.

DETERMINANTS OF GROWTH RATE: SOME METHODOLOGICAL ISSUES WITH DATA FROM FIJI

B. Bhaskara Rao

rao_b@usp.ac.fj

University of the South Pacific, Suva (Fiji)

Maheshwar Rao

rao_m@usp.ac.fj

University of the South Pacific, Suva (Fiji)

Abstract

Compared to many cross-country studies on the determinants of growth rate, time series approaches are relatively few and limited in scope. However, time series studies are useful for country-specific policies. But in many recent works *ad hoc* specifications have been used to analyze the contribution of various factors to growth. This paper examines the specification and estimation issues in the time series approach and provides some guidelines. Our approach is used to illustrate the effects of trade openness on the growth rate of Fiji.

JEL: N1, O1, O4;

KEYWORDS: The Solow Growth Model, Production Function, General to Specific Approach, Trade Openness and Growth.

* We wish to thank Rup Singh for providing the data and for comments.

I. INTRODUCTION

The seminal cross section works on the determinants of the growth rate by Barro (1991, 1999), Levine and Renelt (1992) and Sala-I-Martin (1997) have induced scores of empirical works with cross section and panel data. Hoover and Perez (2004) and Durlauf, Johnson and Temple (2004) have surveyed and evaluated several works. Although the scope of cross section studies is wide and perhaps more appropriate for development accounting, they assume similar structures for all countries in the sample. Consequently, it is difficult to identify country specific growth policies. For example, if expenditure on R&D is found to be a significant determinant of growth rate, it may not be useful for growth policies of the developing countries which have not yet fully utilized available technologies. Therefore, country specific studies based on time series data, in spite of some limitations, are useful.[1]

Some seminal works with time series data, e.g. Young (1995), have examined a limited range of broad issues from a growth accounting perspective. While they are useful for identifying the relative contributions of factor accumulation and the Solow residual, it is not known on what factors the latter depends. This residual, which could be as much as fifty percent, is attributed to unknown improvements in efficiency. Although endogenous growth theories have identified some key determinants of the residual, Barro's seminal cross section work has identified several additional potential determinants and served as a benchmark for subsequent empirical works. More recently, Bosworth and Collins (2003) have synthesized various developments and provided an elegant cross section framework for further investigations. They draw a distinction between a set of conditioning variables and various other potential determinants of growth. These conditioning variables are retained in alternative regressions while analyzing the

[1] The need for time series studies can be further justified for other reasons. Although cross section studies have provided many useful insights, their immediate policy implications for improving growth rates are not attractive to policy makers. For example, policy makers in a developing country are less interested in whether India or Fiji will converge to US standards in another 100 years. Similarly, there is no distinction between policies that can be quickly implemented to improve growth rates and those that need considerable time (and resources) for their effects to take place. For example, policies that improve factor growth, say through investment incentives, are quicker to implement than raising the levels of education or increasing expenditure on R&D.

effects other potential determinants of growth.

The aforesaid developments in the cross section studies have useful implications for developing time series approaches. Durlauf, Johnson and Temple (2004) have observed, the number of potential determinants of growth, other than factor accumulation, could be as many as the number of countries in a cross section study. It is important, therefore, to avoid *ad hoc* specifications to demonstrate the relevance or irrelevance of a small set of selected variables. Following Bosworth and Collins (2003), it is useful to identify some key conditioning determinants of growth and retain them in the subsequent regressions to analyze the significance of other potential determinants. This approach is also consistent with the *chipping away* strategy of Caselli (2004) to reduce the size of the residual in the growth and development accounting exercises.[2] However, many recent country specific time series works have used *ad hoc* specifications of the growth equation. Often these works show that growth and one or two selected variables, say $X1$ and $X2$ are cointegrated and $X1$ and $X2$ Granger cause growth and therefore a 10% increase say in $X1$ leads to 2% improvement in the growth rate.[3] Our paper is concerned with the methodological issues in the specification and estimation of growth equations with time series data since these are useful for understanding country specific policies and are likely to become popular. Its

[2] Caselli also suggests that improvements in measuring the basic conditioning variables, e.g. factor inputs, could also reduce the residual.

[3] There is also considerable confusion about the limitations of the Granger causality tests, in spite of many warnings by Granger. The Granger causality tests are essentially tests on whether one of the right-hand side variables, say X_t, changes when there was disequilibrium in the left-hand dependent variable Y in period $t-1$. This is the weak exogeneity test. If ΔX_t is also not affected by ΔY_t, then X is strongly Granger exogenous and ΔX_t may be included in the ARDL for ΔY_t. Granger causality tests are not, therefore, cause and effect tests. This point is especially emphasized by Stock and Watson (2003, p.449) with the observation "While 'Granger predictability' is a more accurate term than 'Granger causality' the latter has become part of the jargon of econometrics."

Insights into the nature of cause and effect relationships, therefore, should be based on the underlying economic theory. The endogenous growth theories are not developed after conducting Granger causality tests. For these reasons Sims (2000) is critical about cointegration techniques for using economic theory in a casual manner for identification.

At an empirical level Edwards (1998) and Asterious and Price (2004) are two good examples, offering adequate theoretical justification, for the inclusion of openness and growth of financial sector in growth equations respectively.

outline is as follows. In Section II the specification and estimation problems are discussed. Section III has empirical results for Fiji and Section IV concludes.

II. SPECIFICATION

Like in several cross section studies, the basic framework in time series studies is the Solow growth model in which the rate of growth of output, in the non-steady state, depends on the rates of growth of factors of production (capital and labour) and the technology residual. Behind this growth equation is the neoclassical production function in which the level of output (Y) depends on the levels of capital stock (K), employment (L) and the stock of technology (A) and this can be stated as:

$$Y_t = F(K_t, L_t, A_t) \tag{1}$$

Following the developments in the endogenous growth theory, Barro has examined the significance of various shift variables to (1). Scores of cross-country studies have investigated the relative importance of the key variables in (1) and alternative shift variables, of which some important ones are the openness of trade, determinants of human capital and R&D, government policy, quality of institutions and political freedom, development aid, financial reforms etc. For a brief survey see Sala-I-Martin (2002). Furthermore, due to lack of reliable data on capital stock in many countries, the ratio of investment to output (investment ratio) is used in several cross-country studies. In a limited number of time series studies similar practices are also followed. Bosworth and Collins (2003) is perhaps an exception to this trend. In fact they show that investment ratio, as a proxy for capital, gives poor results.

A stylized fact about estimating production functions and conducting growth and development exercises is that factor accumulation explains about half the variation in output growth. The rest is the famous Solow residual. As stated at the outset the Solow residual is actually our measure of ignorance of the determinants of the growth rate. Inclusion of a trend variable in the production function does not essentially change the nature of the Solow residual. A significant trend only implies that there are other potential shift variables and these are highly trended. Endogenous growth theories may be seen as rationalizations for the inclusion of some key shift variables into the neo classical production function such as the determinants of human capital formation and R&D expenditure. These variables may also have significant externalities and therefore it is necessary to relax the constant returns and perfect competition assumptions of the Solow model. However, it is well known that Mankiw, Romer and Weil (1992) have shown, by including human capital as a shift variable into the neo classical production function, our measure of ignorance can be considerably reduced and without the need for changing the basic simplifying assumptions of the Solow model. Their cross section study has explained about 80% variation in the growth rate when the neoclassical production function was augmented with human capital. Acemoglu (2004), therefore, considers Mankiw, Romer and Weil (2002) as an attempt to revive the usefulness of the basic Slow growth model. Hall and Jones (1999) take a different view on the adequacy of the Solow model by emphasizing that differences in the social infrastructure are more important than human capital. Klenow and Rodriguez (1998) argue that if enrollments in primary education, which does not show much variation across the countries, is used as a measure of human capital, then factor accumulation explains only 40% variation in the growth rate. The main difficulty in using human capital as a shift variable is that it is hard to develop a satisfactory measure reflecting differences in the quality of education. In more recent development accounting exercises, augmenting the production function with human capital, at best, produced weak or ambiguous results; see Bosworth and Collins (2003), Caselli (2004) and Lindaur and Pritchett (2002). This may be due to the inclusion of more than one or two potential shift variables in the recent studies implying that ignoring these additional variables leads to the omitted variables bias. In this respect, it may be said that these recent works are more useful for policy than the earlier limited debates on whether factor accumulation or the Solow residual is a more important determinant of the growth rate. If these more recent developments are to be incorporated into time series works to investigate the significance of other potential shift variables, we may schematically write (1) as:

$$Y_t = F(K_t, L_t, A_t, Z_t) \tag{2}$$

where Z_t is a vector of some potential shift variables. Within this framework whether factor accumulation or the Solow residual is the more important determinant of growth is secondary. First, it helps to understand how much of the total variation in growth can be explained by factor accumulation and other shift variables and second it helps to get insights into some potential key determinants, other than a time trend, of the Solow residual. For these reasons, time series approaches are more promising for analyzing country specific growth policies.

In the time series studies, in contrast to cross section studies, the dynamics underlying (2) is important. Since (1) and (2) are purely theoretical static equilibrium equations in the *levels* of the variables, several current empirical works have used cointegration methods to capture the long run equilibrium relationship between the levels of variables and the error-correction (ECM) plus ARDL specifications to develop the short run dynamics of the growth rate. However, in virtually all such empirical works, capital and labour–the conditioning variables–have been ignored. Different techniques have been applied to find cointegrating vectors between the levels of output (Y) and only the hypothesized shift variable or variables in the vector Z. Needless to say ignoring the two key conditioning variables, K and L, amounts to misspecification and leads to the usual omitted variables bias. Cointegrating equations, without these conditioning variables, are therefore suspect.

A popular shift variable in (2), especially for the developing countries, is trade openness. There are scores of time series empirical works based on the misspecified growth equations where the links between growth and openness are examined. Instead of lengthening our list of references, we draw attention to a couple of recent works by Chandra (2003) and Sharma and Panagiotidid (2004) which apply cointegration and ECM approach to analyze the effects of trade on the growth rate of India. This is not to pillory these works in particular, because Sharma and Panagiotidid has a useful evaluation of trade policies in India and both works survey and give references to earlier works. For examples with other shift variables, using misspecified specifications, see Fasano and Wang (2002) for the effects of government expenditure on growth and Abu-Badar and Abu-Qarn (2003) for the effects of military spending on growth and so forth.

A useful first approximation for openness is the ratio of exports plus imports to output. However, there are other measures of openness and trade liberalization. For example, in a benchmark cross section study on growth and openness Edwards (1998) has used nine alternative measures of trade openness and also a composite index based on the principle components technique. However, many of his indices are appropriate for cross section regressions because data on all of these variables are not available for use in time series regressions.[4] Bosworth and Collins (2003) have used the Frankel-Romer (1999) trade instrument and the popular Sachs and Warner (1995) measures. In a novel attempt, Chand and Sen (2002) have used the difference between the industry specific price indices in India and the USA to proxy trade openness. But these works have also used cross section data and Bosworth and Collins have retained several conditioning variables, including capital per worker, in their specification. Similarly, Chand and Sen have more explicitly retained K and L in their panel data study of the effects of trade liberalization on technical progress in the Indian manufacturing industries.

It is important to pay attention to the methodology underlying such recent cross section studies to understand the need to retain the conditioning variables in the time series studies. However, in contrast to the aforesaid time series studies with misspecified growth equations, Asteriou and Price (2004) have retained the conditioning variables in their analysis of the effects of developments in the financial sector on UK's growth rate.[5] Since our objective is methodological, we shall ignore secondary issues like what are the most appropriate cointegration techniques or which measure of openness is the best. Therefore, we do not claim that this paper is a definitive attempt to investigate whether trade openness is or is not an important determinant of the growth rate in Fiji. We have also avoided empirical results for other countries, based on our methodology, since our results are adequate

[4] The nine measures used by Edwards are: (1) Sachs and Warner (1995)openness index (either 1 or 0) (2) World Development Report's outward orientation index (ranges from 1 to 4) (3) Leamer's (1988) openness index (4) average black market exchange rate premium (5) average import tariff on manufacture goods (6) average coverage of non-tariff barriers (7) the Heritage Foundation's index of distortions in international trade (ranges from 1 to 5) (8) trade taxes ratio and (9) Wolf's regression based index of import distortions. In principle (5) and (8) are more useful in time series regressions but these proxies need considerable effort to estimate on a continuous basis. Furthermore, it is hard to say that these two measures openness better than the trade ratio.

[5] Asteriou and Price (2004) seems to be the first systematic time series work to retain the conditioning variables to analyze the significance of the potential shift variables in the Solow production function. Although they have used their approach to analyze the significance of growth in the financial sector on output, their methodology is useful to analyze the significance of other potential shift variables.

to illustrate our main point.

III. ESTIMATION

We assume a log-linear relationship for (2) with Hicks neutral technology and that A_t grows at a constant rate. Furthermore, for illustrative purpose, we assume that there is a single shift variable viz., openness of the economy, which is the ratio of exports plus imports to GDP. Therefore, (2) can be expressed as:

$$lnY_t = \alpha_0 + \alpha_1 T + \alpha_2 lnK_t + \alpha_3 lnL_t + \alpha_4 lnZ_t + \epsilon_t \tag{3}$$

where T is time, Z_t is a measure of trade openness and ϵ is an error with the usual classical properties. The implied growth equation is:

$$\Delta lnY_t = \alpha_1 + \alpha_2 \Delta lnK_t + \alpha_3 \Delta lnL_t + \alpha_4 \Delta lnZ_t + \xi_t \tag{4}$$

Note that ξ is also a random error since by assumption, ϵ_t is not correlated with its lagged values.

In virtually all empirical works with shift variables, cointegrating relationships are estimated only between Y and Z, ignoring the conditioning determinants K and L; see Ekanayake (1999), Dubey (2003), Chandra (2003), and Sharma and Panagiotidis (2004) and the references cited in these works. While these procedures are intuitively appealing, they ignore the underlying basic Solow model, causing omitted variables bias and inferences from misspecified growth equation are unreliable. The appropriate dynamic version for (4), irrespective of the method of estimation, incorporating the theoretical information on the levels of the variables is:

$$\begin{aligned}\Delta lnY_t = & \sum_{i=1}^{n1} \beta_{1i} \Delta lnK_{t-i} + \sum_{i=1}^{n2} \beta_{2i} \Delta lnL_{t-i} \\ & + \sum_{i=1}^{n3} \beta_{3i} \Delta lnZ_{t-i} + \sum_{i=1}^{n4} \beta_{4i} \Delta lnY_{t-i} \\ & - \lambda \Big[lnY_{t-1} - (\alpha_0 + \alpha_1 T + \alpha_2 lnK_{t-1} + \alpha_3 lnL_{t-1} + \alpha_4 lnZ_{t-1}) \Big] \\ & + \omega_t \end{aligned} \tag{5}$$

where λ is the adjustment coefficient and the expression in the square brackets is the lagged error. The order of $n1, n2, n3$ and $n4$ is selected to be consistent with the underlying data generating process (DGP). If the right hand variables are Granger exogenous, their contemporaneous first differences may be included in (5). The term in the square brackets is important since it is the underlying equilibrium relationship between the levels of the variables.

For comparison with (5) the misspecified specification, used by many, is of the following type or its variants depending on whether the intercept and trend are constrained and included in the cointegrating equation:

$$\begin{aligned}\Delta lnY_t = \pi_0 &+ \sum_{i=1}^{m1} \pi_{1i} \Delta lnZ_{t-i} \\ &+ \sum_{i=1}^{m2} \pi_{2i} \Delta lnY_{t-i} \\ &- \lambda \Big[lnY_{t-1} - (\gamma_0 + \gamma_1 T + \gamma_2 lnZ_{t-1}) \Big] + \varepsilon_t \end{aligned} \qquad (5A)$$

If all the variables in (5) are non-stationary in their levels and stationary in first differences, standard cointegration techniques, like the Engle-Granger two step (EG), Phillips-Hansen fully modified OLS (FMOLS) and Johansen maximum likelihood (VECM) methods, can be used and the corresponding error correction model (ECM) in (5) can be estimated. The underlying long run equilibrium relationship is captured by the estimated cointegrating vector(s). Although the Johansen VECM is widely used, often it is difficult to get meaningful cointegrating vectors with small samples where the order of the VAR is restricted. In contrast EG and FMOLS are easy to implement. However, it is well known that FMOLS is an improvement on EG in that it takes into account (a) serial correlation in the residuals (b) endogeneity of the variables in the cointegrating vector and (c) lack of any dynamics in the first stage OLS equation in EG. A technique similar to FMOLS is the LSE-Hendry general to specific approach (GETS). In its current form, GETS is consistent with the standard EG cointegration approach. However, GETS is often criticized because, it estimates both the long run equilibrium parameters and the ARDL parameters in one step. Therefore, it gives the impression that it is a regression of I(0) first differences and I(1) variables in levels. Hendry has stated many times that this criticism is not correct because if the I(1) level variables are cointegrated, their linear combination is I(0); see Hendry and Doorink (1994) and Hendry and Krolzig (2000). Furthermore, Banerjee et.al. (1993) and Hendry (1994) have shown that, like FMOLS, GETS is an improvement on EG and asymptotically equivalent to FMOLS; see also Patterson (2000). Therefore, in this paper we shall use both FMOLS and GETS to illustrate the consequences of estimating misspecified growth equations.

Data from Fiji are used for the period 1970 to 2002 and the capital stock series are constructed with TSP, using the perpetual inventory method, with the assumption that the depreciation rate is 4%. In the cross section studies depreciation rates from 4% to 6% are used to estimate capital stock. In their recent study Bosworth and Collins (2003) have used 4% depreciation rate. Further details on the definitions of the variables and sources of data are in the Appendix. All the variables are tested for unit roots and found to be I(1) in levels and I(0) in their first differences.[6]

Equations (6) and (7) in Table-1 give estimates of the misspecified growth equation (5A) with FMOLS and GETS respectively. The coefficients of the cointegrating vector from FMOLS are explicity shown for comparison with GETS. The latter is estimated with the non-linear least squares (NLLS) for easy identification of the parameters and their standard errors. It is noteworthy that both methods give close results and imply that output and openness of trade are cointegrated and their long run relationship is significant.[7]

The short run dynamic ARDL equations for both methods are similar and imply that a 10% increase in openness leads to approximately an 8% increase in growth. However, such an implication is hard to believe and it is reasonable to suspect that our trade variable is capturing the effects of other missing variables in the growth equation. Furthermore, the trade variable has left a large residual in both equations since their $\bar{R}^2$s are low at about 0.3. We have reestimated equations (6) and (7) by adding a trend variable and the estimates are in equations (8) and (9). While trend is insignificant in the FMOLS equation (8), it is significant in the GETS equation (9). There is

[6] We have used the ADF, Phillips-Perron and KPSS tests. KPSS test unequivocally confirmed at the 5% level that all the variables are I(1) in levels. In the ADF and PP tests output was I(1) at the 10% level. The test results may be obtained from the authors.

[7] There is no formal cointegration test for GETS. Therefore, analogous to the CRADF test on the residuals of the first stage EG equation, we have used this test on the residuals of equation (7). The computed CRADF statistic is -6.1518 and the 5% critical value is -5.2651. The null of no cointegration, therefore, is rejected.

Table – 1
Determinants of Growth in Fiji: 1972 – 2002
Dependent Variable Δln Y_t

Variables Estimated Method	(6) FMOLS	(7) GETS-NLLS	(8) FMOLS	(9) GETS-NLLS
Intercept	0.042 (4.944)*	1.45 (1.793)**	0.042 (4.944)*	3.756 (2.35)*
λ	-0.187 (-1.852)**	-0.189 (-1.747)**	-0.187 (-1.852)*	-0.52 (-2.30)*
Trend			0.0013 (0.142)	0.011 (1.653)*
$\ln Z_{t-1}$	0.801 (9.258)*	0.789 (5.27)*	0.801 (9.258)*	0.145 (0.766)
$\Delta\ln Y_{t-1}$	-0.344 (-2.349)*	-0.344 (-2.303)*	-0.342 (-2.269)*	-0.174 (-0.98)
$\Delta\ln Z_{t-3}$	-0.134 (-1.734)*	-0.133 (-1.616)	-0.137 (-1.677)**	-0.127 (-1.599)
$\bar{R}^2$	0.325	0.297	0.297	0.344
SEE	0.038	0.0389	0.0388	0.038
$\chi^2(sc)$	1.486 (0.223)	1.548 (0.213)	1.695 (0.193)	0.933 (0.334)
$\chi^2(ff)$	0.067 (0.796)	0.092 (0.762)	0.029 (0.865)	0.575 (0.448)
$\chi^2(n)$	0.146 (0.93)	0.133 (0.936)	0.171 (0.918)	0.102 (0.950)
$\chi^2(hs)$	0.0146 (0.904)	0.024 (0.877)	0.002 (0.962)	0.708 (0.400)

Notes: t-ratios for the coefficients and p-ratios for χ^2 tests are in the parentheses
* Significant at 5%, ** Significant at 10%. Intercept in the ARDL for the FMOLS equations (6) and (8) are not reported. χ^2 tests are respectively for serial correlation, functional form misspecification, non-normality of residuals and heteroscadasticity in the residuals.

no significant improvement in their $\bar{R}^2$s. Furthermore, in the GETS equation the coefficient of the openness variable lnZ has declined from 0.79 in (7) to 0.145 and now became insignificant. These results indicate that the openness variable is strongly trended and therefore inclusion of trend has weakened its effects. A regression between lnZ_t and time trend indicated that the $\bar{R}^2$ is high at 0.93 and confirms our conjuncture. These four misspecified equations are useful to show how a proper specification of the growth equation may improve the estimates and reduce the size of the Solow residual.

In order to reduce our measure of ignorance of the determinants of growth, we have estimated the underlying growth equation by incorporating the production function and found that the constraint that there are constant returns is easily accepted in GETS but not in FMOLS. However, it should be noted that in FMOLS there is some arbitrariness in selecting the lag length for the window and this depends on the significance of the coefficients in the correlogram of the residuals from the first stage EG OLS equation and the hypothesized autoregressive structure for the explanatory variables. The constant returns assumption was not accepted even after increasing the lag length for the window. We shall address this issue later in this paper and proceed further by imposing the constant returns constraint on our production function.[8] This amounts to estimating the production function in per worker terms i.e., the dependent variable now is $ln(Y/L)$ and the explanatory variable is $ln(K/L)$. FMOLS and GETS growth equations with these variables and with trend, are given in Table-2 by equations (10) and (11) respectively.

These two equations are useful for comparisons with the corresponding misspecified equations in Table-1 and subsequently when the production function is augmented with the openness variable Z. Equations (10) and (11) are well determined and their summary statistics are impressive. In comparison to the two misspecified equations with trend in Table-1, with $\bar{R}^2$s of about 0.3 for the FMOLS and .35 for the GETS equations, there are significant improvements in their overall explanatory power. The $\bar{R}^2$s of the FMOLS equation is now 0.55 and for GETS 0.7.[9] In equations (10) and (11) trend is significant. When trend is removed, their overall fit has decreased. While equations (10) and (11) are well determined, the estimated share of capital income at about 0.385 in the FMOLS equation is higher than 0.23

---

[8] When the production function is augmented with the openness variable lnZ, the constant returns constraint was not rejected, at the 5% level, by the FMOLS cointegrating equation at lag lengths of 6 and more.

[9] It is, however, not possible to formally test if the equations in Table-2 are better than those in Table-1, say by using the non-nested hypothesis tests because their dependent variables are different. Therefore, we have reestimated the GETS equation (11) with OLS, where the dependent variable is changed to ΔlnY and tested with the non-nested hypothesis tests against the corresponding misspecified equation (9) in Table-1. Both the AIC and SBC criteria have clearly rejected the misspecified equation.

Table – 2
Determinants of Growth in Fiji: 1972 – 2002
Dependent Variable: $\Delta \ln (Y/L)_t$

Variables Estimated Method	(10) FMOLS	(11) GETS-NLLS	(12) FMOLS	(13) GETS-NLLS
Intercept	-0.064 (-2.887)*	-3.388 (-6.056)*	-0.064 (-2.887)*	-3.278 (-5.669)*
λ	-0.324 (-2.014)*	-1.035 (-6.016)*	-0.785 (-4.623)*	-1.022 (-6.527)*
Trend	0.004 (3.228)*	0.007 (5.494)*	0.004 (3.906)*	0.006 (4.884)*
$\ln(K/L)_{t-1}$	0.385 (6.692)*	0.229 (6.583)*	0.385 (6.692)*	0.248 (6.372)*
$\Delta \ln(K/L)_t$	0.625 (4.849)*	0.507 (4.628)*	0.651 (5.447)*	0.509 (7.738)*
COUP			-0.066 (-2.383)*	-0.035 (-2.422)*
$\bar{R}^2$	0.546	0.698	0.613	0.710
SEE	0.039	0.032	0.036	0.032
$\chi^2(sc)$	0.146 (0.702)	1.462 (0.227)	0.402 (0.526)	0.529 (0.467)
$\chi^2(ff)$	0.497 (0.481)	0.287 (0.592)	0.207 (0.649)	0.162 (0.687)
$\chi^2(n)$	0.625 (0.731)	0.617 (0.735)	1.177 (0.555)	0.516 (0.773)
$\chi^2(hs)$	2.862 (0.091)	0.182 (0.669)	2.994 (0.084)	0.553 (0.457)

Notes: t-ratios for the coefficients and p-ratios for χ^2 tests are in the parentheses
* Significant at 5%, ** Significant at 10%. Intercept in the ARDL for the FMOLS equations (10) and (12) are not reported. χ^2 tests are respectively for serial correlation, functional form misspecification, non-normality of residuals and heteroscadasticity in the residuals.

with GETS. Judged by the conventional goodness of fit measures, the GETS equation (11) is better in that it has higher $\bar{R}^2$ of 0.698 against 0.546 in the FMOLS equation (10). The log likelihood of (11) is also higher at 65.31 against 56.40 for (10).[10]

[10] Strictly speaking the FMOLS and GETS equations are not nested and therefore the usual likelihood ratio test is inappropriate. However, when we used the non-nested tests, the encompassing model could not be estimated because of multicollinearity between the variables. Therefore, judgment on the relative merits of

Inspection of the residuals of (10) and (11) indicated two outliers during 1987 and 1988 and this may be due to the first and second political coups in 1987 and their aftermath effects. Therefore, these two equations are estimated with a dummy variable, which is 1 during 1987 and 1988 and zero in other periods. The results are in equations (12) and (13). The coup dummy is significant and negative as expected. While it has increased the $\bar{R}^2$ of the FMOLS equation (10) noticeably to 0.62, there is only a marginal improvement in the GETS equation (11). We shall use these four equations for comparison when the production function is augmented with the openness variable Z.

Estimates of the growth equation, after augmenting the production function with the trade openness variable lnZ as a shift variable, are in Table-3. FMOLS and GETS estimates with the trend are in equations (14) and (15). While trend is insignificant and lnZ is significant in the FMOLS equation (14), it is significant in the GETS equation (15), but lnZ became insignificant. Addition of the coup dummy variable did not have any effect and the coup dummy is insignificant in both equations. Since the trend variable is not present in the first stage estimation of the cointegrating relationship in FMOLS, it is hard to say whether the long run relationship between output, capital and trade openness is better captured by FMOLS or GETS. However, it is noteworthy that, in the presence of the trend variable, the estimated share of profit income in FMOLS and GETS equations are much closer now compared to the estimates in Table-2. The adjustment coefficients and the coefficients of $\Delta ln(K/L)$ are also close in both equations. Since trend is not significant in the FMOLS equation, and its other coefficients are close to those in the GETS equation, we have estimated these two equations without trend. These are in equations (16) and (17). Removal of trend has marginally increased the $\bar{R}^2$ of both equations, since there is a small increase in the degrees of freedom. However, it is interesting to note now that lnZ became significant in the GETS equation and the estimated parameters, with these two different procedures, are even more closer than earlier. The share of profit income is 0.28 in FMOLS and 0.29 in GETS. More importantly, the two coefficients of the trade openness variable lnZ are very close, ranging from 0.176 in FMOLS to 0.189 in GETS.

Such close estimates with two different techniques are reassuring that our framework and methodology are reasonably robust. On the basis of our findings we may say that openness of trade is a positive

---

these two equations is based on visual inspection of their summary statistics.

Table – 3
Determinants of Growth in Fiji: 1973 – 2002
Dependent Variable: $\Delta \ln (Y/L)_t$

Variables Estimated Method	(14) FMOLS	(15) GETS NLLS	(16) FMOLS	(17) GETS NLLS	(18) GETS NLLS	(19) GETS NLLS-IV
Intercept	-3.025	-3.248	-3.025	-2.858	-3.201	-3.120
	(-30.422)*	(-4.888)*	(-30.422)*	(-5.723)*	(-6.230)*	(-4.159)*
λ	-0.957	-1.010	-0.991	-0.957	-1.034	-1.016
	(-5.664)*	(-5.442)*	(-6.107)*	(-5.841)*	(-6.291)*	(-4.690)*
Trend	0.001	0.005				
	(0.784)	(2.080)*				
$\ln(K/L)_{t-1}$	0.280	0.243	0.280	0.293	0.307	0.319
	(8.231)*	(4.733)*	(8.231)*	(7.924)*	(9.355)*	(6.994)*
$\ln Z_{t-1}$	0.176	0.032	0.176	0.189		
	(8.642)*	(0.399)	(8.642)*	(7.062)*		
Z_{t-1}					0.151	0.158
					(7.980)*	(6.362)*
$\Delta\ln(K/L)_t$	0.542	0.523	0.501	0.540	0.504	0.611
	(4.934)*	(4.436)*	(5.244)*	(4.761)*	(4.642)*	(2.094)*
$\bar{R}^2$	0.714	0.688	0.718	0.705	0.728	0.717 GR $\bar{R}^2$ =0.493
SEE	0.032	0.033	0.032	0.032	0.031	0.032
$\chi^2(sc)$	0.617	1.754	0.399	0.547	0.111	0.025
	(0.432)	(0.185)	(0.529)	(0.459)	(0.740)	(0.875)
$\chi^2(ff)$	0.350	0.272	0.305	0.376	1.003	0.018
	(0.554)	(0.602)	(0.581)	(0.540)	(0.317)	(0.895)
$\chi^2(n)$	0.171	0.423	0.451	0.160	0.292	0.227
	(0.918)	(0.809)	(0.798)	(0.923)	(0.864)	(0.875)
$\chi^2(hs)$	0.787	0.444	0.455	0.769	0.224	0.185
	(0.375)	(0.505)	(0.500)	(0.380)	(0.636)	(0.667)
Saragan's $\chi^2(3)$						1.208
						(0.751)

Notes: t-ratios for the coefficients and p-ratios for χ^2 tests are in the parentheses.
* Significant at 5%, ** Significant at 10%. Intercept in the ARDL for the FMOLS equations (14) and (16) are not reported. χ^2 tests are respectively for serial correlation, functional form misspecification, non-normality of residuals and heteroscadasticity in the residuals. t-ratios in equation (19) are the White heteroscadasticity adjusted. Instruments in this equations are: Intercept, Z_{t-2}, $\ln(Y/L)_{t-2}$, $\ln(K/L)_{t-2}$, $\Delta\ln(Y/L)_{t-1}$, $\Delta\ln(K/L)_{t-1}$, $\Delta\ln(Y/L)_{t-2}$ and $\Delta\ln(K/L)_{t-2}$,

growth factor and augmenting the neo classical production function with lnZ has significantly contributed to a reduction in our ignorance of the determinants of growth. Using $\bar{R}^2$s as a rough measure for the explained variation in the growth rate, the $\bar{R}^2$s of the two non-augmented growth equations, without trend, of Table-2 are less than 0.4. In the two augmented equations of Table-3 the $\bar{R}^2$s exceed 0.7.

To further improve our results we have used the GETS equation and found that when the ratio of trade to output instead of its logarithmic value is used, i.e. Z instead of $ln\ Z$ is used, there is a small improvement in the $\bar{R}^2$. This formulation also enables testing for non-linearities in the effects of Z on growth. The estimated equation (18) is in Table-3. There are no significant changes in the estimates of the coefficients of variables other than Z_{t-1} and the $\bar{R}^2$ increased from 0.705 to 0.728. This equation has been reestimated by adding Z_{t-1}^2 as an additional variable to find if there are any non-linear effects of openness on growth. However, the coefficients of both Z_{t-1} and Z_{t-1}^2 became insignificant. This result is not shown in Table-3 to conserve space.

Finally, although FMOLS takes into account endogeneity of variables and GETS estimates with NLLS have given close coefficient estimates, we have reestimated GETS equation (18) with the instrumental variable (NLLS-IV) method and the results are in equation (19) in Table-3. The Saragan's χ^2 statistic is insignificant indicating that our choice of instruments is valid. The only noticeable change is in the estimated share of profits and it has increased from about 0.3 to 0.32. However, it is not significantly different from 0.3 and the Wald test static $\chi^2 = 0.111$ with a p-values of 0.739 is insignificant. The generalized $\bar{R}^2$ i.e. $\overline{G}R^2$ at 0.493 is based on the residuals of the second stage equation and useful for comparisons with other NLLS-IV estimates. For example, when trend is used as an instrumental variable, $\overline{G}R^2$ has increased slightly to 0.532. For comparison with equation (18), the standard $\bar{R}^2$ may be used and there is only a small difference between these two $\bar{R}^2$s.[11]

On the basis of these results, it can be said that our methodology is useful to increase further our understanding of the determinants of growth by adding shift variable to the production function. Similar

[11] The endogeneity of trade variables is an unresolved issue, although this issue is not adequately addressed in time series applications. Lee, Ricci and Rigobon (2004) address this issue in cross section studies and argue that it is difficult to identify proper instrumental variables. Therefore, they have used what is known as the "identification through heteroscedasticity" (IH) approach. They have reestimated the coefficients of trade variables, using the data of Vamvakidis (2002), for 100 countries from 1961 to 2000 with 8 panels of 5 year averages. Four trade measure have been used viz., trade ratio, tariff indicator, import duties and black market premium and these are similar to those in Edwards (1998). Their main findings are that trade ratio is a satisfactory measure of openness and its coefficient will be much smaller when estimated with IH procedure compared to the OLS estimates.

improvement can also be achieved, according to Caselli (2004), by improving the measurement of variables. However, in this regard, it is worth pointing out that in the recent empirical works with cross section data, adjustments to labour force for improvement in skills, did not produce the expected optimistic results. Bosworth and Collins (2003) point out that this might be due to significant differences in the quality of education and inadequate measures to capture such differences. We also want to stress that production functions with a time trend do not contribute to a reduction in our ignorance of growth determinants. In fact inclusion of other valid shift variables, like openness of trade, is likely to make the trend variable insignificant.

IV. CONCLUSIONS

In this paper we have provided some guidelines for developing and estimating growth equations with time series data. Our framework, similar to Asteriou and Price (2004), showed how the basic Solow growth equation can be extended when the underlying production function is augmented with additional explanatory variables. Our empirical results for Fiji showed that the effects of trade openness on growth differ significantly between those based on *ad hoc* specifications and those properly derived from the underlying neo classical production function and the Solow growth model. Although we have used two alternative techniques to estimate the long and short run relationships, both techniques have given close and similar estimates of the parameters.

An important finding of our paper is that the size of the Solow residual can be reduced if the production function is augmented with appropriate shift variables and without the need for a trend in the growth equation. Although our results indicate that about 70% variation in the growth rate can be explained with factor accumulation and trade openness, we take the view that there is a need to improve by augmenting the production function with additional explanatory variables. Edwards (1998) particularly stresses the need for country specific time series studies to analyze the significance of openness for growth. Although his cross section work showed that openness is a significant contributor to growth, through its effects on factor productivity, his standardized beta coefficients imply that human capital contributes more to productivity than openness. Within our approach this implies that human capital is a relatively more important shift variable than trade openness. However, it is hard to draw conclusions on the relative importance of alternative shift variables until additional shift variables are identified and analyzed to show that the Solow residual can be significantly reduced. In this context it is also important to note that Rodriguez and Rodrik (2000), in their critical survey, note that the nature of the relationship between openness and growth is still an unresolved issue. For these reasons, although our empirical results imply that a 10% increase in trade openness may increase growth rate by about 2%, we do not attach much significance to this result until further improvements are made to understand country specific growth determinants with time series approaches.

Data Appendix

Z is the ratio of Fiji's total exports of goods and services plus imports of goods services to GDP.

Y is the real gross domestic product in 1990 prices.

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 millions is from the Reserve Bank of Fiji RBF. Investment data used to compute K includes investment in private and public corporate sectors.

L is employment and these are from the Government of Fiji and RBF publications.

Sources: Data are from the IFS CD-ROM 2003 and the Reserve Bank of Fiji Quarterly Review, for various years.

References

Abu-Badar, S. and Abu-Qarn, A.S., (2003) "Government expenditures, military spending and economic growth: Causality evidence from Egypt, Israel, and Syria," *Journal of Policy Modeling,* 25, 567-583.

Acemoglu, D., (ed.) (2004) *Recent Developments in Growth Theory,* Edward Elgar Publishing.

Asterious, D. and Price, S., (2004) " Financial development and economic growth: Time series evidence for the case of U.K.," *Discussion Paper 80,* Department of Economics, City University, London.

Barro, R.J., (1991) "Economic growth in a cross section of countries," *Quarterly Journal of Economics,* pp.407-433.

——— (1999) *Determinants of Economic Growth,* Cambridge, MA: The MIT Press.

Banarjee, A. , Dolado, J. J., Galbraith, J. W. and Hendry, D.F., (1993) *Cointegration, Error-Correction and the Econometric Analysis of Non-stationary Data,* Oxford: Oxford University Press.

Bosworth, B. and Collins, S. M., (2003) "The empirics of growth: An update," *Brookings Institution, September 22, 2003.*

Caselli, F., (2004) "Accounting for cross-country income differences," Working Paper No. 10828, National Bureau of Economic Research, Cambridge, MA., forthcoming, *Handbook of Economic Growth.*

Chandra, R. (2003) "Reinvestigating export-led growth in India using a multivariate cointegration framework," *The Journal of Developing Areas,* pp.73-86.

Chand, S. and Sen, K., (2002) "Trade liberalization and productivity growth: Evidence from Indian manufacturing," *Review of Development Economics,* pp.120-132.

Dube, S., (2004) "An application of ARDL model to the determinants of economic growth in Botswana," *Mimeo,* Department of Economics, California State University, Sacramento.

Duraluf, S.N. Johnson, P.A. and Temple, J.R.W., (2004) "Growth econometrics," forthcoming, *Handbook of Economic Growth.*

Edwards, S., (1998) "Openness, productivity and growth: What do we really know?" *Economic Journal,* pp.383-398.

Ekanayake, E. M., (1999) "Exports and economic growth in Asian developing countries: Cointegration and error-correction models," *Journal of Economic Development,* pp.43-56.

Fasano, U., and Q. Wang (2002) "Testing the relationship between government spending and revenue: Evidence from GCC countries," *IMF Working Paper Wp/02/201,* Washington: Policy and Development Review Department, IMF.

Frankel, J. A. and and Romer, D., (1999) "Does trade cause growth?" *American Economic Review,* pp.379-399.

Hall, R.E. and Jones, C. I., (1999) "On the limitations of government borrowing: A framework for empirical testing," *Quarterly Journal of Economics,* pp.83-116.

Hendry, D. F., (1995) *Dynamic Econometrics,* Oxford: Oxford University Press.

Hendry, D.F. and Doornik, J. A., (1994) "Modeling linear dynamic econometric systems," *Scottish Journal of Political Economy,"* pp.1-33.

—- and Krolzig, H.M., (2000) " The econometrics of general to simple modelling," *Mimeo,* Economics Department, Oxford University. **check year**

Hoover, K. D. and Perez, S. J., (2004) "Truth and robustness in cross-country growth regressions," *Oxford Bulletin of Economics and Statistics,* pp.763-798.

Klenow and Rodriguez-Clare, A., (1998) "The neoclaswsical revival in growth economics: Has it gone too far?" in Bernanke, B. S. and Rotemberg, J. J., (eds.) *NBER Macroeconomic Annual,* pp.73-103. Cambridge: MIT Press.

Leamer, E., (1988) "Measures of openness," in Baldwin, R. (ed.) *Trade Policy and Empirical Analysis,* Chicago: University of Chicago Press.

Lee, H. Y., Ricci, L. A. and Rigobon, R., (2004) "Once again, is openness good for growth?" *Working Paper: 10749,* Cambridge: NBER.

Levine, R. and Renelt, D., (1992) "A sensitivity analysis of cross-country growth equations," *American Economic Review,* pp.942-963.

Lindaur, D. L. and Pritchett, L., (2002) "What's is the big idea? The third generation of policies for economic growth," *Economia,* pp.1-39.

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

Patterson, K. (2000) *An Introduction to Applied Econometrics: A Time Series Approach,* Baisngstoke: Palgrave.

Rodiguez, F. and Rodrik, D., (2000) "Trade policy and economic growth: A skeptic's guide to the cross-national evidence," n Bernanke, B. S. and Rotemberg, J. J., (eds.) *NBER Macroeconomic Annual.* Cambridge: MIT Press.

Sachs, J. and Warner, A., (1995) "Economic reform and the process of global integration," *Brookings Papers on Economic Activity,* pp.1-118.

Sala-I-Martin, X., (1997) "I have just run two million regressions," *American Economic Review,* pp.178-183.

——— (2002) "15 years of new growth economics: What have we learnt?" *Discussion Paper: 0102-47*, Department of Economics, Columbia University.

Sharma, A. and Panagiotidis, T., (2004) "An analysis of exports and growth in India: Cointegration and causality evidence (1971-2001)" *Review of Economic Development,* pp.

Sims, C., (2000) "Econometric techniques: General discussion," in Backhouse, R. E. and Salanti, A., (eds.) *Macroeconomics and the Real World,* Volume 1, Oxford: Oxford University Press.

Stock, J. H. and Watson, M. W. (2003) *Introduction to Econometrics,* Boston: Addision Wesley.

Vamvakidis, A., (2002) "How robust is the growth openness connection?" *Journal of Economic Growth,* pp.57-80.

Young, A., (1995) "The tyranny of numbers, confronting the statistical realities of the East Asian growth experience," *Quarterly Journal of Economics,* pp.641-680.