than 20% and this has declined to less than 10% by the mid 1980s.

Figure 6: Steady State Growth of Korea



To increase SSGR by another 0.5% points there are two options. First, Korea may increase its absorption of efficient technologies and management practices from the advanced countries. Second, Korea could improve its LBD programmes say by another 25% to achieve an additional 0.5% point increase in its SSGR.

5 Alternative Estimates of SSGRs

Our findings in the previous section are based on values of α found through the grid search method. If the true value of this parameter equals its stylized value of one third, our grid search causes slight over estimation of ϕ when $\phi < 1$ which in fact is the case. Consequently, SSGRs will be also over estimated.[18]

To examine the sensitivity of the estimates of SSGRs and the relative importance of LBD and TRADE, we have re-estimated equation (III) for Singapore and equations (IV) to (VIII) for the other countries with the assumption that $\alpha = 0.33$. The details of these estimates are not reported to conserve space but summarized in Table 3.

[18] $\frac{\partial SSGR}{\partial \phi} = \frac{g+\phi n}{(1-\phi)^2} + \frac{n}{(1-\phi)} > 0 \quad for\ \phi < 1$. Note that SSGR is not defined at $\phi = 1$, but it declines with increasing values of ϕ when $\phi > 1$.

In the upper panel of Table 3, results with the estimated values of g_2, ϕ and α (with grid search) of equations (III) to (VIII) are reported. The lower panel shows estimates of g_2 and ϕ from equations (III) to (VIII) with the assumption that $\alpha = 0.33$. The mean values of TRADE and the rate of growth of employment are used to compute SSGRs in both panels.

Table 3: Externalities in the Asian Countries

Variable	SGP	MAL	THA	HKG	KOR	PHL
Average Δlny	0.043	0.036	0.037	0.037	0.047	0.006
Average (I/Y)	0.325	0.247	0.342	0.280	0.312	0.182
Average ΔlnL	0.028	0.032	0.023	0.023	0.021	0.029
α **(grid search)**	0.240	0.250	0.240	0.240	0.260	0.300
$\hat{g}$	0.011	0.006	0.012	0.004	0.006	0.000
$\hat{\phi}$	0.220	0.312	0.285	0.292	0.289	0.357
$\widehat{SSGR}$	0.032	0.015	0.023	0.024	0.022	0.016
Due to TRADE	75.63%	68.15%	51.56%	52.71%	61.61%	0.00%
Due to LBD	24.37%	31.85%	48.44%	47.29%	38.39%	100.00%
α **(stylized)**	0.330	0.330	0.330	0.330	0.330	0.330
$\hat{g}$	0.013	0.008	0.012	0.004	0.006	0.000
$\hat{\phi}$	0.153	0.058	0.242	0.242	0.265	0.352
$\widehat{SSGR}$	0.032	0.013	0.020	0.022	0.021	0.015
Due to TRADE	84.09%	85.40%	56.47%	58.90%	64.54%	0.00%
Due to LBD	15.91%	14.60%	43.53%	41.10%	35.46%	100.00%

As indicated above a comparison between the upper and lower panel values of SSGRs shows that they are slightly over estimated with the grid search method. For Singapore and the Philippines this difference is small at about 2% and for Korea slightly higher at 3.7%. SSGRs for Malaysia, Thailand and Hong Kong this difference higher by 11%. However, the relative importance of the contribution of TRADE and LBD to SSGRs qualitatively remains the same, but the need for Malaysia to improve LBD policies increases because its ϕ has now declined substantially from 0.132 to 0.058. Therefore, to increase

Malaysia's SSGR by 0.5% points from 1.5% to 2%, the effectiveness of its LBD programmes needs to be improved by more than 50%.

6 Conclusion

In this paper we showed that the Solow (1956) exogenous model can be extended and used to estimate country specific SSGRs which in turn can be used for growth policy. We showed how this can be achieved by estimating SSGRs for 6 Asian countries who benifited from two externalities viz., LBD and TRADE. Our results showed that these externalities are significant in these 6 newly industrializing Asian countries, with the exception of the Phillipines where only LBD is significant. We have computed the SSGRs for these 6 countries and examined policies needed to improve these long run growth rates. The estimated SSGRs ranged from about 3% for Singapore to a low of 1.5% for Malaysia and the Philippines. For Korea, Hong Kong and Thailand, SSGRs range from 2% to 2.5%. While the SSGRs for Singapore, Malaysia and Thailand showed a mild upward trend, in Hong Kong, Korea and the Philippines the trend is downwards.

While the effects of both LBD and TRADE are found to be generally important in all the six countries, trade openness seems to have played a relatively dominant role in the growth of Singapore, Malaysia and Korea. In contrast, Philippines seems to be a relatively closed economy and did not benefit from the potential externalities due to trade openness. However, LBD seems to be more important in the Philippines, Thailand, Hong Kong and Korea followed by Singapore. Its effectiveness is low in Malaysia.

There is scope to improve the low SSGRs especially in Malaysia and the Philippines. For example if LBD programmes are significantly improved, say by about 50%, in Malaysia its SSGR can be increased to about 2%. Similarly, if Philippines introduces trade liberalization policies and they are effective with the same intensity in Malaysia, its SSGR can be improved to about 2%. Both Thailand and Hong Kong also have some potential to increase their SSGRs. Thailand needs to liberalize trade to absorb more efficient technologies and management skills. Hong Kong needs to improve its LBD programmes. The need to improve the already high SSGR of 3% of Singapore seems to be less urgent. Perhaps Singapore may ensure that its high SSGR can be sustained.

Needless to say there are some limitations in our paper. First, the structure of our model is simple and ignores factors that may have significant externalities and that determine the SSGRs. Second, we could not estimate the profit share parameter and employed a grid search method. However, in our view this may not be a serious limitation in that the assumed values for this parameter do not deviate significantly from the stylized value of one third which is frequently used in the growth accounting exercises. When the stylized value of one third is used for α, our estimates of the SSGRs did not change much especially for Singapore, Korea and the Philippines. The changes in the SSGRs for Malaysia, Thailand and Hong Kong are in the third decimal place. Third, there are alternative proxies for LBD and trade openness and it is desirable to use them to examine the sensitivity of our results. However, this is beyond the scope of the current paper. Fourth, we cannot claim that our model has adequately captured all the relevant externalities. Nevertheless, since the coefficient of trend was insignificant in all the equations, we can make a modest claim that our approach has adequately captured the growth effects of the missing and trended growth improving variables. Finally, our model did not take into account externalities which need additional resources to improve TFP such as expenditure on R&D and education.[19] But the effects externalities due to R&D are perhaps not important for the developing countries. They can use the vast amount of technology that already exists in the advanced countries. Perhaps development policy makers would pay attention to the factors that are hindering the utilization of existing technologies.

We hope that our approach and empirical findings would be useful for further extensions to the Solow model to develop other policies to permanently increase the long run growth rates in the other developing countries. It would be also valuable to compare the results based on our approach with those based on the techniques of Greiner et. al. (2004) and simulations with the general equilibrium models of Albelo and Manresa (2005) and Sequeira (2008).

[19] Government investment on infrastructure is taken into account in our estimate of the capital stock.

Data Appendix

Y is the real GDP at constant 1990 prices (in million national currency). Data are from the UN National accounts database.

L is labour force or population in the working age group (15-64), whichever is available. Data obtained from the World Development Indicator CD-ROM 2002 and new WDI online.

URL:http://www.worldbank.org/data/onlinedatabases/onlinedatabases.html

K is real capital stock estimated with the perpetual inventory method with the assumption that the depreciation rate is 4%. The initial capital stock is 1.5 times the real GDP in 1969 (in million national currency). Investment data includes total investment on fixed capital from the national accounts. Data are from the UN National accounts database.

TRADE is computed as a ratio of exports and imports of goods and services on GDP. Data are obtained from UN's national accounts.

Investment ratio is computed as the ratio of total nominal investment to nominal GDP. Data are obtained from UN's national accounts.

References

Albelo, C. A. and Manresa, A., (2005) "Internal learning by doing and economic growth," *Journal of Economic Development,* Vol. 30(2): 1-23.

Arnold, R., (1994) "Recent developments in the theory of long run growth: A critical evaluation," *CBO Papers October 1994,* Washington, DC: Congressional Budget Office.

Arrow, K. J., (1962) "The economic implications of learning by doing," *Review of Economic Studies,* Vol.29(3): 155-173.

Aw, B., Chung, S. and Roberts, M. J., (2002) "Productivity, Output, and Failure: A comparison of Taiwanese and Korean manufacturers," *NBER Working Paper No.8766.*

Barro, R. J., (1990) "Government spending in a simple model of endogenous growth," *Journal of Political Economy,* Vol. 98(5): S103-S25.

Baily, R., (2001) "Post-Scarcity Prophet: Economist Paul Romer on growth, technological change, and an unlimited human future," *Reason,* available from: http://www.reason.com/news/show/28243.html

DeLong, B.J., Summers, L.H. (1991) Equipment Investment and Economic Growth," *Quarterly Journal of Economics,* Vol. 106: 445-502.

Ericsson, N. R. and McKinnon, J.G., (2002) "Distributions of error correction tests for cointegration,"*Econometrics Journal,* Vol. 5 (2): 285-318.

Frankel, J. A., (1997) "Determinants of long term growth," Background Paper for the Morning Session of the Meeting of the Asia-Pacific Economic Cooperation Economic Advisers, Vancouver, Canada, November 20, 1997.

Grossman, G.M. and Helpman, E., (1991) *Innovation and Growth in the Global Economy,* 2nd edition, Cambridge, Mass: MIT Press.

Greiner, A. (2008) "Fiscal policy in an endogenous growth model with human capital and heterogenous agents," *Economic Modelling,* Vol.25(4): 643657.

Greiner, A., Semler, W. and Gong, G., (2004) *The Forces of Economic Growth: A Time Series Perspective,* Princeton, NJ: Princeton University Press.

Hendry, D. F. and Krolzig, H. M., (2001) "Automatic econometric model selection," Oxford: Timberlake Consultants Press.

——-and ——- (2005) "The properties of automatic GETS modeling", the *Economic Journal,* Vol.115(XX): C32-C61.

Huang, C., (2002) "How do endogenous growth models explain the Asian growth experiences? A time series study of eleven Asian economies," *Working Paper No. 2002,* Department of Economics, National Tsing Hua University.

Hoover, K. and Perez, S., (2004). "Truth and robustness in cross-country growth regressions, *Oxford Bulletin of Economics and Statistics,* Vol. 66(5): 765-798.

Jones, C., (1995) "R&D-based models for economic growth," *Journal of Political Economy,* Vol. 103(4): 759-84.

Kohcerlakota , N. and Kei-Mu Yi., (1996) "A simple time series test of endogenous vs. exogenous growth models: An application to the United States," *Review of Economics and Statistics,* Vol. 78(1): 126-134.

Lau, S.-H. P. (2008), Using an error-correction model to test whether endogenous long-run growth exists, *Journal of Economic Dynamics and Control,* Vol. 32(X): 648-676.

Levine, R., Renelt, D. (1992) A Sensitivity Analysis of Cross-Country Growth Re- gression." *American Economic Review,* Vol. 82: 942-963.

Lucas, R.E. (1988) "On the mechanics of economic development," *Journal of Monetary Economics,* Vol. 22: 3-42.

Mankiw, N.G. Romer, D. and Weil, D., (1992) "A contribution to the empirics of economic growth," *Quarterly Journal of Economics,* Vol. 116: 407-437.

Rao, B. B., (2008) "Time series econometrics of growth models: A guide for applied economists, forthcoming, *Applied Economics.*

Rao, B. B., Singh, R. and Kumar, S., (2008) "Do we need time series econometrics? forthcoming, *Applied Economics Letters.*

Rebelo, S., (1991) "Long run policy analysis and long run growth," *Journal of Political Economy,* Vol. 96(3): 500-521.

Romer, P. M., (1986) "Increasing returns and long-run growth," *Journal of Political Economy,* Vol. 94(5): 1002-1037.

Romer, P., (1990) "Endogenous technical change," *Journal of Political Economy,* Vol. 98(5): S71-S102.

Sala-i-Martin, X. (1997) I just ran two million regressions," *American Economic Review,* Vol. 87: 1325-1352.

Sarel, M., (1995) "Growth in East Asia: What we can and what we cannot infer from it," *Productivity and Growth, Proceedings of a Conference,* in Andersen, P., Dwyer,J. and Gruen, D. (eds.), Sydney: Reserve Bank of Australia, pp. 237-259.

Sato, R., (1963) "Fiscal policy in a neo-classical growth model: An analysis of time required for equilibrating adjustment," *Review of Economic Studies,* Vol. 30(1): 16-23.

Sequeira, T. N. (2008) "On the effects of human capital and R&D policies in an endogenous growth model," *Economic Modelling,* Vol.25(5): 968982. ? ?

Solow, R.M., (1956) "A contribution to the theory of economic growth", *Quarterly Journal of Economics,* Vol. 70(1): 65-94.

Uzawa, H., (1965) "Optimum technical change in an aggregate model of economic growth," *International Economic Review,* Vol. 6(1): 18-31.

Young, A., (1995) "The tyranny of numbers: Confronting the statistical realities of the East Asian growth experience," *Quarterly Journal of Economics,* Vol.110(3?): 641-680.