New Zealand Economic Growth - Endogenous or Exogenous?

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Abstract: Economic growth has, once again, taken centre-stage in macroeconomics. Attempting to discriminate empirically between exogenous and endogenous engines of growth has become an important element of this resurgence and this paper adds to the debate. In this paper we present two contributions to the literature on economic growth. Firstly, a standard two-sector model of growth is extended to consider *m*-types of capital, where one of these can be human capital. The second contribution relates to the empirical application based upon New Zealand annual data 1965-1994. The results presented here lead to some support for exogenous growth models as an explanation of the growth process in New Zealand. However, the evidence is not overwhelming and further work is required both in terms of data used and types of tests employed.

1. INTRODUCTION

Economic growth has, once again, taken centre-stage in macroeconomics. Part of the resurgence in interest undoubtedly stems from a number of theoretical developments proposed by for example, Baumol (1990), Romer (1986), Jones and Manuelli (1990) and Rebelo (1991). Common features of these new developments are the crucial and separate roles for Research and Development (R&D), and human, as distinct from physical capital, in the growth process. Typically, the 'engine of growth' focuses on the accumulation of knowledge and 'learning-by-doing'. Such issues are in sharp contrast to the traditional features of neoclassical, exogenous technological progress, growth models. Attempts to distinguish between exogenous and endogenous growth models have become an important aspect of the current research agenda, see for example, Lau and Sin (1997a), Crowder and Himarios (1997), Blomstrom *et al.* (1996), Cheng and Hsu (1997), and Evans (1997). Results presented in this paper will add to this literature.

In a series of contributions, Romer (1990 and 1996), Grossman and Helpman (1991) and Aghion and Howitt (1992) consider the nature and importance of knowledge acquisition, and the determinants and allocation of resources to R&D, for the process of economic growth. The crucial feature of knowledge is that it is *non rival,* in contrast to private economic goods and is typically not completely governed by perfectly competitive forces. However, although non-rival it has the property of *excludability*, which creates heterogeneity and the potential for capture. The excludability feature acts both as an incentive to innovate and a potential to inhibit other individuals or firms, at the micro level, or countries, at the macro level, from capturing the benefits of "investment". Governments may have a role here via legal enforcement of patent laws and regulations relating to the export of high-tech., capital, but their involvement is not required to prevent capture.

In the area of economic growth, these issues often lead to the possibility that one (or a small group) of countries can follow a growth path, which consistently differs, from that of others.

These theoretical developments have typically not been reflected in the empirical literature. The availability of the Summers and Heston (1988) data set has spawned numerous papers which have sought to test variations of the Solow model (see for example Temple 1998a, b), but these data do not permit tests of some the major implications of the Romer *et al.* approach. Furthermore, the typical econometric methods applied to the data relate to cross-sectional or panel methods which at best requires considerable care, see Lee *et al.* (1997) and Temple 1998b), or at worst is inappropriate, see Bernard and Durlauf (1996).

In this paper we will present two contributions to the literature on economic growth. The first contribution is developed in Section 2 where an extended two-sector model which permits m possible types of capital (see Zhu (1997) for formal proofs), is presented. The dynamics of this extension are such that with $m>1$ types of capital, economies which satisfy the conditions for a steady-state solution require their m investment counterparts to grow at the same rate. Secondly, for an economy exhibiting a steady-state, the growth rate of each m type of investment *per capita*, the growth rate of GDP *per capita* and the growth rate of technological progress, must be identical.

The second contribution stems from empirical tests of the implications derived in Section 2. Lau and Sin (1997a, b) utilise the concepts of non-stationarity and cointegration to formulate tests of exogenous versus endogenous theories of growth. This type of testing framework is used in Section 3 to investigate the role of human capital and R&D in the economic growth of NZ, 1965-1994.

Lau and Sin (1997a), show that under certain conditions "observational equivalence" of exogenous and endogenous growth models arises. In these circumstances the empirical testing procedure followed in this paper will be a two-stage process involving, as the second stage, Toda and Yamamoto (1995)-type tests of causality. The results of such tests and the implications for the debate on exogenous versus endogenous 'engines for growth' are considered in Section 3.3. Section 4 concludes with a discussion of the implications of the results of the paper for the important debate on the determinants of growth - exogenous technological change following Solow (1956), or endogenous change following the new growth literature of Romer *et al.*

2. THEORETICAL ANALYSIS

In this section we consider the properties of a typical two-sector model and generalise it to consider m-types of capital.

2.1 A Two-Sector Model

Romer's (1996) two-sector model, which is a simplification of Romer (1990), Grossman and Helpman (1991), and Aghion and Howitt (1992), is the starting point for the theoretical development in this paper. The model serves as a good example for growth studies, since it has a clear economic background and incorporates both Solow's (1956) exogenous and Romer's (1990) endogenous growth model. Consider, initially, the properties of the original model based upon an economy with two sectors, the goods-production sector and the R&D sector:

$$Y_t=[(1-a_K)K_t]^{\alpha}[A_t(1-a_L)L_t]^{1-\alpha} \quad 0<\alpha<1 \quad (1)$$

$$\dot{A}_t=B(a_K K_t)^{\beta}(a_L L_t)^{\gamma}A_t^{\theta} \quad B>0, \beta\geq 0, \gamma\geq 0 \quad (2)$$

n.b., a 'dot' over a variable denotes the derivative with respect to time.

where Y_t, K_t, L_t, and A_t represent output, total capital stock, labour, and technology at time t, respectively; a_K and a_L are the fractions of K_t and L_t used in the R&D; n represents the growth rate of labour force; α, β, γ, θ, and B are parameters.

The behaviour of A_t, K_t, and Y_t depend on the value (sum) of two parameters: β and θ. It can be shown that there exist three cases: whether $\beta + \theta$ is less than, greater than or equals to 1, see Romer (1996) and that the dynamics of growth depend crucially on these values.

2.2 An Extended Two-Sector Model

Traditional two-sector models assume that there is only one type of capital, i.e., the aggregate capital stock. In this section we develop an extension of the standard two-sector model by considering m different types of capital. The extended version encompasses the standard two-sector model when $m = 1$.

The expanded Cobb-Douglas production function with Harrod-neutral technology, an exogenous savings rate, and an exogenous growth rate of labour constitute the core assumptions of the model. As in Romer (1996), it is possible to show that under some circumstances an economy will have a unique steady state and can reach that point either *exogenously* or *endogenously*. Therefore, the steady state is an attractor not only for exogenous growth models, but also for some endogenous growth alternatives. Furthermore, the growth rate of each factor *per capita* will grow equally along the balanced growth path. It is this characteristic that gives our empirical studies a powerful underpinning.

As in standard models of this type, the extended model considers an economy with two sectors. One is a goods-producing sector where output is produced, and the other, an R&D sector where additions to the stock of knowledge are made. Four kinds of variables are included in the model: output (Y_t), input factors including labour (L_t), technology (A_t), and m-types of capital: K_{t1}, K_{t2}, ..., K_{tm} (e.g., physical private capital, physical public capital, and human capital). A fraction a_L of the labor force is employed in the R&D sector and a fraction $1 - a_L$ in the goods-producing sector. Likewise, fraction a_{Ki} of the ith-type capital stock ($i = 1, 2, \ldots, m$) is used in the R&D sector and $1 - a_{Ki}$ in goods production. Due to the nonrival characteristic of knowledge, both sectors utilize the full stock of knowledge A_t so that we need not to divide it between those two sectors.

The production functions at time t of both sectors are assumed to take the expanded Cobb-Douglas form with labor-augmenting in goods-producing sector:

$$\text{Goods Sector: } Y_t = [A_t(1-a_L)L_t]^{1-\sum_{i=1}^{m}\alpha_i} \prod_{i=1}^{m}[(1-a_{K_i})K_{i_t}]^{\alpha_i}; \quad 0 < \sum_{i=1}^{m}\alpha_i < 1, \tag{3}$$

$$\text{R\&D Sector: } \dot{A}_t = B[\prod_{i=1}^{m}(a_{K_i}K_{i_t})^{\beta_i}](a_L L_t)^{\gamma} A_t^{\theta}. \quad (B > 0, \beta_i \geq 0, \gamma \geq 0) \tag{4}$$

The production function for knowledge is not assumed to have constant returns to scale, B is a shift parameter because in the case of knowledge production, replication would give rise to the same discoveries being found twice, thereby leaving A unchanged. That is, diminishing returns in R&D are possible. Similarly, co-operation among researchers, fixed set-up costs, etc., may be so efficient that doubling capital and labor inputs may result in more than a doubling in output. Therefore, increasing returns are also possible.

As in the Solow model, a fraction s_i of output invested in each type of capital is assumed to be exogenous and constant. The population growth (n) is also taken as exogenous. δ_i represents the depreciation of the related capital.

$$\dot{K}_t = s_i Y_t - \delta_i K_t; \qquad i = 1,2,....m \tag{5}$$

$$\dot{L}_t = nL_t \qquad n \geq 0 \tag{6}$$

These four equations ((3) ~ (6)) complete the description of the extended model.

2.3 Implications of the Extended Two-Sector Growth Model

The first implication of the extended model is that, if m-types of capital stock grow at the same constant rate (i.e., there exists a steady state point), their investment counterparts will grow equally at the same rate. This is proved in Lemma 2 of Zhu (1997).

A further implication of the extended growth model is that, for a growth model with a steady state, the growth rate of each type of investment per capita, the growth rate of the real GDP per capita, and the growth rate of technology progress are identical. This can be demonstrated via Lemma 1 and the first implication discussed above.

Finally, since all of those growth rates are equal (= g_A*) along the steady state, the ratio of the *per capita* real GDP (denoted as GDPPC) to the *per capita ith*-type investment (denoted as PI_i) must be constant. This is because:

$GDPPC_t = GDPPC_0(1 + g_A^*)^t$;
$PI_{i,t} = PI_{i,0}(1 + g_A^*)^t$;
Thus, $GDPPC_t/PI_{i,t} = GDPPC_0/PI_{i,0}$ = constant.
Similarly, $GDPPC_t/A_t$ = constant.

Taking natural logarithms:
$\log(GDPPC_t) - \log(PI_{i,t}) = \log(\text{constant}) \sim I(0)$;
(where I(0) denotes
$\log(GDPPC_t) - \log(A_t) = \log(\text{constant}) \sim I(0)$.
integrated of order 0.)

The variables are therefore cointegrated, CI(1, 1). Since there are k (= m+2) variables, the number of independent cointegrating vectors, i.e., the cointegration rank r, must equal k-1. It is this result which constitutes the theoretical basis of the empirical investigation in the paper.

To summarise:
If ***no cointegrating relationships exist*** among the *per capita* real GDP and the *per capita m* types of capital stock or investment,
or if they do, but the cointegration rank, r, is less than k-1 (where $k = m + 1$ with a multivariate system including real GDP and m types of per capita investment)
or $k = m + 2$ when we also include a variables to represent technological progress)
then this *fails to support the exogenous growth models* since no steady state will be reached.

This is the first characteristic used to undertake empirical tests of endogenous and/or exogenous models.

However,
if r equals k-1, ***then*** both exogenous growth models and some types of endogenous growth models with steady states all satisfy the rule.

In this case we can not distinguish them from each other. They are "observationally equivalent" (see Lau and Sin 1997a). Other tests based upon Granger causality will then be used to help identify the models.

Finally,
if $r > k$-1 (i.e., $r = k$), this implies that *all variables are trend stationary*.
Thus, *the endogenous growth model is rejected* since the mechanism of an economy may involve an exogenous component, i.e., time (See Evans 1997, Lau and Sin 1997b).

3. TESTING METHODOLOGY

The testable implications of the extended model hinge upon the time series properties of the data. In particular, the crucial role of bi-variate and multi-variate cointegration.

Consider initially the simplest version of the extended two-sector model, i.e., where $m = 1$. Here the simplification leads to analysis only of the relationship between real aggregate investment *per capita* and real GDP *per capita*, where technological progresses, if any is ignored. From the earlier theoretical results we know that, if these two variables are not cointegrated, i.e., (LGDP, LINV) $\neq$ CI(1,1), it will not support exogenous growth theories. However, if (LGDP, LINV) ~ CI(1,1), further analysis will be required to attempt to distinguish endogenous from exogenous growth, since in this case, both endogenous and exogenous growth models satisfy the condition.

Data Sources

Annual NZ data from 1965 to 1994 are used in this paper. In particular, LGDP represents the log., of real GDP per capita based; LRHK measures the log., of the ration of the number of students enrolled in tertiary studies to total population[1]. LINV, LPRTINV, and LPUBINV represent the logs., of per capita gross fixed investment, gross private fixed investment, and gross public fixed investment, respectively[2].LRDEXP represents the per capita R&D expenditure[3]

3.1 An Extended Two-Sector Model

In this section results from the fully extended two-sector model are presented.

i) Order of Integration

Initially, consider the order of integration of the data. The Augmented Dickey-Fuller (ADF) test is used, with both AIC and SBC criteria are employed to choose the appropriate lag orders. Table 1 below reports the results. On the basis of these results the null of a unit root is not rejected for any of the variables.

Table 1

Unit Root Tests for Levels of Each Variable

Variable	ADF(.)
LGDP	-2.579 (0)
LINV	-1.894 (1)
LPRTINV	-1.981 (1)
LPUBINV	-1.108 (0)
LRDEXP	-0.680 (4)
LRHK	-0.388 (1)

Data in parentheses are the optimal lag length chosen on the basis of Information Criteria.

The next stage involves the testing for cointegration. Based upon AIC and SBC the order of the VAR in the Johansen estimation procedure is chosen as 4 and Table 2 presents the results.

Both eigenvalue and trace tests suggest a rank of 4.

Table 2

Cointegration test results, Max. Eigenvalue). 1969-1994

Test	Ho	H1	Stat.	95%	90%
	r=0	r=1	81.4*	33.6	31.0
	r≤1	r=2	50.9*	27.4	24.9
	r≤2	r=3	35.2*	21.1	19.0
	r≤3	r=4	28.7*	14.8	12.9
	r≤4	r=5	0.68	8.07	6.50

*denotes significant at the 5% level based upon MacKinnon (1991).

Table 3 presents the normalised coefficient estimates for the relevant cointegrating vectors.

Table 3

Estimated (normalized) cointegrating vectors, (Var=4), 1969-1994

Coeff.	lgdp	linv prv	linv pub	lrdexp	lhk
Vec. 1	-1.0	0.5	-0.2	-0.02	-0.04
Vec. 2	-1.0	-0.4	-0.1	-0.16	0.28
Vec. 3	-1.0	0.2	0.1	-0.01	0.18
Vec. 4	-1.0	-4.6	0.2	2.21	-0.6

Cointegration, however, is a necessary but not sufficient condition and the implied restrictions in this case become:

$$\begin{matrix} 1 & -1 & 0 & 0 & 0 \\ 1 & 0 & -1 & 0 & 0 \\ 1 & 0 & 0 & -1 & 0 \\ 1 & 0 & 0 & 0 & -1 \end{matrix}$$

A LR test of these restrictions produces a $\chi^2(4) = 54.5919$, with p-value $=0.000$. *Therefore, the null hypothesis is rejected, which suggests rejection of exogenous growth models*

3.2 Causality Tests

Given the identification of cointegration for each of the above models, but mixed results on the determinants of growth, it is necessary to

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[1] The data are taken from Thorns and Sedgwick (1997).

[2] Data taken from "NZ Statistics, Monthly", for the period before 1978; and from "The Key Statistics", onwards.

[3] Data from OECD.

consider the second stage of the testing methodology based upon tests of causality.

One implication of the endogenous growth theory is that changes in some policy variables such as public investment will affect output permanently, whereas exogenous growth theory suggests they have only temporary effects. Consequently, if changes in public investment do "cause" output along the balanced growth path, it implies support for the endogenous growth model. Because of the nature of the model used, Crowder and Himarios (1997), Evans (1997) and Lau and Sin (1997b), are only able to consider the issue of causality between GDP and one type of investment, typically public sector investment of investment in infrastructure. In this section we will consider the existence and direction of causality between not only GDP and public investment, but also a fully extended model including private investment, R&D expenditure and human capital. The testing approach is based upon Toda and Yamamoto ((1995), which is a two stage process involving choice of optimal lag in the univariate VAR and the subsequent (augmented) Granger-type test of significance of included lags.

3.3 Causality Tests on LGDP, LPRTINV; LGDP, LRDEXP; LGDP, LRHK

Consider the Toda-Yamamoto type Granger causality test results for pairwise combinations of LGDP on LPRTINV, LRDEXP, and LRDEGREE. For simplicity, we only consider bi-variate relationships between LGDP and the other variables. However, since the lag orders of these variables are different, we use SURE. Stage 1 of the Toda and Yamamoto (1995), approach involves the determination of optimal lag lengths in the univariate series. Table 4 above presents results for each of the variables of interest.

Table 4
Stage-1 of T&Y causality tests: Using FPE to choose lag lengths

Dep. var	p=1	p=2	p=3	p=4	p=5	p=6
lgdp	**6.42**	6.91	7.22	7.52	8.18	9.30
Linv pub	**2.45**	2.70	3.00	3.41	3.89	4.52
linv prv	1.19	1.33	1.35	**1.08**	1.22	1.40
lrdex	6.24	5.00	**4.95**	5.40	6.07	5.27
lhk	**1.60**	1.78	1.67	1.88	2.15	2.38

The second stage involves the construction of Granger tests of causality. Table 5 presents the results.

Table 5
Step-2 of T&Y: Wald tests of bi-variate causality

Ho	Wald test p-value
lgdp ≠> linvprv	0.320
linvprv ≠>lgdp	0.571
lgdp ≠> lrdexp	0.158
lrdexp ≠> lgdp	0.662
lgdp ≠> lhk	0.025*
lhk ≠> lgdp	0.701

* denotes significant at the 5% level.

The results suggest strong evidence in favour of GDP unidirectionally *causing* human capital with all other bi-variate comparisons implying statistical independence. These latter results therefore suggest *weak evidence in favour of an exogenous explanation of growth in NZ* as the causality identified implies unidirectional causality from GDP.

4. CONCLUSIONS

Models of economic growth are typically categorised as either exogenous or endogenous where the distinction is relatively clear at the theoretical level. Empirically, however, distinguishing the causes of economic growth has proved more elusive.

In this paper we consider an extension of the standard two-sector model which encompasses not only an exogenous explanation of growth, a la Solow (1956), as a special case, but also Romer's (1996), R&D and human capital variants. This generalisation, which permits *m*-types of capital to be modelled, allows considerable generalities to be considered. However, as with standard two-sector models it has the capability to exhibit 'observational equivalence' of exogenous and endogenous explanations of growth. When translated into an empirically testable framework, the extended two-sector model developed in section 2 of the paper, the time series properties of the data act as a first-pass test of exogenous versus endogenous explanations of growth. Non-cointegrated bi-variate or multi-variate relationships between LGDP and the relevant components of the *m*-types of capital lead to rejection of exogenous growth as no steady state equilibrium exists. Likewise individually trend stationary series lead to a rejection of endogenous growth as the mechanism involves an exogenous component, time. However, bi- and multi-variate cointegration can lead to observational equivalence and a second criterion is required to discriminate between the models. In this paper the criteria relates to Granger-type causality tests.

In section 3 annual data on GDP, R&D expenditure, private and public sector investment, and a measure of human capital based on tertiary graduates as a proportion of the population, for the New Zealand, 1965-1994, show that the five time series are individually I(1) and jointly cointegrated. Parameter restrictions, which would allow a clear discrimination of an endogenous explanation of growth, are not satisfied, leaving second-stage causality testing as a final arbiter. The results here find in favour of weak support for an exogenous explanation of growth. On balance, however, there appears to be a conflict in the results derived with lack of support based upon cointegration-based tests, for exogenous models (except very simple versions) and lack of support for endogenous formulations when considering causality testing frameworks. Part of the conflict may arise from the data used to proxy various types of capital and this will be examined in later work. However, it may be that the existence of *observational equivalence* simply cannot be resolved with any of the tests currently employed.

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