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An Empirical Evaluation of the Balanced Growth Hypothesis: Evidence from Australia*

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This article evaluates a stochastic neoclassical growth model by testing its predictions for the existence of great ratios. The article also examines whether the inclusion of public sector and open economy sector in the data alters the results. Standard unit root and cointegration tests are employed. The overall findings suggest that the Australian data shows a departure from the theoretical implications of the stochastic growth models.

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1. INTRODUCTION

A key characterisation of the balanced growth path is the constancy of ratios of certain macroeconomic variables. An analogous implication for the stochastic environment is that the 'great ratios' should be stationary; exhibiting neither deterministic nor stochastic trends. Econometric approaches to the great ratios traditionally focus on testing for unit roots and common stochastic trends in a group of variables using cointegration (Kunst and Neusser, 1990; King *et al*., 1991; Neusser, 1991). The theoretical basis for cointegration-based tests of the great ratios is that economic growth in one-sector stochastic growth model is driven by a single stochastic process representing exogenous technological progress.[1)] When technology follows the random walk, it generates a common trend in output, consumption and investment.

Ample empirical work has examined the great ratios (Kunst and Neusser, 1990; King *et al*., 1991; Neusser, 1991; Serletis, 1994; Serletis and Krichel, 1995; Serletis, 1996; Bohl, 1999; Hossain and Chung, 1999; Harvey *et al*., 2003). Despite the evident theoretical underpinning, however, the empirical findings for a number of industrialised economies have seen little success except for US data (King *et al*., 1991). Most authors found the ratios non-stationary in unit-root tests. Or even if they are cointegrated, cointegrating vectors are not unity and the number of common trends often violates the prediction of the models. Neusser (1991) suggests that the unique empirical results for the US may be due to the long period of uninterrupted growth which allowed the US to grow on a steady-state path, unlike some European countries that have experienced destructive episodes such as World War II. If this argument is correct, the data for Australia, which among industrialised economies has not been exposed to such disruptions, would have

[1)] Lau (2000) shows that the long run identifying restrictions used in King *et al.* (1991) and Blanchard and Quah (1989) are valid for exogenous growth models but not for endogenous growth models. The author argues, in particular, that if an exogenous growth model nests a cointegrated system, then there should be at least one structural disturbance producing temporary effects on variables and at least one disturbance producing permanent effects.

considerable relevance to the validity of the ratios. However, Australia was not an exception among a majority of the industrialised economies whose great ratio data do not agree with the theoretical predictions. Hossain and Chung (1999) has examined the Australian data for the period 1961 to 1995 and have found that there exists one common trend driving output, consumption and investment in Australia, but the formal restriction of unity on cointegrating vectors is strongly rejected.

While the present article revisits the Australian data, it also considers several issues that have been arising from the past works. Stochastic growth models inherit their model building philosophy from the Solow growth model. Despite the methodological progress from the Solow growth model to stochastic growth models, the existence of certain great ratios remains intact. That is, a set of ratios of real variables should be stationary even when the notion of Ramsey-Cass-Koopmans type of dynamic utility optimisation and stochastic real shocks such as productivity are introduced into the model. Additionally in these models productivity drives the real variable system as common stochastic shock. Consequently, the long-run implication in stochastic environment delivers several more great ratios. For example, the stochastic growth model proposed by Campbell (1994) can be used to develop a more extensive set of testable implications other than consumption-output and investment-output ratios.

Another issue to address is concerned with whether the inclusion of the public sector affects results. The basic stochastic growth models do not include a government sector. An empirical strategy is to use standard national accounting data for all variables simply ignoring the presence of the public sector. A somewhat better approach is to try and remove the public sector from the national accounts data to produce private sector measures of consumption, investment and output. Work by Serletis (1996) indicates that there is no significant difference in the results between the private sector and the total economy for Canada. Harvey *et al*., (2003) also experiment on public and private measures for the US but reach the opposite conclusion to Serletis (1996).

Although most past work has ignored the open economy sector, some studies (Kunst and Neusser, 1990; Serletis and Krichel, 1995) have included exports in the cointegrating vector but their results are mixed. The present study uses the real export share as a great ratio following Kunst and Neusser (1990). This is not an entirely appealing approach but nevertheless it provides a means of treating the open economy sector.

In summary the primary aim of this article is to offer some empirical evidence on the existence of great ratios or otherwise in the Australian economy. As part of this analysis the following are considered: the effect of accounting for the government sector; the importance of the open economy.

Section 2 outlines the theoretical background of the great ratios. Data details and empirical findings are presented in section 3. Section 4 concludes the article.

2. THE RATIOS

To illustrate briefly the theoretical background of the great ratios, a simple basic neoclassical growth model (Solow, 1956; Swan, 1956) is described by Cobb-Douglas production function.

$$Y_t = (A_t N_t)^{1-\alpha} K_t^{\alpha}, \tag{1}$$

where Y_t is output, C_t consumption, I_t investment, N_t labour, K_t capital and A_t technology.

A_t follows

$$\log(A_t) = \mu + \log(A_t) + \xi_t, \quad \text{where } \xi_t \sim \text{i.i.d. } (0,\ \sigma^2). \tag{2}$$

Then, per-capita variables of C, I, K, and Y all grow at $(\mu + \xi_t)/\alpha$ in steady-state. Logged ratios of the per-capita variables, *C/Y*, *I/Y*, and *K/Y*, are all stationary in the steady-state.

In addition, it is possible to develop more testable implications of the stochastic growth model proposed by Campbell (1994). This author shows the following ratios as functions of structural parameters[2]:

$$\frac{A}{K}=\left(\frac{Q^{\gamma}/\beta-(1-\delta)}{1-\alpha}\right)^{1/\alpha}\approx\left(\frac{r+\delta}{1-\alpha}\right)^{1/\alpha},$$

$$\frac{Y}{K}=\left(\frac{A}{K}\right)^{\alpha}\approx\frac{r+\delta}{1-\alpha}, \tag{3}$$

$$\frac{C}{Y}=\frac{C/K}{Y/K}\approx 1-\frac{(1-\alpha)(q+\delta)}{r+\delta},$$

$$\frac{A}{K}=\left(\frac{r+\delta}{1-\alpha}\right)^{1/\alpha}, \tag{4}$$

$$\frac{C}{K}=\frac{(r+\delta)-(1-\alpha)(q+\delta)}{1-\alpha}, \tag{5}$$

$$\frac{G}{Y}=1-(C/Y)-(I/Y), \tag{6}$$

where δ is the depreciation rate, β the discount factor, γ the coefficient of relative risk aversion, $\sigma\equiv 1/\gamma$ the elasticity of intertemporal substitution for leisure, $Q\equiv A_{t+1}/A_t$, $q=\sigma\log(\beta)+\sigma\gamma$, G the government consumption and R the steady-state value of R_{t+1} (see, for details, Campbell, 1994).

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[2] Since the model is a standard set-up for a stochastic growth model and widely cited, I only collect the ratios from the model to conserve space.

3. EMPIRICAL FINDINGS

As discussed above there are at least seven ratios that ought to be stationary (great ratios) in the steady-state; namely, *C/Y*, *I/Y*, *K/Y*, *G/Y*, *A/K*, *C/K*, and *X/Y*.[3)]

3.1. Data

195 observations of quarterly data for the period of 1960 to 2008 were obtained from the *Australian Bureau of Statistics Treasury Model Database* (ABS TRYM) and the *Australian Bureau of Statistics Time Series Statistics Plus*. Variables are seasonally adjusted, logged and measured in constant 2006/2007 prices.[4)]

In the literature there are differing approaches to the definitions of some variables. For instance, King *et al*. (1991) exclude government spending and focus on private measures of output, consumption and investment. In contrast, Neusser (1991) includes the government sector by focusing on the total or conventional national accounting measures of these variables. In the following empirical analysis for Australia I use total measures first and consider the results from private measures. To obtain the private measures I use private consumption, private investment and gross domestic product less (government consumption plus government investment) following King *et al.* (1991).

Technology *A* is measured using Solow residuals. I use the standard identity, $\log A_t = \log Y_t - (1-\alpha)\log K_t - \alpha \log N_t$, to calculate the residuals. The value of α is set to 2/3, which is a standard value for this parameter.[5)]

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3) *X* denotes net export. Stationarity of net export share (*X/Y*) stems from the aggregate demand identity. The share should be stationary if *C/Y*, *I/Y*, *K/Y*, and *G/Y* are stationary. Following Neusser and Kunst (1990) and Serletis (1996), the practice of including net exports is adopted here to account for the openness of Australian economy when testing for cointegration among real variables.

4) Precise data details are presented in Appendix 1.

5) Australia has been a subject of calibration exercise in RBC literature not as often as other industrialised countries. Also there has been minimal justification for and consistency in adopting values for the elasticity of output with respect to capital. Baxter and Crucini

Employment, *N*, is measured using the total number of civilian employees. *Y* is the gross domestic product and *K* is the capital stock.

3.2. Plots of the Great Ratios

Figures 1 to 3 show all six ratios great ratios for Australia using aggregate (or total) measures of the variables and also measures for the private economy.[6] Figures 1 and 2 show some degree of mean reversion for *C/Y* and *I/Y*.[7]

3.3. Unit Root Tests

Augmented Dickey-Fuller (ADF) tests were conducted and the results are reported in table 1.[8] In theory the great ratios should be free of any deterministic trends and this suggests use of the ADF test regression with only an intercept term. However, practical issues such as measurement errors or the possibility of local trends imply that it may be important to also present results using the ADF test with a time trend, particularly when the intercept-only model fails to reject the unit root hypothesis.

(1995) use a relatively high value, 0.42, whereas a recent work by Creedy and Guest (2008) simulates a small value, 0.27, into their calibration system. None of these studies provides the justification. Unlike other parameters in conventional calibration exercises, an understandable difficulty in selecting a value for the parameter is non-separability in capital and labour. Capital and labour may be interwoven in contribution to production in industries where separation of the contribution may be unclear. Therefore, I use a standard value for the analysis here and admit that a more formal approach such as estimation from data or sensitivity analysis to a selection of values for the parameter is possible for next step to develop this work.

6) In each figure, data units are normalised to show relative movements between series, which involves subtraction of mean from data and division by their standard deviation.

7) A Preliminary visual inspection indicates that the other ratios do not show any sign of reverting behaviour.

8) An issue that arises with the implementation of this test is the choice of the order of autoregression. Many previous studies have fixed the lag order according to data frequency. But Hall (1994) and Ng and Perron (1995) suggested that data-dependent lag selection is superior to a prior choice of lag order. I determine the lag order from an upper bound and reduce the number of lags until the final lag is significant at 5%. In determining the upper bound I follow the Said and Dickey's $T^{1/3}$ rule.

Figure 1 Ratio of Log C/Y for the Aggregate Economy and for the Private Economy

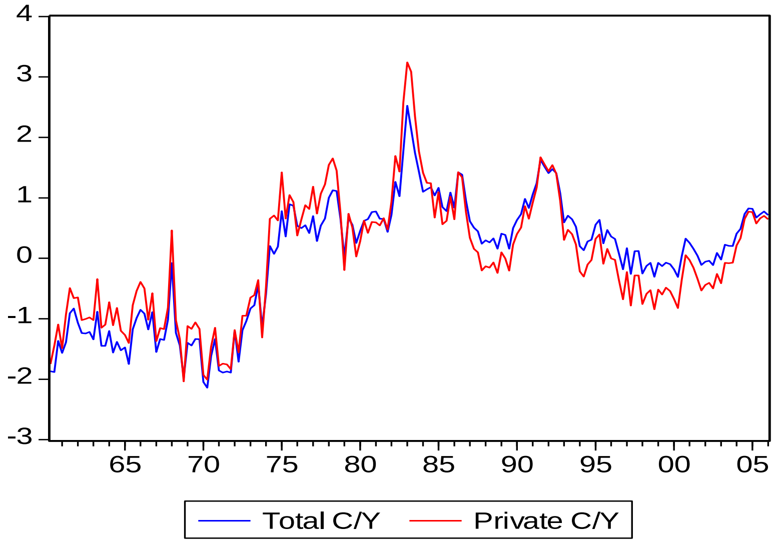

Figure 2 Ratio of Log I/Y for the Aggregate Economy and for the Private Economy

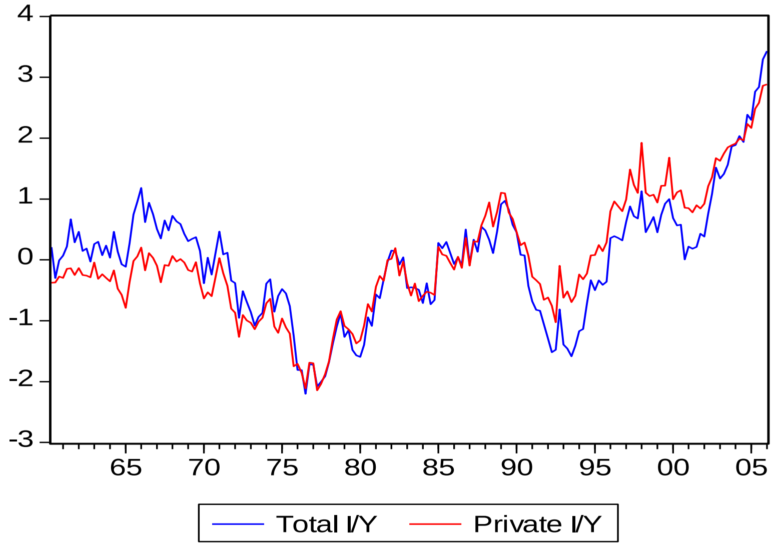

Figure 3 Ratio of Log K/Y for the Aggregate Economy and for the Private Economy

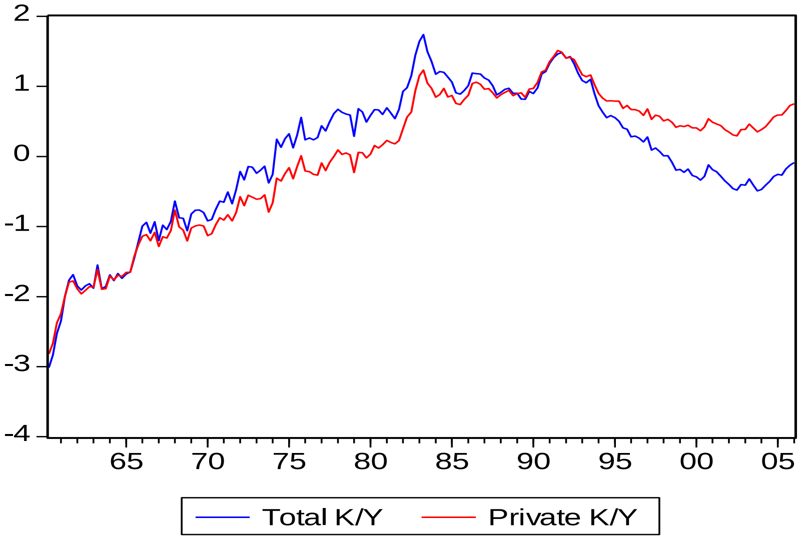

Table 1 ADF Test Results for Great Ratios and Implied Great Ratios (Total Measures)

Variables	ADF Test Statistic Intercept Only		ADF Test Statistic Intercept and Trend		AR Lag Order
	Level	First Difference	Level	First Difference	
Great Ratios					
C(Total)/*Y*(Total)	–1.764 (0.39)	–7.02* (0)	–1.83 (0.68)	–7.00* (0)	5
I(Total)/*Y*(Total)	–0.48 (0.88)	–7.20* (0)	–0.92 (0.94)	–7.41* (0)	3
K(Total)/*Y*(Total)	–1.87 (0.43)	–4.38* (0)	–1.01 (0.93)	–4.75* (0)	6
Implied Great Ratios					
A/*K*(Total)	–3.86* (0)	–5.20* (0)	–1.91 (0.64)	–5.11* (0)	4
X/*Y*(Total)	–3.00* (0.03)	–11.18* (0)			2
C(Total)/*K*(Total)	–3.78* (0)	–9.06* (0)			2

Notes: Parenthesis contains *P*-value. AR stands for OLS AR coefficient estimate. Asterisk *q* stands for AR lag order which has been selected by using general-to-specific approach. I start an upper *q* that satisfies the $T^{1/3}$ rule and reduce lag by eliminating insignificant lag. Ljung-Box Q Statistic is also referred to ensure no serial correlation.

Table 2 ADF Test Results for Great Ratios and Implied Great Ratios (Private Measures)

Variables	ADF Test Statistic Intercept only		ADF Test Statistic Intercept and Trend		AR Lag Order
	Level	First Difference	Level	First Difference	
Great Ratios					
C(Private)/*Y*(Private)	–2.65* (0.08)	–10.80* (0)			2
I(Private)/*Y*(Private)	0.09 (0.96)	–10.05* (0)	–1.21 (0.90)	–10.22* (0)	2
K(Private)/*Y*(Private)	–2.07 (0.25)	–5.79* (0)	–1.09 (0.92)	–6.00* (0)	6
Implied Great Ratios					
A/*K*(Private)	–3.01* (0.03)	–5.72* (0)	–1.21 (0.74)	–6.21* (0)	5
X/Y(Private)	–2.95*(0.04)	–11.17* (0)			2
C(Private)/*K*(Private)	–4.56* (0)	–11.42* (0)			2

Notes: Parenthesis contains *P*-value. AR stands for OLS AR coefficient estimate. *q* stands for AR lag order which has been selected by using general-to-specific approach. I start an upper q that satisfies the $T^{1/3}$ rule and reduce lag by eliminating insignificant lag. Ljung-Box Q Statistic is also referred to ensure no serial correlation. ARCH LM test has been conducted to detect conditional heteroscedasticity at lag 4.

Results in tables 1 and 2 indicate that the long-run implications of the stochastic growth models find some partial support from the Australian data. Consider table 1 which presents results for using total economy variables. The null hypothesis of a unit root hypothesis cannot be rejected for any of traditional great ratios, *C/Y*, *I/Y*, and *K/Y*. In contrast a unit root is rejected for *X/Y* and *C/K*.

The results for *A/K* are something of a puzzle. In general the ADF test rejects the null of a unit root for the model with just a constant, but does not reject it when a constant and time trend are both included. It is not apparent why omitting the time trend leads to the finding of stationarity.

The robustness of the above results can be checked by considering the results for the private economy. In general the results from table 2 for the private measures are consistent with those in table 1. The one notable exception is for private *C/Y* where the unit root hypothesis is rejected.[9)]

In general the results obtained from the ADF tests suggest that the traditional great ratios *C/Y*, *I/Y*, and *K/Y* are not stationary for Australia with the one exception being the private consumption to private output ratio.[10)] In contrast the unit roots tests do provide some evidence that the ratios of government spending to output *X/Y* and consumption to the capital stock *C/K* are stationary. In the case of *A*/*K* it seems most likely that the ratio is non-stationary in Australia.

3.4. Cointegration Tests

The other approach to testing for the presence of great ratios is to test for cointegration among sets of relevant variables e.g., consumption, investment and output. If the great ratios exist, these variables should be cointegarted on a pair-wise basis and share one common trend. Past studies have considered a range of systems from six variables (consumption, investment, output, the real interest rate, the real money balance and inflation) to simpler three variable systems (consumption, investment and output). However work to date suggests that the number of variables included in the system makes little difference to the results for most countries. This section examines a variety of systems ranging from five variables down to two variables.

Assuming that $\log C$, $\log I$, and $\log Y$ are driven by a common stochastic shock, a common trend representation due to Stock and Waston (1988) is given by

9) Preliminary results suggest that using GNP in place of GDP does not affect our previous conclusions regarding *C*/*Y*, *I*/*Y*, or *K*/*Y*. It is noted that private and total measures of GNP are used. Private measure of GNP is used when GNP is used in ratios with private measures of consumption and investment. Otherwise, (total measure of) GNP (used with total measures) includes government consumption and public investment.

10) For robustness check, alternative unit root tests (KPSS, Phillips and Perron tests) have been used but results are qualitatively the same as ADF test results.

$$\begin{pmatrix} \log Y_t \\ \log C_t \\ \log I_t \end{pmatrix} = \begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix} \tau_t + u_t, \tag{7}$$

where τ is a random walk with drift and u is a stationary stochastic process.

Equation (7) can be re-written as

$$\beta' z_t = \begin{pmatrix} 1 & -1 & 0 \\ 1 & 0 & -1 \end{pmatrix} \begin{pmatrix} \log Y_t \\ \log C_t \\ \log I_t \end{pmatrix} = \text{stationary.} \tag{8}$$

Equation (8) implies that the consumption-output and investment-output ratios to be stationary (i.e., cointegrated), where the cointegrating vector is given by β'.

A larger system consisting of five variables also analysed. Consider the following more general version model of (8).

$$\beta' z_t = \begin{pmatrix} 1 & -1 & 0 & 0 & 0 \\ 1 & 0 & -1 & 0 & 0 \\ 1 & 0 & 0 & -1 & 0 \end{pmatrix} \begin{pmatrix} \log Y_t \\ \log C_t \\ \log I_t \\ \log G_t \\ \log X_t \end{pmatrix} = \text{stationary.} \tag{9}$$

Real exports $\log X$ and government consumption $\log G$ are now included in the system. Following the approach of Kunst and Neusser (1990) and Serletis and Krichel (1995) these variables are designed to account for the openness and the government sector in the Australian economy. Both *G* and *X* are expected to share the same common trend with *C*, *I*, and *Y*, although this is not imposed in the empirical analysis. For *X*, an appropriate state vector in β' should be valid to reflect the stationarity of *G/Y* but no such specific cointegrating state vector for *X* and *Y* exists.

Table 3 ADF Test Results for All Real Variables

Variable	ADF Test Statistic		AR Lag Order
	Intercept Only	Intercept and Trend	
Y(Total)	–1.19 (0.67)	–1.98 (0.60)	5
Y(Private)	–0.86 (0.79)	–2.22 (0.47)	6
Y(GNP)	–1.36 (0.60)	–1.93 (0.63)	5
C(Total)	–2.26 (0.18)	–1.76 (0.71)	2
C(Private)	–1.20 (0.67)	–1.74 (0.72)	1
K(Total)	–0.54 (0.87)	–2.6 (0.24)	6
K(Private)	–0.88 (0.79)	–2.81 (0.19)	6
I(Total)	0.75 (0.99)	–1.38 (0.86)	3
I(Private)	0.90 (0.99)	–1.28 (0.88)	2
G	–2.61 (0.09)	–1.57 (0.79)	2
X	–1.31 (0.62)	–2.59 (0.28)	3
A	–0.66 (0.85)	–2.77 (0.20)	4

Notes: Parenthesis contains *P*-value. AR stands for OLS AR coefficient estimate. *q* stands for AR lag order which has been selected by using general-to-specific approach. I start an upper q that satisfies the $T^{1/3}$ rule and reduce lag by eliminating insignificant lag. Ljung-Box Q Statistic is also referred to ensure no serial correlation.

Johansen's procedure (1991 and 1995a) is applied to used to estimate the number of cointegrating relationships (equivalently the number of common trends) and to test the restrictions implied by (8) and (9). The number of lags used in the VAR model that forms the basis of Johansen's estimator is chosen to eliminate serial correlation in the residuals of each equation.

Since the cointegration tests are based on the levels rather than the ratios of variables, table 3 reports the results of ADF tests on the relevant series. All variables appear to be *I*(1).

In applying the Johansen procedure models (8) and (9), I firstly test for the number of cointegrating vectors and then the appropriate restrictions on β' from (8) and (9) are tested. When the restrictions are rejected, free parameters denoted by *f* for the vector β' are estimated as a measure of the departure of the data from theoretical implication. Finally assumptions about the presence of trends in data needs some mention.[11)] Consistent with stochastic growth models, the correct assumption is for a 'trend' in data. However as a practical matter it may be useful to allow for the possibility of no trend in data.

Table 4 presents cointegration test results for the five variable model of *Y*(total), *C*(private), *I*(private), *G*(spending), *X*, which represents total economy where both government consumption and government investment are included *G*(spending). Private measures with government consumption denoted by *G* are tested in table 5. The expectation is four cointegrating relations or equivalently one common trend, which is in fact strongly rejected for both data sets. Unless no trend in data is assumed in the total economy data, only one cointegration relation is detected, total or private.

Some differences in results arise depending on the inclusion (or exclusion) of the government sector from output. The most notable difference arises with the tests of restrictions. When a trend in data is assumed the restrictions for each vector in β' (using total output) are rejected, see table 4. However for private output table 5 the restrictions for *C/Y* and *G/Y* are not rejected, i.e., the restrictions, (1, –1, 0, 0, 0), for *C/Y* and (1, 0, 0, –1, 0) for *G/Y* in cointegrating vector are not rejected. Not too much should be drawn from these statistical results as the estimated free parameters of –1.03 and –1.05, for *C/Y* and *G/Y* in the total economy are close to unity. Similar results are found for the case when no trend is assumed in data.[12)]

[11)] When testing for cointegration, one has to choose whether data is assumed to have trend. In the growth models used in this chapter, a trend is theoretically predicted to arise in the data. However, consistent with the unit root testing strategy in previous section, both assumptions (trend and no trend in data) are used in the cointegration tests.

[12)] Replacing GDP with GNP produces qualitatively similar results as reported. The results are available upon request.

Table 4 log *Y*(Total), log *C*(Private), log *I*(Private), log *G*, log *X*

Null Hypothesis	log *Y*(Total), log *C*(Private), log *I*(Private), log *X*, log *EX*			
	Trend in Data, q=8		No Trend in Data, q=8	
	Trace	λ_{max}	Trace	λ_{max}
$r=0$	83.16* (0.00)	41.63* (0.00)	117.36* (0.00)	62.11* (0.00)
$r \leq 1$	41.52 (0.17)	22.04 (0.21)	55.24* (0.03)	26.38* (0.09)
$r \leq 2$	19.48 (0.45)	14.28 (0.34)	28.86 (0.20)	14.89 (0.38)
$r \leq 3$	5.20 (0.78)	5.20 (0.71)	13.96 (0.29)	10.44 (0.29)
$r \leq 4$	0.00 (0.99)	0.00 (0.99)	3.51 (0.48)	3.51 (0.48)

Testing Restrictions

	$r=1$		$r=2$
	Test Statistics		Test Statistics
(1, –1, 0, 0, 0)	25.68* (0.00)	(1, –1, 0, 0, 0) (1, 0, –1, 0, 0)	37.17* (0.00)
	Cointegrating Vectors Estimates		Cointegrating Vectors Estimates
(1, f, 0, 0, 0)	f = –1.03, t-ratio = –93.42	(1, f_1, 0, 0, 0) (1, 0, f_2, 0, 0)	f_1=–1.01, t-ratio=–85.18 f_2=–0.65, t-ratio=–15.81
(1, 0, –1, 0, 0)	39.33* (0.00)	(1, 0, –1, 0, 0) (1, 0, 0, –1, 0)	23.28* (0.00)
	Cointegrating Vectors Estimates		Cointegrating Vectors Estimates
(1, 0, f, 0, 0)	f = –0.65, t-ratio = –19.26	(1, 0, f_1, 0, 0) (1, 0, 0, f_2, 0)	f_1=–0.67, t-ratio=–12.21 f_2=–1.03, t-ratio=–27.06
(1, 0, 0, –1, 0)	11.26* (0.02)	(1, 0, 0, –1, 0) (1, -1, 0, 0, 0)	22.05* (0.00)
	Cointegrating Vectors Estimates		Cointegrating Vectors Estimates
(1, 0, 0, f, 0)	f = –1.05, t-ratio = –39.31	(1, 0, 0, f_1, 0) (1, f_2, 0, 0, 0)	f_1=–1.05, t-ratio=–37.83 f_2=–1.02, t-ratio=–64.80
Normalized Cointegrating Coefficient	(1.00, –0.60, 0.11, –0.43, –0.08)	Normalized Cointegrating Coefficient	(1.00, –1.58, 0.57, –0.61, 0.16)

Table 5 log *Y*(Private), log *C*(Private), log *I*(Private), log *G*, log *X*

Null Hypothesis	*Y*(Private), log *C*(Private), log *I*(Private), log *G*, log *X*			
	Trend in Data, q =8		No Trend in Data, q =8	
	Trace	λ_{max}	Trace	λ_{max}
r =0	69.83* (0.04)	34.26* (0.04)	99.17* (0.00)	49.89* (0.00)
$r \leq 1$	35.57 (0.41)	17.13 (0.56)	49.28 (0.12)	21.13 (0.33)
$r \leq 2$	18.43 (0.53)	12.03 (0.54)	28.15 (0.23)	12.29 (0.62)
$r \leq 3$	6.39 (0.64)	6.36 (0.56)	15.85 (0.18)	10.43 (0.29)
$r \leq 4$	0.03 (0.85)	0.03 (0.85)	5.41 (0.24)	5.41 (0.24)
	Testing Restrictions			
	r =1		r =1	
	Test Statistics		Test Statistics	
(1, –1, 0, 0, 0)	5.93 (0.20)		6.83 (0.14)	
(1, 0, –1, 0, 0)	32.06* (0.00)		20.27* (0.00)	
	Cointegrating Vectors Estimates		Cointegrating Vectors Estimates	
(1, 0, f , 0, 0)	f = –0.62, t-ratio = –15.92		f = –0.63, t-ratio = –14.40	
(1, 0, 0, –1, 0)	6.19 (0.18)		6.63 (0.15)	
Normalized Cointegrating Coefficient	(1.00, –0.85, 0.10, –0.22, –0.03)		(1.00, –1.48, 0.33, –0.28, 0.15)	

Since the results for the five variable models are somewhat weak, the smaller system of (8) is estimated. The system contains only three variables (consumption, investment and output) as in Hossain and Chung (1999) and Harvey *et al.* (2003). Even after reducing the system to three variables, the three real variable models in tables 6 and 7 do not support the single common trend hypothesis (regardless of how variables are measured). The tables indicate that a single cointegration is found for total economy of *Y*(total), *C*(private), *I*(private) and the private counterpart of *Y*(private), *C*(private), *I*(private). The theoretical restriction on *C/Y* restriction for the private economy is not rejected, while the restriction on *I/Y* is strongly rejected.[13)]

[13)] Replacing GND with GNP for the three variable models reported. The results are available upon request.

Table 6 log *Y*(Total), log *C*(Total), log *I*(Total)

Null Hypothesis	log *Y*(Total), log *C*(Total), log *I*(Total)			
	Trend in Data, q =1		No Trend in Data, q =1	
	Trace	λ_{max}	Trace	λ_{max}
r =0	25.80 (0.13)	17.08 (0.16)	189.28* (0.00)	174.77* (0.00)
$r \leq 1$	8.71 (0.39)	8.71 (0.31)	14.50 (0.25)	11.75 (0.20)
$r \leq 2$	0.00 (0.93)	0.00 (0.93)	2.75 (0.62)	2.75 (0.62)

Testing Restrictions

	r =0	r =1
	Test Statistics	Test Statistics
(1, –1, 0)		0.18 (0.91)
(1, 0, –1)		10.21* (0.00)
	Cointegrating Vectors Estimates	Cointegrating Vectors Estimates
(1, 0, f)		f = –0.75, t-ratio = –8.40
Normalized Cointegrating Coefficient	(1.00, –0.91, –0.05)	(1.00, –1.06, 0.06)

Table 7 log *Y*(Total), log *C*(Private), log *I*(Private)

Null Hypothesis	log *Y*(Total), log *C*(Private), log *I*(Private)			
	Trend in Data, q =1		No Trend in Data, q =1	
	Trace	λ_{max}	Trace	λ_{max}
r =0	31.54* (0.03)	22.92* (0.02)	190.96* (0.00)	175.54* (0.00)
$r \leq 1$	8.62 (0.40)	8.56 (0.32)	15.42 (0.20)	11.54 (0.21)
$r \leq 2$	0.05 (0.80)	0.05 (0.80)	3.88 (0.42)	3.88 (0.42)

Testing Restrictions

	r =1	r =1
	Test Statistics	Test Statistics
(1, –1, 0)	1.28 (0.52)	3.86 (0.14)
(1, 0, –1)	21.02* (0.00)	14.98* (0.00)
	Cointegrating Vectors Estimates	Cointegrating Vectors Estimates
(1, 0, f)	f = –0.67, t-ratio = –10.24	f = –0.68, t-ratio = –8.62
Normalized Cointegrating Coefficient	(1.00, –1.03, 0.01)	(1.00, –1.09, 0.05)

The results for the three variable systems confirm the basic findings of Hossain and Chung (1999), despite the use of an additional ten years of data in this study. However, assuming that cointegrating relation exists for consumption and output, confirmation is made to suggest that *C/Y* appears to have a long-run relation. None of the vector restrictions, (1, –1, 0, 0, 0) and (1, –1, 0) in β', for *C/Y* is rejected, whereas restrictions for *I/Y* are all rejected. Also the inclusion of exports uncovers little, since both private three and five variable models find one cointegrating relation and restriction valid for *C/Y*. However, a new finding is added in that *G/Y* can be cointegrated for Australia.

The *I/Y* restriction is strongly rejected consistently across various models and measures. Data in fact show a significant departure from theory. Free parameters for coefficient on *I* in (1, 0, *f*, 0, 0) and (1, 0, *f*) vectors are all estimated to be in the range of 0.5 to 0.7. A possible step to take for the *I/Y* inconsistency is a bivariate system, given that three and five variable models support restrictions for *C/Y*. Now I further reduce the system to bivariate where I impose (1, –1) restriction for β'. For total and private *I/Y*, bivariate models in tables 8 and 9 do not change results from *I/Y* in three and five variable systems. Although one common trend is detected, the vector restriction, (1, –1), is rejected.

Since traditional great ratios comprising consumption, investment and output have failed the one common trend implication with marginal success in uncovering long-run equilibrium relations in *C/Y* and *G/Y*, now I examine remaining great ratios in bivariate system. These ratios are *A/K*, *C/K* and *K/Y*. Table 10 presents results for *A/K*. Unless no trend in data is assumed, no cointegration is detected. Results for *C/K* in table 11 seem promising. *C* and *K* share one common trend and vector restriction is not rejected. But *K/Y* in table 12 displays no evidence of cointegration.

In short neither the five nor the three variable models achieve much success in finding one common trend in the Australian data. This finding is consistent with those reported by Kunst and Neusser (1990) and Neusser (1991) for other countries. The strongest support for the great ratios is found

Table 8 log *I*(Total), log *Y*(Total)

Null Hypothesis	log *I*(Total), log *Y*(Total)			
	Trend in Data, q =9		No Trend in Data, q =9	
	Trace	λ_{max}	Trace	λ_{max}
r =0	17.40* (0.02)	17.29* (0.01)	42.64* (0.00)	39.44* (0.00)
$r \leq 1$	0.11 (0.73)	0.11 (0.73)	3.19 (0.54)	3.19 (0.54)
Testing Restrictions				
	r =1		r =1	
	Test Statistics		Test Statistics	
(1, –1)	15.60* (0.00)		12.66* (0.00)	
	Cointegrating Vectors Estimates		Cointegrating Vectors Estimates	
(1, f)	f = –0.74, t-ratio = –12.62		f = –0.75, t-ratio = –12.42	
Normalized Cointegrating Coefficient	(1.00, –0.74)		(1.00, –0.75)	

Table 9 log *I*(Private), log *Y*(Private)

Null Hypothesis	log *I*(Private), log *Y*(Private)			
	Trend in Data, q =9		No Trend in Data, q =9	
	Trace	λ_{max}	Trace	λ_{max}
r =0	16.32* (0.03)	16.29* (0.02)	45.23*(0.00)	41.17* (0.00)
$r \leq 1$	0.03 (0.84)	0.03 (0.84)	4.06 (0.40)	4.06 (0.40)
Testing Restrictions				
	r =1		r =1	
	Test Statistics		Test Statistics	
(1, –1)	16.00* (0.00)		11.99* (0.00)	
	Cointegrating Vectors Estimates		Cointegrating Vectors Estimates	
(1, f)	f = –0.64, t-ratio = –12.65		f = –0.65, t-ratio = –11.80	
Normalized Cointegrating Coefficient	(1.00, –0.64)		(1.00, –0.65)	

Table 10 log *A*(Total), log *K*(Total)

Null Hypothesis	log *A*(Total), log *K*(Total)			
	Trend in Data, q =13		No Trend in Data, q =13	
	Trace	λ_{max}	Trace	λ_{max}
r =0	12.21 (0.14)	11.42 (0.13)	17.69 (0.10)	14.45* (0.08)
$r \leq 1$	0.78 (0.37)	0.78 (0.37)	3.24 (0.53)	3.24 (0.53)
Testing Restrictions				
	r =0		r =1	
	Test Statistics		Test Statistics	
(1, –1)			6.59* (0.01)	
	Cointegrating Vvectors Estimates		Cointegrating Vectors Estimates	
(1, *f*)			*f* = –0.39, *t*-ratio = –9.01	
Normalized Cointegrating Coefficient	(1.00, –0.38)		(1.00, –0.39)	

Table 11 log *C*(Total), log *K*(Total)

Null Hypothesis	log *C*(Total), log *K*(Total)			
	Trend in Data, q =13		No Trend in Data, q =13	
	Trace	λ_{max}	Trace	λ_{max}
r =0	15.44* (0.05)	15.26* (0.03)	27.81* (0.00)	22.28* (0.00)
$r \leq 1$	0.17 (0.67)	0.17 (0.67)	5.52 (0.23)	5.52 (0.23)
Testing Restrictions				
	r =1		r =1	
	Test Statistics		Test Statistics	
(1, –1)	0.44 (0.50)		0.20 (0.64)	
	Cointegrating Vectors Estimates		Cointegrating Vectors Estimates	
(1, *f*)				
Normalized Cointegrating Coefficient	(1.00, –1.02)		(1.00, –1.02)	

Table 12 log *K*(Total), log *Y*(Total)

Null Hypothesis	log *K*(Total), log *Y*(Total)			
	Trend in Data, q =9		No Trend in data, q =9	
	Trace	λ_{max}	Trace	λ_{max}
r =0	7.10 (0.56)	6.71 (0.52)	17.14 (0.12)	11.45 (0.21)
$r \leq 1$	0.39 (0.53)	0.39 (0.53)	5.69 (0.21)	5.69 (0.21)

Testing Restrictions

	r =0	r =0
	Test Statistics	Test Statistics
(1, –1)		
Normalized Cointegrating Coefficient	(1.00, –0.92)	(1.00, –0.85)

with the private economy data. In the five variable model the cointegrating relation is likely to be for *C/Y* and *G/Y*. The *C/Y* restriction is also confirmed for private three variable model.

4. CONCLUSION

To examine validity of Australian great ratios, I have used unit root test and cointegration tests. Unit root tests suggest that traditional great ratios of *C/Y*, *I/Y*, and *K/Y* are non-stationary except for private *C/Y*. But some of the implied great ratios (*C/K* and *G/Y*) are tested to be stationary. Sub-sampling in unit root tests have been used to check the possibility of structural changes for *C/Y*, *I/Y*, and *K/Y*. Sub-sampling tests have concluded that only *C/Y* may have experienced the changes. Using GNP in place of GDP reveals little change in these results.

Cointegration tests offer consistent findings with the unit root tests. In spite of much fewer cointegrating relations found in data than theory, both five variable (consumption, investment, government expenditure, export and output) and three variable (consumption, investment and output) models do not reject restrictions for *C/Y*. These findings are new to previous studies (Hossain and Chung, 1999) on Australia. Hossain and Chung finds one common trend and rejected joint restriction for *C/Y* and *I/Y*. Using longer period data, I find less favourable evidence for Australia.

Some attention should be paid to the fact that restriction for *G/Y* is not rejected which is another new finding. No past studies have attempted to test for *G/Y*. This is probably because most standard stochastic growth models do not include public sector. Given that *G/Y* is valid for Australia, extensions of standard models such as Campbell (1994) who incorporates public sector may deliver some gain in studying long-run implications.

Effects of the inclusion of public sector in data on results have been unclear. Neusser (1991) and Serletis (1996) document that no difference is shown in results between total and private economies, while Harvey *et al*. (2003) finds some difference. According to cointegration results here, private economy measures from which public sector have been removed in data produce different results from total economy. Total economy finds no cointegration unless no trend in data is assumed. Also an implied great ratio of *C/K* is cointegrated as well as *G/Y*, whereas *I/Y* and *K/Y* show no success.

Several findings are worthwhile noting. First, reasons for empirical consistency of great ratios may be elsewhere rather than uninterrupted growth in steady state. Neusser's argument that unique empirical consistency of US great ratios may be due to uninterrupted growth without destructive historical episodes is invalidated given that overall Australian data largely fail theoretical implications of stochastic growth models. Second, it remains unresolved how to treat public sector in stochastic growth models. Private economy measures in data produce more consistent than total with theory for Australia, whereas the inclusion of public sector as a separate variable in *G/Y* is cointegrated.

Among the findings what would matter to researchers in macroeconomics is the only marginal success or overall failure of RBC models to meet data. Interpreting model evaluative work such as this article, one always faces a question. Does the model fail data or the data fails the model? Unfortunately the results presented in this study seem to direct subsequent work in both ways. For example, evidence from fitting structural breaks suggests that global or local deterministic trends in the ratios may be by-product of dynamics from changes in structural parameters. Relaxing the stability assumption of structural parameters and studying how consequential dynamics affect great ratios may be a fruitful exercise. Also the differences in results between data measures gives clue of possibly flaws on empirical side. Great ratios by definition are bounded variables. Increase in length of data set should improve results. It may be the case where accurate measures or historical data should take the model closer to the data.

APPENDIX

Table A1 Details of Compositions of Variable Measures

Measures	Compositions
Total Output	Gross Domestic Output
Total Consumption	Final Consumption Expenditure
Total Investment	Private Gross Fixed Capital Formulation + Public Gross Fixed Capital Formulation
Total Capital	Enterprise Sector Capital Stock + General Government Capital Stock
Private Output	Gross Domestic Output – Government Consumption – Public Gross Fixed Capital Formulation
Private Consumption	Final Consumption Expenditure – Government Consumption
Private Investment	Private Gross Fixed Capital Formulation
Private Capital	Enterprise Sector Capital Stock

Note: Enterprise Sector Capital Stock measures business capital stock.

REFERENCES

Baxter, M. and M. J. Crucini, “Business Cycles and the Asset Structure of Foreign Trade,” *International Economic Review*, 36(4), 1995, pp. 821-854.

Blanchard, Olivier Jean and Quah Danny, “The Dynamic Effects of Aggregate Demand and Supply Disturbances,” *American Economic Review*, 79(4), American Economic Association, September 1989, pp. 655-673.

Bohl, M. T., “Testing the Long-run Implications of the Neoclassical Stochastic Growth Model: A Panel-Based Unit Root Investigation for West German Lander, 1970-1994,” *Journal of Macroeconomics*, 21(1), 1999, pp. 155-164.

Campbell, J. Y., “Inspecting the Mechanism: An Analytical Approach to the Stochastic Growth Model,” *Journal of Monetary Economics*, 33(3), 1994, pp. 463-506.

Creedy, J. and R. Guest, “Discounting and the Time Preference Rate,” *Economic Record*, 84(264), 2008, pp. 109-127.

Hall, A. R., “Testing for a Unit Root in Time Series with Pretest Data-Based Model Selection,” *Journal of Business and Economic Statistics*, 12(4), 1994, pp. 461-470.

Harvey, D. I., S. J. Leybourne, and P. Newbold, “How Great Are the Great Ratios?,” *Applied Economics*, 35(2), 2003, pp. 163-177.

Hossain, F. and P. J. Chung, “Long-run Implications of Neoclassical Growth Models: Empirical Evidence from Australia, New Zealand, South Korea and Taiwan,” *Applied Economics*, 31(9), 1999, pp. 1073-1082.

King, R. G., “Stochastic Trends and Economic Fluctuations,” *American Economic Review*, 81(4), 1991, pp. 819-840.

King, Robert G., Charles I. Plosser, James H. Stock, and Mark W. Watson, “Stochastic Trends and Economic Fluctuations,” *American Economic Review*, American Economic Association, 81(4), 1991, pp. 819-840,

Kunst, R. and K. Neusser, “Cointegration in a Macroeconomic System,” *Journal of Applied Econometrics*, 5(4), 1990, pp. 351-365.

Lau, P., "On the Validity and Identification of Long-run Restrictions for a Cointegrated System," *Economic Modelling*, 17(4), December 2000, pp. 485-496.

Neusser, K., "Testing the Long-Run Implications of the Neoclassical Growth Model," *Journal of Monetary Economics*, 27(1), 1991, pp. 3-37.

Ng, S. and P. Perron, "Unit Root Tests in ARMA Models with Data-Dependent Methods for the Selection of the Truncation Lag," *Journal of the American Statistical Association*, 90(429), 1995, pp. 268-281.

Serletis, A., "Testing the Long-run Implications of the Neoclassical Growth Model for Canada," *Journal of Macroeconomics*, 16(2), 1994, pp. 329-346.

____________, "Government Activities and Tests of the Long-run Implications of the Neoclassical Growth Model for Canada," *Canadian Journal of Economics*, 29(3), 1996, pp. 635-642.

Serletis, A. and T. Krichel, "International Evidence on the Long-run Implications of the Neoclassical Growth Model," *Applied Economics*, 27(2), 1995, pp. 205-210.

Solow, Robert M., "A Contribution to the Theory of Economic Growth," *Quarterly Journal of Economics*, 70(1), The MIT Press, 1956, pp. 65-94.

Stock, J. H. and M. W. Watson, "Testing for Common Trends," *Journal of the American Statistical Association*, 83(404), 1988, pp. 1097-1107.

Swan, T., "Economic Growth and Capital Accumulation," *Economic Record*, 32, 1956, pp. 334-361.