An extension to the neoclassical growth modelto Estimate Growth and Level Effects

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Abstract

The neoclassical growth model was extended by Mankiw, Romer and Weil (1992) to estimate the level effects of additional factors like human capital. We suggest a further extension to capture their permanent growth effects. Time series data from Fiji are used to show that the growth effect of human capital, although small, is significant. Furthermore, in our sample the specifications with a permanent growth effect performed better than specifications with only level effects.

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1. INTRODUCTION

In spite of the theoretical significance of the endogenous growth models (EGMs), doubts have been raised on their empirical significance by Mankiw, Romer and Weil (1992), Jones (1995) and Parente (2001). Solow (2000, p. 153) takes a similar view with the observation that "The second wave of runaway interest in growth theory-the endogenous-growth literature sparked by Romer and Lucas in the 1980s, following the neoclassical wave of the 1950s and 1960s-appears to be dwindling to a modest flow of normal science". More recent attempts by Gong, Greiner and Semmler (2004a, 2004b) to estimate EGMs with time series data have yielded less than impressive empirical results.[1]

The main contribution of the EGMs are twofold. They identify factors that affect the rate of technical progress, which is exogenous in the neoclassical growth model (NCGM), and show that these factors have permanent growth effects. Using some of these insights, Mankiw, Romer and Weil (1992), MRW henceforth, have extended NCGM by adding these variables as shift variables in the production function. Their extended NCGM explained about 80% of the variation in the growth rate. Subsequently, Bloom, Canning and Sevilla (2004), BCS hereafter, have used a modification to allow for non-linear level effects of the shift variables. The implication of these extensions is that the NCGM is satisfactory for growth accounting and development policy. However, these extensions did not capture an important difference between EGMs and NCGM. While in the extended NCGM, shift variables like human capital have only permanent level effects, in the EGMs they have permanent growth effects. In this paper we show that the NCGM can be modified to capture both the level and growth effects of the shift variables. Although due to multi-collinearity, it is difficult to empirically estimate both effects simultaneously it is possible to determine which of these two is more dominant. In our empirical

[1] Difficulties in estimating the deep parameters of the inter-temporal constant risk aversion utility functions (CRAUFs) are well known from the empirical work on Hall's (1978, 1988) random walk hypothesis. However, Ogaki and Reinhart (1998) and Fuse (2004) proposed a method of estimation by using durable and non-durable consumption expenditures. Nevertheless, EGMs based on the optimization framework with CRAUFs are important to identify growth determinants. Otherwise there, as Duraloauf, Johnson and Temple (2005) have observed, is no limit to the number of arbitrary variables in the empirical literature.

estimates with data from Fiji, we found that the growth effect of human capital, although very small, is significant and more dominant. The outline of this paper is as follows. Section 2 briefly considers a few modifications and alternative specifications to estimate level and growth effects with time series data. Section 3 presents our empirical results of the level and growth effects of human capital in Fiji for the period 1970 to 2002. Conclusions and limitations are in the final Section 4.

2. LEVEL AND GROWTH EFFECTS

Estimates of NCGM, with time series data, are closer in spirit to Solow (1957), which is the basis for growth accounting, than Solow (1956).[2] The production function is estimated by taking into account that the variables are generally non-stationary in levels and stationary in their first differences. Therefore, specifications based on the familiar error correction model (ECM) are used in the empirical works.[3] A widely used autoregressive distributed lag specification with ECM, known as the LSE-Hendry general to specific approach (GETS), and a constant returns Cobb-Douglas production function with the Hicks neutral technical progress is as follows:

$$\begin{aligned}\Delta ln\ Y_t = & -\lambda[ln\ Y_{t-1} - (ln\ A_0 + gT + \alpha ln\ K_{t-1} + (1-\alpha) ln\ L_{t-1})] \\ & + \sum_{i=0}^{n1} \gamma_{1i} \Delta ln\ L_{t-i} + \sum_{i=0}^{n2} \gamma_{2i} \Delta ln\ K_{t-i} + \sum_{i=1}^{n3} \gamma_{3i} \Delta ln\ Y_{t-i} \quad (1)\end{aligned}$$

where Y is output, T is time trend, K is capital and L is employment. The coefficient of trend g captures the rate of technical progress, λ is the speed of adjustment to equilibrium and A_0 is the initial stock of capital.[4]

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[2] Since the estimated parameters of the production function are adequate for analyzing the steady state properties in Solow (1956), time series estimates can be also used for this purpose.

[3] There are several works based on *ad hoc* specifications in which the rate of growth of output is regressed on a variable or a set of variables to determine their contribution to growth. To conserve space we avoid citations to such works.

[4] In per worker terms (1) will be

$$\Delta ln\ y_t = -\lambda\Big[ln\ y_{t-1} - (ln\ A_0 + gT + \alpha ln\ k_{t-1}\Big]$$

Following MRW, the effects of shift variables like human capital, openness of the economy and investment ratio etc., are introduced into the specification with the implicit assumption that they only have level effects. If Z is a shift variable and it is a factor efficiency improving shift variable, e.g., human capital, it can be introduced into (1) with the assumption that it affects the measured employment.

$$\begin{aligned}\Delta ln\ Y_t = -\lambda\Big[& ln\ Y_{t-1} - (ln\ A_0 + \alpha ln\ K_{t-1} \\ & + (1-\alpha)\ ln(\ L_{t-1} \times Z_{t-1})\Big] + \sum_{i=0}^{n1} \gamma_{1i} \Delta ln\ L_{t-i} \\ & + \sum_{i=0}^{n2} \gamma_{2i} \Delta ln\ K_{t-i} + \sum_{i=1}^{n3} \gamma_{3i} \Delta ln\ Y_{t-i} + \sum_{i=0}^{n4} \gamma_{4i} \Delta Z_{t-i}\end{aligned} \quad (2)$$

On the other hand, if Z simply shifts the production function, e.g., openness of the economy, it can be introduced into (1) as follows:

$$\begin{aligned}\Delta ln\ Y_t = -\lambda\Big[& ln\ Y_{t-1} - (ln\ A_0 + A_1 Z_{t-1} + \alpha ln\ K_{t-1} \\ & + (1-\alpha) ln\ L_{t-1})\Big] + \sum_{i=0}^{n1} \gamma_{1i} \Delta ln\ L_{t-i} \\ & + \sum_{i=0}^{n2} \gamma_{2i} \Delta ln\ K_{t-i} + \sum_{i=1}^{n3} \gamma_{3i} \Delta ln\ Y_{t-i} + \sum_{i=0}^{n4} \gamma_{4i} \Delta Z_{t-i}\end{aligned} \quad (3)$$

There is an one to one relationship between (2) and (3) and it is hard to decide which is better. However, (3) is convenient for capturing any non-linear effects Z may have as follows:

$$+ \sum_{i=0}^{n2} \pi_{2i} \Delta ln\ k_{t-i} + \sum_{i=1}^{n3} \pi_{3i} \Delta ln\ y_{t-i} \quad (1A)$$

where $y = (Y/L)$ and $k = (K/L)$. Both specifications have been used in the time series country specific studies.

$$\begin{aligned}\Delta ln\ Y_t = -\lambda\Big[&ln\ Y_{t-1} - (ln\ A_0 + A_1 Z_{t-1} + A_2 Z_{t-1}^2 + \alpha ln\ K_{t-1} \\ &+ (1-\alpha) ln\ L_{t-1})\Big] + \sum_{i=0}^{n1} \gamma_{1i} \Delta ln\ L_{t-i} + \sum_{i=0}^{n2} \gamma_{2i} \Delta ln\ K_{t-i} \\ &+ \sum_{i=1}^{n3} \gamma_{3i} \Delta ln\ Y_{t-i} + \sum_{i=0}^{n4} \gamma_{4i} \Delta Z_{t-i} + \sum_{i=0}^{n5} \gamma_{5i} \Delta Z_{t-i}^2\end{aligned} \tag{4}$$

The specification in (2) is consistent with the MRW specification in their cross-country study. Equations (2) and (3) have been used by BCS in their cross-country study to capture the effects of improvements in health on growth.

In extending the NCGM to capture the permanent growth effects of Z, it is important to remember Jones' (1995) finding that there is no evidence that shift variables like Z had actually increased the growth rate continuously. In other words, these growth effects seem to converge to a limit as the shift variables increase over time. Note that if Z has a permanent growth effect, it should affect the magnitude of g in (1), i.e., $g = \Phi(Z)$. We propose a simple specification which is consistent with the observations of Jones as follows:

$$\begin{aligned}\Delta ln\ Y_t = -\lambda\Big[&ln\ Y_{t-1} - (ln\ A_0 + (\theta_1 - \theta_2/Z_t)T + \alpha ln\ K_{t-1} \\ &+ (1-\alpha) ln\ L_{t-1})\Big] + \sum_{i=0}^{n1} \gamma_{1i} \Delta ln\ L_{t-i} + \sum_{i=0}^{n2} \gamma_{2i} \Delta ln\ K_{t-i} \\ &+ \sum_{i=1}^{n3} \gamma_{3i} \Delta ln\ Y_{t-i} + \sum_{i=0}^{n4} \gamma_{4i} \Delta Z_{t-i}^{-1}\end{aligned} \tag{5}$$

It is easy now to develop a specification that captures both the level and growth effects of Z. For illustration, we shall use the BCS linear level effects and it is:

$$
\begin{aligned}
\Delta ln\ Y_t = -\lambda\Big[& ln\ Y_{t-1} - (ln\ A_0 + A_1 Z_{t-1} + (\theta_1 - \theta_2/Z_{t-1})T \\
& + \alpha ln\ K_{t-1} + (1-\alpha) ln\ L_{t-1})\Big] + \sum_{i=0}^{n1} \gamma_{1i} \Delta ln\ L_{t-i} \\
& + \sum_{i=0}^{n2} \gamma_{2i} \Delta ln\ K_{t-i} \sum_{i=1}^{n3} \gamma_{3i} \Delta ln\ Y_{t-i} \\
& + \sum_{i=0}^{n4} \gamma_{4i} \Delta Z_{t-i}^{-1} + \sum_{i=0}^{n5} \gamma_{4i} \Delta Z_{t-i}
\end{aligned} \tag{6}
$$

In (5) and (6), as Z increases, the parameters of T converge to θ_1. The initial period estimate of the rate of technical progress, if Z is measured as an index number and set to unity at the beginning of the sample period, will be $(\theta_1 - \theta_2)$.

3. EMPIRICAL RESULTS

We assume that there is only one shift variable viz., human capital HKI. It is measured as the product of two index numbers viz., education levels (EDU) and life expectancy (LE) since both variables improve labour efficiency. Data from Fiji for the period 1970 to 2002 are used for estimation and the details of the definitions of variables and sources of data are in the Appendix. All the variables are tested for their order and found to be $I(1)$ in levels and $I(0)$ in first differences. To conserve space these are not reported but may be obtained from the authors.

All the six specifications from the previous section have been estimated with the two stage non-liner instrumental variables method to minimize endogenous variables bias. Lagged values of the variables are used as instruments. Equation I in Table-1 is an estimate of the standard production function in (1) with the trend to capture the average rate of growth of technical progress. All the coefficients are significant at the conventional levels and the summary χ^2 tests show that serial correlation, functional form misspecification, non-normality of residuals and heteroscedasticity are insignificant. The Saragan χ^2 is insignificant indicating that the choice of instruments is valid. The Pesaran and Smith $\bar{R}^2 = 0.572$ and implies that about 57% the variation in the growth rate is explained by equation I.

A somewhat standard but unfair criticism of the LSE-Hendry GETS approach is as follows. GETS is flawed because both $I(1)$ level variables (in the ECM part) and $I(0)$ (in the ARDL part) appear in its specification. This is not consistent with the standard approach used in the time series econometrics. Furthermore, GETS does not have a formal procedure for testing for cointegration. In the context it is important to note that Banejee, Dolado, Galbraith, and Hendry (1993) have argued that GETS is asymptotically as good as the fully modified OLS (FMOLS) approach of Phillips and Hansen. It is also important to note that, unlike FMOLS, GETS equations can be also estimated with the instrumental variables method to minimize the endogenous variable bias if any; see also Banerjee, Dolado and Mestre (1998). Recently, Ericsson and MacKinnon (2002) have developed an easy to use test for cointegration between the levels of the variables in the GETS equations. This is similar to the MacKinnon test for testing cointegration in the Engle and Granger two-step procedure. The Ericsson and MacKinnon test shows that the null of no cointegration can be rejected in equation I at the 5% level. The 5% critical value for this test statistic ($K_{ct}(3)$) is -4.1139 and is less than the t-ratio of λ of 5.8228 in equation I. The estimated share of capital at 0.22 is plausible. The coefficient of trend indicates that technical progress is very low in Fiji at about half percent per year. When equation I is re-estimate without the trend (not reported to conserve space) $\overline{G}R^2$ deteriorated to 0.29 and the residuals are found to be serially correlated. This implies that there are some unknown factors that affect output and they are highly trended.

While estimating the MRW specification in equation (2) we found that several coefficients are insignificant. When the constraint that the coefficients of employment and human capital are equal is relaxed, the estimated coefficients became significant and these are reported in equation II of Table-1. Although its summary χ^2 statistics are satisfactory, it is a disappointing result because, compared to equation I with time trend, its $\overline{G}R^2$ has declined to 0.409 and the t-ratio of the λ is less than the Ericsson and MacKinnon test statistic, implying that there is no cointegration.[5]

Equation III and IV are estimates of the BCS specifications in equations (3) and (4), with linear and non-liner effects of HKI re-

[5] From now on we shall use the values for θ_∞as the critical values, without the small sample adjustment in Ericsson and MacKinnon (2002), unless the t-ratio of λ is on the borderline.

TABLE-1
Level and Growth Effects of HKI in Fiji: 1970 - 2002
2SNLLS-IV ESTIMATES

	I	II	III	IV	V	VI	VII
Const.	-3.263 (34.25)*	-3.308 (17.61)*	-3.287 (22.36)*	-3.034 (5.05)*	-3.241 (29.74)*	-3.237 (35.07)*	-3.229 (35.24)*
Trend	0.005 (7.34)*						
λ	-1.238 (5.82)*	-0.900 (3.71)*	-1.030 (5.08)*	-1.024 (9.67)*	-1.245 (6.29)*	-1.248 (6.54)*	-1.237 (6.23)*
HKI_{t-1}			0.035 (2.14)*	-0.074 (0.58)			-0.005 (0.25)
HKI^2_{t-1}				0.023 (0.18)			
θ_1					0.005 (4.73)*	0.005 (7.41)*	0.006 (3.70)*
θ_2					-0.002 (0.49)	-0.002 (c)	-0.002 (c)
$\ln K_{t-1}$	0.217 (7.18)*	0.201 (3.47)*	0.196 (4.39)*	0.242 (3.58)*	0.223 (6.72)*	0.224 (7.55)*	0.224 (7.34)*
$\ln L_{t-1}$	0.783 (c)	0.799 (c)	0.804 (c)	0.758 (c)	0.777 (c)	0.776 (c)	0.776 (c)
$\ln HKI_{t-1}$		0.125 (3.34)*					
$\Delta \ln L_t$	0.554 (2.75)*	0.721 (2.63)*	0.587 (2.98)*	0.527 (3.02)*	0.604 (3.80)*	0.606 (3.94)*	0.595 (3.66)*
$\Delta \ln K_t$			-0.789 (2.38)*	-0.786 (2.35)			
COUP	-0.038 (2.57)*	-0.031 (1.59)	-0.037 (2.26)*	-0.037 (2.59)	-0.037 (2.56)*	-0.037 (2.61)*	-0.038 (2.57)*
DUM95	0.038 (c)	0.031 (c)	0.037 (c)	0.037 (c)	0.037 (c)	0.037 (c)	0.038 (c)
$\overline{R}^2$	0.604	0.328	0.490	0.479	0.580	0.598	0.582
$\overline{GR}^2$	0.572	0.409	0.556	0.561	0.661	0.675	0.662
Saragan's χ^2	3.400 [0.76]	7.894 [0.25]	7.062 [0.42]	6.533 [0.48]	2.237 [0.86]	3.382 [0.91]	3.192 [0.87]
SER	0.031	0.040	0.035	0.035	0.032	0.031	0.032
$\chi^2(sc)$	0.253 [0.62]	2.130 [0.14]	2.159 [0.14]	2.086 [0.15]	1.310 [0.25]	1.301 [0.25]	1.291 [0.26]
$\chi^2(ff)$	0.977 [0.32]	0.001 [0.98]	0.110 [0.74]	0.272 [0.60]	0.780 [0.37]	0.745 [0.39]	0.846 [0.36]
$\chi^2(n)$	1.068 [0.59]	1.365 [0.51]	1.619 [0.45]	1.073 [0.59]	1.337 [0.51]	1.361 [0.51]	1.220 [0.54]
$\chi^2(hs)$	3.178 [0.08]	0.694 [0.41]	2.099 [0.15]	2.040 [0.15]	1.762 [0.18]	1.733 [0.19]	1.803 [0.18]

Notes: The absolute t-ratios are in the parentheses below the coefficients; p-values are in the square brackets for the χ^2 tests; constrained estimates are denoted with (c). The χ^2 test statistics with subscripts are, respectivey, for serial correlation, functional form misspecification, non-normality of the residuals and heteroscedasticity.

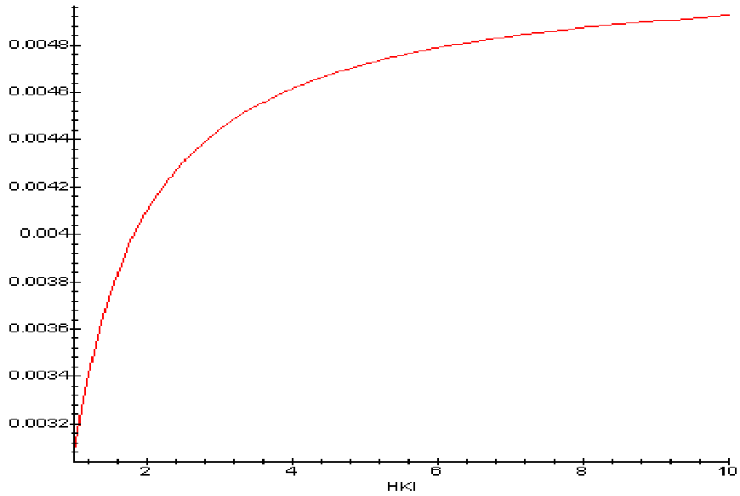
spectively. While the summary χ^2 test stistics of both equations are insignificant, the coefficients of the non-linear effects are insignficant in equation IV. Furthermore, the coefficient of HKI is negative and that of HKI^2 is postive and contrary to espectation. However, compared to IV, equation III with only the linear effects is superior in that all of its coefficients are significant and its $\overline{G}R^2$ is the same. The t-ratio of λ at 5.08 is higher than the Ericsson and MacKinnon 5% critical value of 3.33 rejecting the null of no cointegration.

In equations V and VI we report the unconstrained and constrained versions of the specification with only growth effects in equation (5). This is first estimated without any constraints on the θ_1 and θ_2 and is shown as equation V. Although these parameters have the expected positive and negative signs respectively, θ_2 is insignificant.This may be due to the high correlation of 0.875 between T and HKI^{-1}. There are two possible solutions here. First, V can be estimated with the constraint that the ratio of θ_2 to θ_1 equals their ratio in this equation which as about 0.4. Alternatively, it may be assumed that $\theta_2 = -\theta_1$, which implies that technical progress in the initial period was zero. We report in equation VI of Table-1, only estimates with the first option because its $\overline{G}R^2$ of 0.675 is higher compared to 0.652 with the second option. Equation VI is well determined and has the highest $\overline{G}R^2$ among all our estimates. All of its coefficients are significant and the summary χ^2 test statistics are all insignificant. The t-ratio of λ of 6.54 exceeds the 5% Ericsson and MacKinnon critical value of 3.33, rejecting the null of no cointegration.

Finally, the estimate of (6) with both the growth and level effects is given as equation VII in Table-1. Although its summary χ^2 tests and $\overline{G}R^2$ are good, it can be seen that the BCS level effects are insignificant and also the sign of this coefficient is negative and contrary to expectation. We have also estimated the MRW and the non-linear BCG versions of (6). In the MRW version several coefficients are insignificant and in the BCS non-linear version, the two coefficients of the level effects are insignificant. These are not reported to conserve space. On the basis of these estimates, it can be said that equation VI, with only growth effects, is the best equation. This equation implies that although the growth effects of HKI are small, they are significant and clearly dominates the specifications with only level effects and level and growth effects. At the beginning of the sample period in 1970 when $HKI = 1$, the rate of technical progress in Fiji was very modest at 0.003 per year. However, this has improved by 48%

to 0.0046 by 2002 due to the increase in HKI by about 130%. A further doubling of HKI from its 2002 value of 3.626, say in the next 10 years, will add to the growth rate only by another 0.6 of a percent. Thus, there is some scope to improve Fiji's growth rate by improving HKI, although this growth effect is seems to be very small as shown in Figure-1 below.

FIGURE-1
GROWTH EFFECTS OF HKI



4. CONCLUSIONS

In this paper, we have extended the neoclassical growth model to capture the level and growth effects of the shift variables. Our approach is in the spirit of the MRW and BCS methodology and extended their cross-country specifications for estimating with country specific time series data. We found that in Fiji the growth effects of human capital clearly dominated its level effects. However, these growth effects are very small, but significant. Further application of our framework to other countries, especially with higher rates of technological progress than Fiji, would be useful to indicate if such growth effects always dominate the level effects. In the meantime it may be said that the endogenous growth models which emphasise the permanent growth effects should not be dismissed as empirically unimportant. However, the simpler neoclassical growth model can be extended to capture such permanent growth effects even if they are small.

Data Appendix

Y is the real gross domestic product in 1990 prices.

L is employment in the informal and formal sectors.

K is capital stock, estimated with the perpetual inventory methods with the assumption that the depreciation rate is 4%. The initial capital stock estimate used for 1970 is F$1446.225 million is from Fiji's 8^{th} Economic Development Plan. Investment data used to compute K includes investment in private and public corporate sectors.

LE is life expectancy in years and LEI is the index number of LE with the assumption that in 1970 $LEI = 1$.

EI is the education index number which is 1 in 1970. The proportion of enrollments to population of primary, secondary and university enrollments is used to estimate the education levels of the employed workers. Workers with no formal education are given a weight of one. Workers with primary, secondary and tertiary education are given weights of 1.134, 1.244 and 1.312 respectively. The aggregated series is converted into an index number. The weights selected reflect the earnings differences and these are from Hall and Jones (1999).

HKI is the product of LEI and EI.

COUP is 1 in 1987, 1988 and 1989. Zero in all other periods.

OUTLIERS is a dummy variable taking a value of 1 in 1995, 1996, 2001 and −1 in 1997. In all other periods it is zero.

Sources of Data:

1. Output, employment and investment data are, respectively, from the IFS CD-ROM 2003, BOS publications and the RBF Quarterly Review (various issues).
2. Enrollments data are from the Financial Reports for the Ministry of Education (various issues) and from the Planning and Development Office of the USP.
3. Total population data are from Key Statistics, June 2005 issue.
4. Life expectancy data are from the World Bank Indicators CD-Rom, 2004.

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