The level and growth effects in the empirics of economic growth

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Abstract

Mankiw, Romer and Weil (1992) have extended the Solow (1956) model by augmenting the production function with human capital. Its empirical success is impressive and it showed a procedure to improve the explanatory power of the neoclassical growth model. This paper suggests an empirical procedure to further extend the neoclassical growth model to distinguish between the growth and level effects of shift variables like the human capital. We use time series data from Guatemala to show that while the growth effects of education are small, they are significant and dominate the level effects.

JEL Classification: N1, O1, O4.

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Keywords: The Solow Growth Model, Production Function, Shift Variables, Human Capital Level and Growth Effects.

1. INTRODUCTION

A stylized fact of growth accounting is that the Solow (1956) neoclassical growth model (NCGM) factor accumulation can only explain about half the variation in the growth rate. The remainder, known as the Solow residual (SR), is attributed to the growth in total factor productivity (TFP) and in the empirical work SR is captured with a trend variable. However, since it is not known what factors determine TFP but what determines TFP is not known, For this reason the Solow model is also known as the exogenous growth model and SR is a measure of our measure of ignorance of the determinants of growth. Specifications with a significant trend indicate that the unknown determinants of growth are trended. Therefore, the endogenous growth models (EGMs) of Romer (1986, 1990), Lucas (1988), Barro (1991, 1999) and Aghion and Howitt (1992) have developed alternative frameworks to identify these additional determinants of growth.[2] Permanent changes in these growth enhancing variables, at least according to some EGMs, should lead to permanent changes in the growth rate of. In contrast, the NCGM implies, for example, that by increasing the investment rate a country can increase the level of per capita income but not its growth rate although the growth rate increases during the transition period.[3]

Subsequent developments, however, have raised doubts on the empirical significance of EGMs. Mankiw, Romer and Weil (1992), MRW hereafter, have shown that the explanatory power of NCGM can be significantly increased by augmenting its production function with appropriate shift variables like human capital. Caselli (1994) advocated a similar approach to reduce SR by improving the measurement of capital for changes in its quality. Jones (1995) has

[2] Jones (1995) has listed ten growth factors, identified by the EGMs, and these are: physical investment rates, human capital investment rates, export shares, inward orientation, the strength of property rights, government consumption, population growth, and regulatory pressure.

[3] The transition period between the steady state growth rates is long and therefore, the growth rate will remain above the steady state growth rate for 15 to 20 periods. This insight is based on the simulation results with the closed form solutions of NCGM.

been sceptical about the empirical significance of the EGMs given that although additional growth determinants in the EGMs e.g., expenditure on R&D showed an upward trend, there is no upward trend in the growth rates of USA and other OECD countries. Huang (2003) has used a similar approach and found that there is no support for EGMs from 11 Asian countries.[4] Parente (2001) and Solow (2000) also take a similar view. Solow (2001, p. 153) observe, "the second wave of runaway interest in growth theory the endogenous growth literature sparked by Romer and Lucas in the 1980s, following the neoclassical wave of the 1950s and 1960s – appears to be dwindling to a modest flow of normal science". Attempts by Gong, Greiner and Semmler (2004a, 2004b) to estimate EGMs with time series data have yield less than impressive empirical results.[5] In spite of these limitations, EGMs and their optimization theoretical frameworks are useful to identify additional growth determinants. Without these models, as Duraloauf, Johnson and Temple (2005) have observed, there is no limit to the number of arbitrary variables that may appear in the empirical work on growth models.[6]

An important empirical differences between the augmented MRW type NCGM and EGMs is that while the additional growth determinants have permanent growth effects in the EGMs, they only have permanent level effects in the NCGM. However, it seems possible to extend the NCGM to capture permanent growth and level effects although it may be empirically difficult to disentangle these two effects due to multi-collinearity between the variables. In this paper we show that it is possible to estimate alternative specifications with one of these effects (level or growth) and determine which effect is more dominant. The paper is structured as follows. Section

[4] However, Kocerlakota and Kei-Mu Yi (1996) have found limited support for EGMs with US data. They examined the effects of 7 policy variables on the growth rate and found that only non-military investment and non-military structural investment has some effect on the growth rate.

[5] There seem to be difficulties in estimating the deep parameters underlying the inter-temporal utility optimization models with constant risk aversion utility functions. The main finding of the empirical work based on Hall's (1978, 1988) random walk hypothesis is that it is difficult to estimate the inter-temporal elasticity of substitution and risk aversion parameters. However, Ogaki and Reinhart (1998) proposed a method to estimate these parameters by using durable and non-durable consumption expenditures. See also Campbell and Mankiw (1988).

[6] Hoover and Perez (2004) in their survey of cross-country works, for example, list 64 variables that have been used in various EGMs.

2 discusses some modifications to estimate growth equations utilising time series data and develops alternative specifications for the level and growth effects. Section 3 presents our empirical results of the level and growth effects of human capital in Guatemala for the period 1950 to 2002. Conclusions are in Section 4.

2. GROWTH AND LEVEL EFFECTS

Although cross-country empirical work has limitations for country specific growth policies, the bulk of empirical work with the NCGM and EGMs have used cross-country data. In these empirical studies the steady state level of output equation is estimated. This output equation is derived by replacing the stock of capital with its equilibrium steady state value. A typical specification based on constant returns Cobb-Douglas production function and the Harrod neutral technical progress is:

$$ln\ y_t = A_0 + gt + \frac{a}{1-a}\, ln\ (s) - \frac{a}{1-a}\, ln\ (n + g + d) \tag{1}$$

where y is per worker income, A_0 is initial stock of knowledge, s the rate of investment, n and g are, respectively, rates of growth of employment and technology, d is the depreciation rate and a is the share of profits. Equation (1) implies that in the steady state

$$\Delta \ln yt = g \tag{2}$$

since all other ratios and rates of growth are constants. Derivation of the steady state output equation, with human capital augmented production function is straight forward with the assumption that the steady state growth of human capital, like physical capital, is zero and it is:

$$ln\ y_t = A_0 + gt + \frac{a}{1-a-b}\, ln\ (s_k) + \frac{b}{1-a-b}\, ln\ (s_h) - \frac{a+b}{1-a-b}\, ln\ (n + g + d) \tag{3}$$

where the new parameter ß is the share of income of human capital and s_k and s_h are the investment ratios in physical and human capital respectively. The steady state output growth equation will be the same as (2). It is easy to verify that even if s_h is small, as long as ß > 0, output per capita with human capital augmented production function will be higher. To show this explicitly, MRW (1992) eliminate s_h from (3), by using the steady state solution for per worker human capital (h^*) to get:

$$ln\, y_t = A_0 + gt + \frac{a}{1-a} ln\, (s_k) + \frac{b}{1-a} ln\, (h^*) - \frac{a}{1-a} ln\, (n + g + d) \quad (4)$$

This is the level effect of human capital in the extended NCGM. Thus attempts to revive the NCGM by augmenting the production function with appropriate shift variables is the same as attempts to reduce the Solow residual or in our words our measure of ignorance of the determinants of growth. By augmenting the production function with human capital MRW (1992) have obtained an adjusted R^2 value as high as 0.78 in their cross-country estimates consisting of 98 non-oil producing countries.

While the specifications in (1) and (3) are satisfactory for cross-country studies and estimation with some cross section techniques in which the average values of the variables over 20 years or so are used, it is inappropriate to estimate these equilibrium reduced form equations with country specific time series annual data. If (1) and (3) are the steady state equations, a year is too short a period for any economy to reach its steady state equilibrium. An alternative is to estimate the production function and use the estimated parameters to compute the steady state output in (1) and (3). The steady state growth rate is simply the coefficient of trend in the production function.[7]

Production functions are estimated with the time series by pre-testing if the variables are non-stationary in levels and stationary in their first differences. If this requirement is satisfied, the production is specified so that the dynamic adjustment process is based on the well known error correction method (ECM). A popular autoregressive distributed lag (ARDL) specification,

[7] MRW (1992, p.412) hint that factor shares from national income data can also be used to compute steady state income.

based on ECM and a constant returns Cobb-Douglas production function with Hicks neutral technical progress is:

$$\Delta lnY_t = -l\,[lnY_{t-1} - (lnA_0 + gt + a\,lnK_{t-1} + (1-a)lnL_{t-1})] + \sum_{i=0}^{n1} g_{1i}\Delta lnL_{t-i} + \sum_{i=0}^{n2} g_{2i}\Delta lnK_{t-i} + \sum_{i=1}^{n3} g_{3i}\Delta lnY_{t-i} \qquad (5)$$

where Y is output, K is capital and L is employment. The coefficient of trend g captures the rate of technical progress, ? is the speed of adjustment to equilibrium and A_0 is the initial stock of capital. In per worker terms (5) will be

$$\Delta y_t = -l\ [ln\ y_{t-1} - (ln\ A_0 + gt + a\,ln\ k_{t-1}] + \sum_{i=0}^{n2} p_{2i}\Delta \ln k_{t-i} + \sum_{i=0}^{n3} p_{3i}\Delta \ln y_{t-i} \qquad (5A)$$

where the lower case letters like y are Y/L etc., are per worker variables. Both types of specifications have been used in the time series country specific studies. Additional shift variables like human capital, openness of the economy and aid etc., are introduced into these specifications with the implicit assumption that they only have level effects. Addition of these shift variables is expected to decrease the size of the SR, thus improving our understanding of the growth determinants. Strictly speaking these determinants should be referred to as output determinants and not growth determinants because the main objective of this approach is to estimate the parameters of the equilibrium production function. A growth equation can be derived from the production function and if in the steady state physical and human capital do not increase, the steady state growth rate derived from equations (5) and (5A) depends only on the rate of growth of technical progress.

In this paper, we shall assume that there is only one shift variable viz., human capital *HKI* and it is measured as an index number with an initial value to unity. One way to justify and add this shift variable is to argue that it improves the quality of the measured employment because $L\times HKI$

skilled (educated) workers produce more output than L unskilled workers. The specification below with equation (5), similar to the MRW equation, is:

$$\Delta Y_t = -l \ [ln\ \mathrm{Y}_{t\text{-}1} - (lnA_0 + gt + \mathrm{a}\,lnK_{t-1} + (1 - \mathrm{a})\ ln(L_{t-1} \times HKI_{t-1})]$$
$$+ \sum_{i=0}^{n1} g_{1i} \Delta \ln L_{t-i} + \sum_{i=0}^{n2} g_{2i} \Delta \ln K_{t-i} + \sum_{i=0}^{n3} g_{3i} \Delta \ln Y_{t-i} + \sum_{i=0}^{n4} g_{4i} \Delta \ln HKI_{t-i} \qquad (6)$$

In most empirical studies the dependent variable is the rate of growth of output per worker (*ln ?y*), and the per worker version of the above equation. Using the same notation for the coefficients for convenience, it is:

$$\Delta y_t = -l \ [ln\ \mathrm{y}_{t\text{-}1} - (lnA_0 + gt + \mathrm{a}\,lnk_{t-1} + (1 - \mathrm{a})\ ln\ HKI_{t-1})]$$
$$+ \sum_{i=0}^{n1} g_{1i} \Delta \ln k_{t-i} + \sum_{i=0}^{n2} g_{2i} \Delta \ln y_{t-i} + \sum_{i=0}^{n3} g_{3i} \Delta \ln HKI_{t-i} \qquad (6A)$$

Another alternative of incorporating the shift variable, which was used by Bloom, Canning and Sevilla (2004), BCS hereafter, is :

$$\Delta y_t = -l \ [ln\ \mathrm{y}_{t\text{-}1} - (lnA_0 + gt + \mathrm{A}_1 HKI_{t-1} + \mathrm{a}\,ln\ k_{t\text{-}1}]$$
$$+ \sum_{i=0}^{n1} g_{1i} \Delta \ln k_{t-i} + \sum_{i=0}^{n2} g_{2i} \Delta \ln y_{t-i} + \sum_{i=0}^{n3} g_{3i} \Delta \ln HKI_{t-i} \qquad (7)$$

The BCS formulation implies that the marginal and average products of both inputs (that is capital and labour) will increase with improvements in *HKI*. There is no major difference between the level effects of *HKI* on output in (6) and (7). Equation (7) is convenient for capturing any non-linear effects of *HKI* and this specification takes the following form:

$$\Delta y_t = -l \ [ln\ y_{t\text{-}1} - (lnA_0 + gt + ß_1 HKI_{t-1} + ß_2 \mathrm{HKI}^2_{t\text{-}1} + ln\ k_{t\text{-}1}]$$
$$+ \sum_{i=0}^{n1} g_{1i} \Delta \ln k_{t-i} + \sum_{i=0}^{n2} g_{2i} \Delta \ln y_{t-i} + \sum_{i=0}^{n3} g_{3i} \Delta \ln HKI_{t-i} \qquad (8)$$

Equation (8) implies that when $HKI = 0.5\ (ß_1/ß_2)$, it has its maximum effect on output. For this to be meaningful, one would expect that $ß_2$ is negative.

So far we considered specifications in which variables like human capital have only level effects on output. Before we extend NCGM to capture the permanent growth effects of variables like *HKI*, it should be noted that in both MRW and BCS estimates with cross-country data, the term *gt* does not appear because time is irrelevant in the cross-country sample with average values of the variables over long periods. However, the need for the trend in time series regressions in the above specifications with only level effects is debatable for the following reasons. First, when the production function is augmented with shift variables like *HKI*, there is an implicit assumption that the shift variable significantly reduces SR. Therefore, the coefficient of trend will either decrease or may even become insignificant. Second, if the shift variable is highly trended, due to multi-co-linearity, the estimated coefficients of trend and the shift variable are somewhat unreliable depending on the correlation between time and *HKI*.

In extending NCGM to capture the permanent growth effects of *HKI*, we assume that g, which is the trend rate of growth, depends on *HKI* i.e., g = ? (*HKI*). There are three possibilities here. The relationship between g and *HKI* may be linear, $g = pHKI$ or nonlinear, $g = p_1HKI+p_2HKI^2$. While the linear relation implies that g increases monotonically with *HKI*, the non-linear relation implies that when $HKI = (-\ 0.5p_1/p_2)$ it will have its maximum effect on g. For this to be meaningful p_2 should be negative. A weakness of the nonlinear specification is that it is hard to explain why g declines as *HKI* increases, after it reaches its optimal value although some kind of congestion/overcrowding effect is plausible. In this context it is worth remembering Jones' (1995) finding that there is no evidence that shift variables like *HKI* had actually increased the growth rate continuously. In other words, these growth effects seem to converge to a limit as the shift variables increases over time. If the effect of *HKI* on g eventually converges, then a third alternative is to use a simple specification like $g = (p_1 - (p_2/HKI)$. This implies that the initial period value of g is $(p_1 - p_2)$ and it eventually converges to p1 as *HKI* increases.[8] The specification based on this approach is as follows:

[8] In proposing this specification we are aware that this is an empirical modification. We justify this empirical modification because of its conformity with data. It would be interesting if someone develops a theoretical

$$\Delta y_t = -l\ [ln\ y_{t-1} - (\ lnA_0 + (p_1 - p_2\ HKI^{-1}_{t-1})T + a\,ln\ k_{t-1}] + \sum_{i=0}^{n1} g_{1i}\Delta \ln k_{t-i} + \sum_{i=0}^{n2} g_{2i}\Delta \ln y_{t-i} + \sum_{i=1}^{n3} g_{3i}\Delta \ln HKI_{t-i} \quad (9)$$

It is easy to develop a specification with both the growth and level effects. We shall use the MRW level effects for this purpose and the specification with both effects is:

$$\Delta y_t = -l\ [ln\ y_{t-1} - (\ lnA_0 + (p_1 - p_2 + ß_1 HKI^{-1}_{t-1})\mathrm{T} + a\,ln\ k_{t-1} + (1\text{-}a)ln\mathrm{HKI}_{t-1}] + \sum_{i=0}^{n1} g_{1i}\Delta \ln k_{t-i} + \sum_{i=0}^{n2} g_{2i}\Delta \ln y_{t-i} + \sum_{i=1}^{n3} g_{3i}\Delta \ln HKI_{t-i} \quad (10)$$

However, as noted earlier, it might be difficult to estimate (10) with both the growth and level effects because of multi-co-linearity between the variables.

3. EMPIRICAL RESULTS

To evaluate both the level and growth effects we use data from Guatemala for the period 1950 to 2002 and note some insights from an earlier work on the effects of education on the level of output by Loening (2004). Our estimation method, like in Loening, is based on the general to specific approach (*GETS*) of Hendry (1995), but we use the non-linear two stage instrumental variable method which is an improvement on Loening's indirect OLS. Lagged values of the variables are used as instruments. Details of the variables and data sources are presented in the appendix. We estimate Sargan $?^2$ test statistics and Pesaran and Smith (1994) generalized $\overline{G}R^2$ to determine the validity of the choice of instruments and to judge the goodness of fit of alternative equations.[9] Closeness between the $\overline{R}^2$ and $\overline{GR}^2$ is a rough indicator of how accurately

justification. Essentially what we are assuming amounts to the assumption that technical progress is due to the economy wide externalities of variables like HKI ad for individual firm these effects are like manna from heaven.

[9] The Sargan test statistic is computed when there are over identifying restrictions, with the null hypothesis that the selected instruments are exogenous i.e., they are uncorrelated with the error term. When the null is not rejected, it

the instruments predict the endogenous variables. In the extreme case where the instruments exactly predict the endogenous variables, both measures of goodness of fit will be identical. In all the empirical works with ARDL type specifications the rate of change of per worker income, ? *ln y*, is the dependent variable and many mistakenly interpret this as a growth equation. It should be noted that what is actually estimated is the production function and the steady state growth rate and the level of output (if needed) should be computed with the estimated parameters of the production function. We report the results for the level effects in Table-1 and both the level and growth effects are in Table-2.

We first estimate equation (5a) with the constant returns and Hicks neutral technical progress. In addition to the significant ARDL terms, following Loeining (2004), three outlier dummy variables are included, i.e., *IMP*63 for some positive expectations due to Guatemala's entry into the Central American Common Market. *STEP*77 and *IMP*82 dummies, respectively, for negative effects due to civil strife starting from 1977 and for its peak effects in 1982 (details are explained in the Appendix). The estimate of this equation is shown as equation (I) in Table-1. Its performance is very good in that the summary $?^2$ test statistics are insignificant for serial correlation, functional form misspecification, non-normality of the residuals and heteroscedasticity, and all the estimated coefficients are significant at the 5% level. The estimated coefficient of trend at 0.008 implies that technical progress in Guatemala is low at slightly less than 1% per year and the share of profit income at about 0.43 is plausible. The coefficients of the three dummies with expected signs are close in their absolute values. When the constraint that the coefficients of *IMP*82 and *STEP*77 are equal and the coefficient of *IMP*63 is the same but of opposite in sign, the computed Wald test statistics $?^2$ with its *p*-value in the square brackets is 2.376 [.305], is imposed, the null could not be rejected. Therefore, this equation is re-estimated with these constraints given as equation (II) in Table 1. It may be noted that the $\overline{G}R^2$ is now slightly higher at 0.645 and there are no other significant differences. The recently developed Ericsson and MacKinnion (2002) test statistic ($K_{\alpha}(n)$) for cointegration in the

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can be said that the chosen instruments are exogenous and valid. However, the Sargan test is appropriate for large samples whereas our sample size is modest. The $\overline{GR}^2$ is a measure of goodness of fit of IV estimates, developed by Pesaran and Smith (1994). It is a valid discriminator of models based on IV method.

Hendry GETS specifications, between the levels of the variables in the ECM, rejects the null of no cointegration at the 5% level. The *t*-ratio of ? at 8.11 exceeds the absolute 5% critical value of the test statistic $K_{ct}(2) = 3.79$.

Estimates of the MRW specification in (6) are given as equation (III) in Table-1, which is also well determined. In this and all other subsequent estimates the aforesaid constraints on the dummy variables are retained. The re-estimated equation (III) with trend shows that the coefficient of trend is - 0.002 and insignificant (*t*-ratio of 1.29). This equation is not reported to conserve space. The main difference between equation (III) and the two earlier equations (I) and (II) is that the MRW equation implies a higher share of 0.58 for profit income. It is a well known that the MRW specification overestimates profit share because the MRW model implicitly assumes that labour income is actually profit income. Note that although there is no trend in equation (III), its $\overline{G}R^2$ at 0.632 is almost the same as in equation (II), implying that *HKI* in the MRW specification has adequately captured the unknown determinants of output. The 5% absolute critical value of the Ericsson and MacKinnon cointegration test statistic is $K_c(3) = 3.582$ and less than the *t*-ratio of ? at 6.286. Thus, the null of no cointegration between the levels of the variables can be rejected.

Insert TABLE-1 Level Effects of HKI in Guatemala: 1950 - 2002

2SNLLS-IV ESTIMATES

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Equations IV and V in Table-1 are estimates of the linear and nonlinear specifications of the BCS equations (7) and (8), respectively. Once again both equations perform well and all coefficients are significant at the 5% level, but the coefficient of HKI^2 is insignificant even at the 10% level. This may be partly due to multi-co-linearity between *HKI* and HKI^2. Re-estimation of this equation as (VI), with the constraint that the ratio of the coefficients of these two terms is the same as in equation (V), shows that the $\overline{G}R^2$ values of (IV) to (VI) are very close to those in equations (I), (II), and (III). It is hard to discriminate between the BCS and MRW specifications as there is a one to one relationship between them. The key difference between the BCS equations, compared with the MRW equation, is in the estimated share of profits. The estimated share of profits in equation (IV) at 0.361 is almost identical to its stylized value of one third, while the non-linear BCS equation (V) shows a slightly higher value of 0.40. The Ericsson and MacKinnon 5% critical values for cointegration for these equations are, respectively, $K_c(3) = 3.582$ and $K_c(4) = 3.833$ and both are less than the *t*-ratios of *?* in equations (IV) to (VI), thus reject the null of no cointegration.[10]

It is interesting to note that the constrained BCS non-linear equation implies that *HKI* would have its maximum level effects when it equals a value of 7. In our sample, by the end of the sample period in 2002, *HKI* reached a value of 3.8 and implies that a one percent improvement in education increases per worker income by 0.22 percent and this is not far from an estimate of 0.33 in the cross-country estimates in MRW (1992). Therefore, there is still scope for further improvements in education to have positive level effects, but these effects will decrease when *HKI* reaches its optimal value of 7. Figure-1 shows the declining level effects of *HKI* implied by the non-linear BCS equation (VI). The selection of the best equation from those with level effects is postponed until the equations with both growth and level and growth effects are estimated.

Insert FIGURE-1

NON-LINEAR LEVEL EFFECTS OF HKI

Estimates of the specification in equation (9) with growth and then equation (10) with both level and growth effects are reported in Table-2. As both equations show problem of multi-co-linearity, we used the next best option and constrained these two parameters so that the initial period value of g is zero.[11] This constraint implies that $g = p_1 - p_1\, HKI^{-1}$. The result of specification (9) is

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[10] When trend was included in these equations the coefficient of HKI and HKI^2 became negative and insignificant.

[11] The correlation between trend and *HKI* is high at 0.99 and it is difficult to obtain reliable estimates of the two parameters p_1 and p_2 in equation (9) – see equation (VII), Table-2. The sign of p_2 is positive and contrary to expectation. However, the summary statistics are impressive. We have also estimated an equation with quadratic growth effects. Although this equation is well determined, the $\bar{G}R^2$ was less at 0.639 and implied that HKI has its maximum growth effects when it is 2.8 which seems to be low. This result is not reported to conserve space.

shown in equation (VIII) in Table-2. The model diagnostics perform quite well and the coefficients are all significant at the 5% level. The Ericsson and MacKinnon cointegration test indicated that the null of no cointegration can be rejected at the 5% level. Its $\overline{G}R^2s$ at 0.775 is 22% higher than the equations in Table-1. The estimated profit share at 0.38 is closer to its stylized value. For all these reasons, equation (VIII) with only growth effects, can said to be a significant improvement over all the equations in Table-1. The estimated p value implies that as *HKI* increases, g converges to 0.01 implying that *HKI* permanently adds about a percentage point to the growth rate. The relation between g and *HKI* is shown in Figure-2. At the end of the sample period in 2002, *HKI* reached a value of about 3.8 which implies that, during 1950 to 2002, improvements in education have permanently added 0.008 to the growth rate of Guatemala. Since this is close to the maximum of 0.01, further improvements to *HKI* will only add a small amount of 0.002 points to the growth rate.

The details of the remaining estimates in Table 2 are as follows. Equation (IX) uses a non-liner type growth effect. Equation (X) is with the MRW type level effects and equations (XI) and (XII) use the BCS linear and non-linear level effects. In equation (IX) the summary $?^2$ tests are satisfactory. However, although its $\overline{G}R^2$ is high at 0.764, it has several weaknesses. First, the *t*-ratio of *?* is less than the Ericsson and MacKinnon critical value even at the 10% level and there is no cointegration. Second, the intercept capturing the initial stock of knowledge is insignificant. Third, it implies a high permanent growth effect for *HKI* of 0.024 and this seems to be somewhat implausible. Finally, the high $\overline{G}R^2$ value seems to be due to the growth effects, because addition of the level effects has in fact decreased its $\overline{G}R^2$ to 0.764 and this is due to the loss of one more degree of freedom.

The estimates with the two non-linear BCS specifications also have weaknesses although the *t*-ratios of their ?s indicate that the level variables are cointegrated. In equation (XI) the coefficients of the growth and level effects and the intercept are all insignificant. When this equation is re-estimated (not shown to conserve space) without the intercept, the coefficient of the level effects became negative and significant. In equation (XII) the coefficient of *HKI* is insignificant. Although the coefficient of HKI^2 is negative and significant, it is implausibly high implying that *HKI* has negative level effects. Therefore, it can be concluded that specifications with both level and growth effects are unsatisfactory in comparison to the specification with only growth effects. Adding the level effects to the growth effects seems to have penalised their $\overline{G}R^2$s due to the loss of the degrees of freedom. On the basis of our estimates, it can be said that equation (VIII) with only the growth effects is the best and growth effects are more dominant than the level effects of *HKI*. This is not an unusual result for a country like Guatemala because government expenditure on education is large compared to private expenditures. Therefore, the externalities caused by education are the manna from heaven type i.e., it is virtually free to the individual households and firms. Therefore, education, which more likes a public good, could add directly a permanent growth effect.

Insert FIGURE-2 GROWTH EFFECTS OF HKI

Insert TABLE-2 Growth and Level Effects of HKI in Guatemala: 1950 - 2002
2SNLLS-IV ESTIMATES

4. CONCLUSION

In this paper, we have extended the neoclassical growth model to capture the level and growth effects due to a shift variables. An important feature of our model is the realisation that what is actually estimated with time series data is a production function and not a growth equation. This is noteworthy because in many applied papers, output growth is simply regressed on some ad hoc variables in the ECM part and none of the factor inputs are included. One has to come across production functions where output depend only on variables like tourist arrivals, defence expenditure, overseas development aid and the volume of credit etc.

Our approach is in the spirit of MRW and BCS and extended their cross-country specifications to estimate with time series data. We found that in Guatemala the growth effects of human capital clearly dominated its level effects. Although these growth effects are small, they are significant. Further application of our framework to other countries, with higher rates of technological progress than Guatemala, would be useful to indicate if the growth effects always dominate the level effects. It can be said that the endogenous growth models, which emphasise the permanent growth effects should not be dismissed as empirically unimportant. Also, the simpler neoclassical growth model can be extended to capture such permanent growth effects even if they are small.

A limitation of our paper is that we have ignored other externalities like learning by doing, trade openness and the likes. However, it is difficult to include all the relevant variables and estimate with confidence their individual contribution to the level or growth of output because of multi-co-linearity between the variables. An option is to combine them with the principal components approach, but then it is hard to disentangle their individual effects. Therefore, our estimates of the growth effects of human capital should be interpreted cautiously.

APPENDIX: DATA SOURCE AND DESCRIPTION

The variable measures are as follows: (a) human capital stock (HK), (b) physical capital stock (K), (c) labor force (L) and (d) several time dummies. With the exception of the human capital stock, all time series data, including GDP are from Banco de Guatemala and its sources is available in Loening (2005).

Human Capital Stock (HK): The human capital stock of Guatemala is defined by average years of schooling evident in the labor force. After making some modifications to account for the statistical circumstances in Guatemala, the procedure for constructing estimates of the human capital stock is based on the attainment census method of Barro and Lee (2001). The method constructs current flows of adult population, which are added to the initial benchmark stocks of the labor force in 1950, is from Barro and Lee data set. Other benchmarks data points are taken from nine national representative surveys from 1950-2002. The procedure also requires annual school enrolment ratios taken from various yearbooks of Guatemalan Ministry of Education (MINEDUC) for the 1990s, United Nations Educational, Scientific and Cultural Organization (UNESCO) for earlier periods, and other sources available for Guatemala. The data for primary, secondary and tertiary enrolment ratios are consistent over time. Interpolation techniques were used to fill gaps in the data, but the use of this approach was kept to a minimum.

Labor Force (L): The measure of labor quantity here is the economically active population. For any missing data from official sources, labor is proxied by the number of private contributors to the Guatemalan Social Security System (IGSS). The numbers representing the labor force are calculated by assuming that the social security contributors account for approximately 25 percent of the total labor force. The participation rate is consistent with official estimates and is based on a historical mean value. As evidenced in Loening (2005), the level of the economically active population (but not its growth rate) is in line with International Labor Organization and the Guatemalan National Statistical Institute (INE) estimates. For recent years, the estimate for the economically active population derived from IGSS statistics comes very close to INE.

Physical Capital Stock (K): is computed using the Perpetual Inventory Method. The procedure argues that the stock of capital is the accumulation of the stream of past investments. The overall depreciation rate is assumed at 5 percent. Initial value of the capital-output ratio for 1950 is taken from Nehru and Dhareshwar (1993) data set. Information about gross fixed capital formation was provided directly by the Economic Research Department of the Banco de Guatemala. The data is compiled using the somewhat dated 1953 UN System of National Accounts, is currently under revision. Regarding the armed conflict, which has lasted for 36 years, and several periods of high violence in Guatemala, it was found useful to adopt a high depreciation rate in order to account for both capital destruction and distraction from productive use. The results of the regressions are not sensitive to moderate adjustments in the depreciation rate.

Dummy Variables: The regressions in this analysis include three dummies. First, a 1977 step dummy models a structural change in the long-run relationship of the variables (Chow breakpoint test with p=0.000). The 1977 dummy is very significant and corrects for the deviations resulting from the civil strife. After 1977, social tension in Guatemala culminated in a full-scale civil war that reached genocidal proportions in the early 1980s. Second, a 1982 impulse dummy takes into account a very negative one-off effect stemming from the peak of Guatemala's civil war. Third, a 1963 impulse dummy captures a positive one-off effect stemming from positive expectations regarding Guatemala's entry in the Central American Common Market. It is important to emphasize that the results are not sensitive to impulse dummy variables. However, it is important to model the structural break.

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TABLE-1

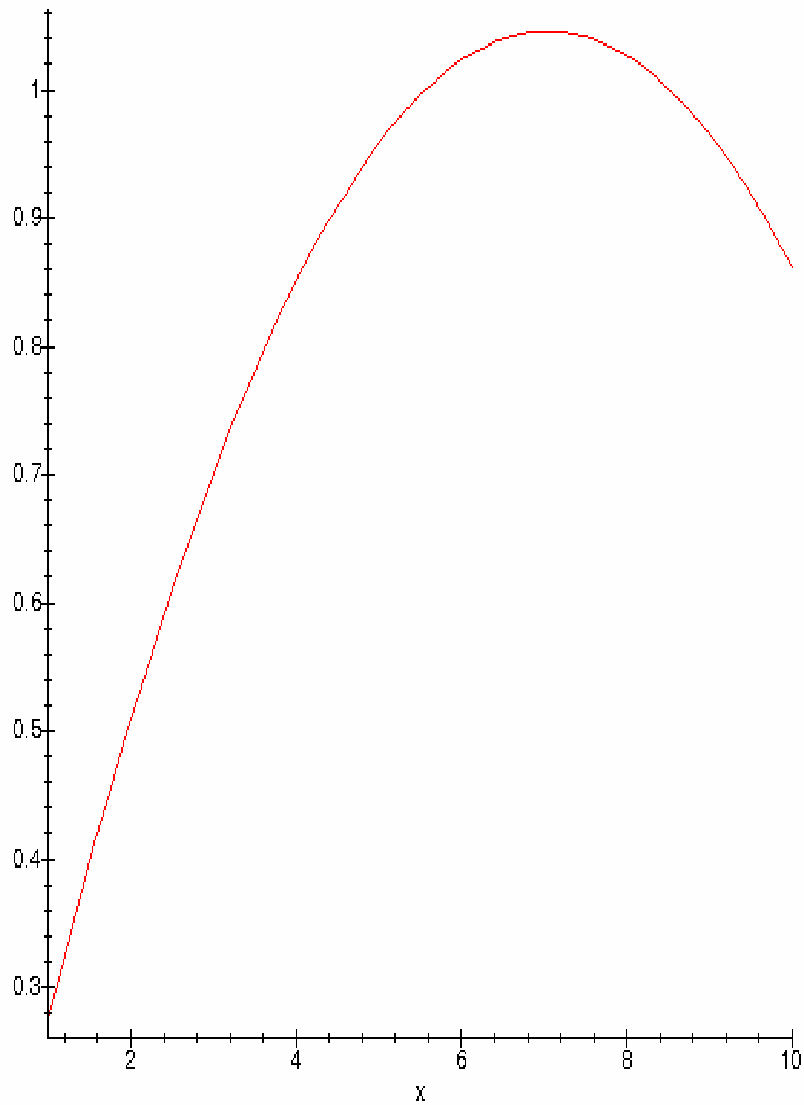
	I	II	III	IV	V	VI
Const.	-0.215 (10.72)*	-0.226 (13.21)*	-0.255 (8.34)*	-0.360 (10.30)*	-0.466 (4.28)*	-0.467 (10.81)*
Trend	0.007 (9.84)*	0.008 (11.74)*				
l	-0.315 (6.77)*	-0.344 (8.11)*	-0.203 (5.69)*	-0.236 (5.72)*	-0.248 (5.80)*	-0.248 (5.98)*
HKI_{t-1}				0.207 (7.38)*	0.296 (3.20)*	0.297 (7.88)*
$\ln HKI_{t-1}$			0.419 (c)			
HKI_{t-1}^2					-0.021 (1.05)	-0.021 (c)
$\ln k_t$	0.426 (7.43)*	0.444 (8.71)*	0.581 (9.98)*	0.361 (4.25)*	0.402 (4.51)*	0.403 (5.20)*
$\Delta \ln k_t$	0.825 (23.29)*	0.830 (23.58)*	0.914 (26.35)*	0.855 (22.50)*	0.859 (22.56)*	0.859 (23.15)*
$\Delta \ln k_{t-1}$	0.140 (3.77)*	0.122 (3.77)*	0.072 (2.29)*	0.102 (3.00)*	0.103 (3.06)*	0.103 (3.10)*
? $\ln HKI_{t-1}$			-0.377 (2.38)*			
? HKI_{t-1}				-0.121 (2.22)*	-0.101 (1.76)**	-0.101 (1.88)**
IMP82	-0.069 (4.51)*	-0.051 (9.69)*	-0.052 (8.08)*	-0.049 (8.66)*	-0.052 (8.18)*	-0.052 (8.91)*
IMP63	0.056 (4.97)*	0.051 (c)	0.052 (c)	0.049 (c)	0.052 (c)	0.052 (c)
STEP77	-0.042 (5.18)*	-0.051 (c)	-0.052 (c)	-0.049 (c)	-0.052 (c)	-0.052 (c)
$\overline{R}^2$	0.969	0.969	0.963	0.966	0.966	0.967
$\overline{GR}^2$	0.631	0.647	0.632	0.634	0.626	0.635
Saragan's c^2	14.805 [0.47]	17.186 [0.44]	18.057 [0.32]	18.698 [0.29]	17.824 [0.27]	18.271 [0.31]
SER	0.011	0.011	0.012	0.011	0.011	0.011
$c^2(sc)$	1.446 [0.23]	0.863 [0.35]	0.124 [0.73]	0.954 [0.33]	1.049 [0.31]	1.042 [0.31]
$c^2(ff)$	0.045 [0.83]	1.319 [0.25]	2.227 [0.14]	0.873 [0.35]	0.898 [0.34]	0.896 [0.34]
$c^2(n)$	0.254 [0.88]	0.081 [0.96]	0.241 [0.89]	0.391 [0.82]	0.314 [0.86]	0.314 [0.86]
$c^2(hs)$	0.508 [0.48]	0.002 [0.97]	0.853 [0.36]	0.083 [0.77]	0.064 [0.80]	0.064 [0.80]

Notes: The absolute t-ratios are in the parentheses below the coefficients; * indicates significance at 5% and ** indicates significance at 10% level; p-values are in the square brackets for the ?^{2} tests; constrained estimates are denoted with (c). The ?^{2} test statistics with subscripts are, respectively, for serial correlation, functional form misspecification, non-normality of the residuals and heteroscedasticity.

TABLE-2

	VII	VIII	IX	X	XI	XII
Const.	-0.227 (3.15)*	-0.096 (2.91)*	-0.205 (7.59)*	-0.017 (0.17)	-0.150 (0.98)	0.190 (1.68)
l	-0.335 (6.34)*	-0.279 (6.84)*	-0.316 (8.10)*	-0.316 (3.40)*	-0.261 (5.53)*	-0.334 (8.07)*
HKI_{t-1}			0.006 (6.53)*		0.019 (0.14)	0.044 (0.45)
HKI_{t-1}^2			-0.001 (4.42)*			-0.040 (2.96)*
p_1	0.007 (4.49)*	0.010 (8.09)*		0.024 (3.69)*	0.010 (1.40)	0.018 (3.59)*
p_2	0.001 (0.23)	-0.010 (c)		-0.024 (c)	-0.010 (c)	-0.018 (c)
$\ln k_{t-1}$	0.466 (6.58)*	0.380 (5.55)*	0.437 (6.83)*	0.575 (3.45)*	0.385 (5.12)*	0.471 (7.61)*
$\ln HKI_{t-1}$				0.425 (c)		
$\Delta \ln k_t$	0.849 (26.29)*	0.846 (25.53)	0.834 (23.53)*	0.905 (23.57)*	0.850 (24.66)*	0.841 (26.87)*
$\Delta \ln k_{t-1}$	0.118 (3.67)*	0.114 (3.47)*	0.116 (3.62)*		0.100 (3.04)*	0.109 (3.50)*
? $HKIINV_{t-1}$	0.192 (0.47)	0.590 (1.78)**				
? $\ln HKI_{t-1}$				-0.439 (2.44)*		
? HKI_{t-1}					-0.105 (1.80)**	
IMP82	-0.050 (9.36)*	-0.048 (8.97)*	-0.054 (9.83)*	-0.034 (5.49)*	-0.047 (8.36)*	-0.054 (9.25)*
IMP63	0.050 (c)	0.048 (c)	0.054 (c)	0.034 (c)	0.047 (c)	0.054 (c)
STEP77	-0.050 (c)	-0.048 (c)	-0.054 (c)	-0.034 (c)	-0.047 (c)	-0.054 (c)
$\overline{R}^2$	0.969	0.967	0.970	0.950	0.967	0.970
$\overline{GR}^2$	0.772	0.775	0.639	0.764	0.770	0.773
Saragan's c^2	18.647 [0.35]	20.116 [0.33]	17.134 [0.45]	27.545 [0.12]	19.427 [0.37]	17.582 [0.48]
SER	0.011	0.011	0.011	0.014	0.011	0.011
$c^2(sc)$	0.732 [0.39]	0.565 [0.45]	2.196 [0.14]	0.670 [0.41]	0.767 [0.38]	1.833 [0.18]
$c^2(ff)$	1.720 [0.19]	2.103 [0.15]	1.343 [0.25]	0.991 [0.32]	2.016 [0.16]	1.893 [0.17]
$c^2(n)$	0.018 [0.99]	0.168 [0.92]	0.233 [0.89]	0.969 [0.62]	0.332 [0.85]	0.037 [0.98]
$c^2(hs)$	0.001 [0.98]	0.005 [0.95]	0.022 [0.88]	0.565 [0.45]	0.013 [0.91]	0.055 [0.82]

Notes: The absolute t-ratios are in the parentheses below the coefficients; * indicates significance at 5% and ** indicates significance at 10% level; p-values are in the square brackets for the $?^2$ tests; constrained estimates are denoted with (c). The $?^2$ test statistics with subscripts are, respectively, for serial correlation, functional form misspecification, non-normality of the residuals and heteroscedasticity.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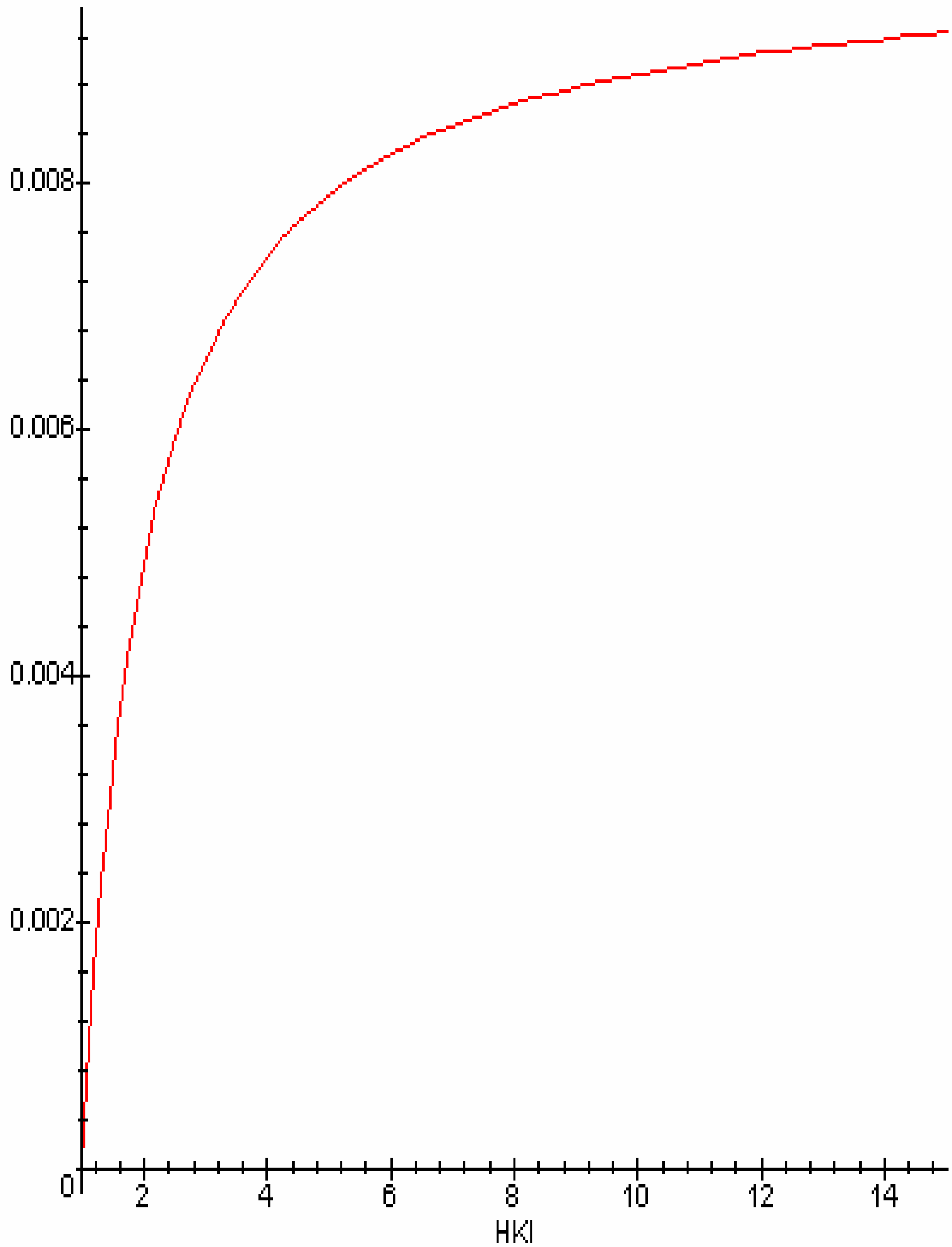
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