Trade Openness, Financial Development Energy Use and Economic Growth in Australia: Evidence on Long Run Relation with Structural Breaks

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Abstract:

The paper implements the autoregressive distributed lag (ARDL) bounds testing, supplemented by the Johansen-Juselius (JJ) approaches to cointegration to explore a long run relation among energy use, economic growth, financial development, capital, and trade openness in Australia. We also apply the vector error correction model (VECM) to understand the short run dynamics. The study period, 1965 – 2009, is hallmarked by major shocks across the globe which can potentially cause structural break in the series. To recognize this possibility, we implement the Zivot-Andrews (1992) and the Clemente et al. (1998) tests. The results confirm the long run relationship among the series. The Granger causality test shows bidirectional causality between energy consumption and economic growth; financial development and energy consumption; trade openness and economic growth; economic growth and financial development; energy consumption and trade openness; and financial development and trade openness. The findings offer fresh perspectives and insight for crafting energy policy for sustained economic growth.

Keywords: Energy, Financial Development, Trade, Structural Break, ARDL, Australia

JEL Codes: Q4, F65, F1, O4, C33

1. **Introduction:**

The objective of paper is to apply the extended Cobb-Douglas production function framework to explore a long run relation among energy use, economic growth, financial development, labor, capital, and trade openness. We follow the approach of Stern (1993, 2000) where GDP depends on energy use and others inputs. The variables chosen here closely capture the particular characteristics of mature economy such as Australia. For a long run relation we implement the Autoregressive Distributed Lag (ARDL), complemented by the Johansen Juselius approaches to cointegration; and the vector error correction model (VECM) for the short run dynamics. The data is annual, spans over four decades – 1965-2009, is hallmarked by major changes (shocks) in the global landscape. Shocks can potentially cause structural break in the series. In testing the stationarity properties of each series, this feature has been taken into consideration.

Despite the emergence of a bourgeoning literature, consensus on the nexus of energy use and economic growth remains elusive, in part due to ad-hoc approach, compounded by omitted variables bias (see Akarca and Long, 1980; Yu and Hwang, 1984; Yu andChoi, 1985; Perman and Stern, 2003; Stern 2004; Zeshan and Ahmed, 2013). It is against this backdrop that more recent studies have adopted multivariate approach by including capital and labor, inter alia (Stern, 1993, 2000). The recent decades have been witnessing remarkable rates of export and economic growth in emerging and developing economies with a concomitant boost in energy use. The specter of a gloomy future in respect of GHG, research focus has shifted to gaining a better understanding of the underlying dynamics of energy use vis-à-vis economic growth (see survey by Ozturk, 2010). Others examine the nexus of exports and GDP (Giles and Williams, 2000; Dritsaki, et al. 2004; Cuadros et al. 2004).

A good knowledge of the above relationship can be critical to policymakers for several reasons. If energy consumption Granger causes output then energy conservation, unrelated to technological change, can have adverse impact on output (Karanfil, 2009). Similarly, if energy consumption Granger causes exports/imports, any reduction in energy use likely will lower potential benefits from trade. In such case, energy conservation policies might conflict with trade policies. If unidirectional Granger causality runs from trade to energy use, conservation policies will have unfavorable effect on trade liberalization policies which may ultimately retard economic growth.

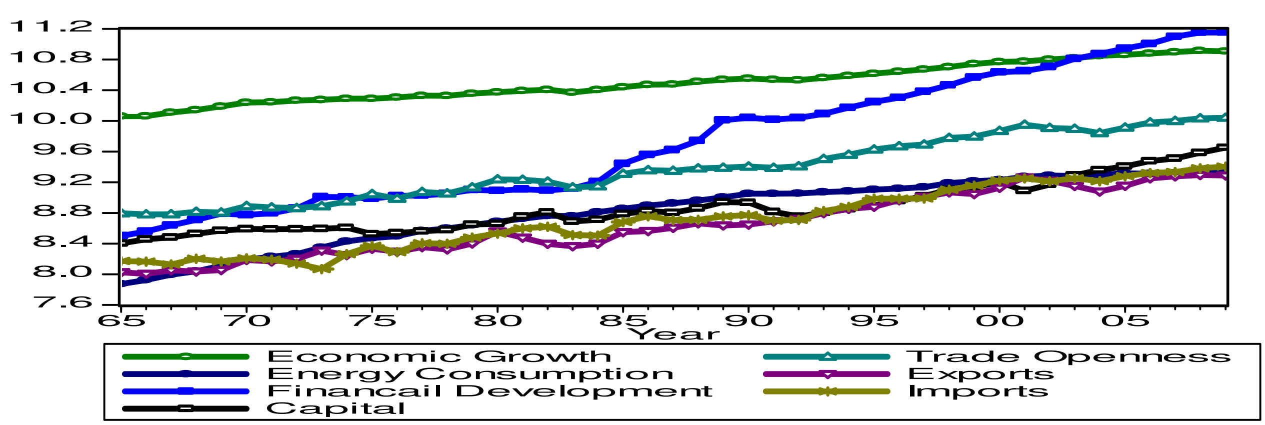
Narayan and Smyth, (2009) and Lean and Smyth, (2010a) appear to be the only published papers examining the relationship between energy consumption and exports. When the relevant variable(s) are excluded the estimates tend to be unreliable, and produce 'no-causality' (Lütkepohl, 1982). For example, the direction of causality changed for some African nations, once capital and labor were included (Wolde-Rufael, 2009). Empirical models that are grounded in sound theory predict better outcomes. Australia is a major player in international trade and has well developed financial market. Research suggests that the latter directly impacts energy use and factor productivity. Thus inclusion of both financial development and international trade along with labor and capital appears justified. The framework we use is conventional energy demand model **(**Kraft and Kraft, 1978; Masih and Masih, 1996; Soytas and Sari, 2003)**.** As noted, the lack of a comprehensive study on the energy-growth nexus in Australian context, a major player on the global stage, is the primary motivation behind the present research.

For a long-run relationship and direction of causality, results can differ by the country studied; and even same country over different periods (see Karanfil, 2009; Payne, 2010a) in part, due to country-specific conditions, data or methodological differences. When relevant variables are omitted, inputs substitution possibilities are left out (Akinlo, 2008; Ghali and El-Sakka, 2004; Stern and Cleveland, 2004). Using Australian data from 1960-1999, Fatai et al. (2004) found cointegration between energy use and electricity consumption; and unidirectional causality from output to electricity consumption. Narayan and Smyth (2005) found cointegration among electricity consumption, employment, and real income; and long-run causality from employment and real income to electricity consumption. Narayan and Prasad (2008) showed the long-run causality to run from electricity consumption to output. The results differ from those found by Chontanawat et al. (2008) for Australia. The latter used the series in per-capita terms. To avoid potential omitted-variable bias, Narayan and Smyth (2005) included index of employment levels in the manufacturing sector and found cointegration and unidirectional long-run causality from income and manufacturing index to electricity consumption. Using data from some developing countries, Mahadevan and Asafu-Adjaye (2007) found cointegration and bidirectional causality between energy consumption and GDP after they included consumer price index. Recently, Shahiduzzaman and Alam (2012) found cointegration and bidirectional causality between GDP and energy. They used energy, capital and labor as arguments in the production function.

The lack of consensus on the causality between energy consumption and income is important enough to warrants further study. The paper uses a model that describes the Australian context to provide evidence on energy economic growth nexus. The findings complement some of the existing research. Our paper contributes to the literature in several ways. (a)This is the first comprehensive research examining the energy consumption and economic growth nexus by taking explicit account of structural break. (b) Use an extended Cobb-Douglas production function to better understand the relationship. (c) Include trade openness to capture the impact of globalization. (d) Use the ARDL bounds testing and Johansen-Juselius approaches to cointegration to check robustness of the results. In particular, our paper is distinct improvement over Shahiduzzaman and Alam, (2012) who use an ad-hoc framework which makes their results suspect due to mis-specification from omission of relevant variable(s). Our findings are intuitively appealing and offer valuable insight for crafting energy policy for sustained economic growth. The contribution of the paper thus is significant.

The findings should help to craft sound policies for Australia, a major GHGs emitter, which ranks 18th among the major energy consumers; and 14th on a per capita basis. Net energy consumption increased at an average annual rate of 1.8 per cent from 1999 to 2010 (Australian Government (AG, 2012)), led by manufacturing and transportation sectors. Residential use grew modestly, but commercial/ mining sectors have remained steady (AG, 2011b). Australia's primary sources of energy are coal (37%), petroleum products (35%) and gas (23%). The share of renewable energy has remained steady at 5% over the last decade (AG, 2012). Electricity sector accounts for 36% of emissions, the largest contributor to GHG, followed by stationary sources 18%, transport 16%, agriculture 14%, fugitive7%, industrial processes 6% and waste 3% (AG, 2011a).

Fig-1: Trends of economic growth, energy consumption, financial development and trade openness



The rest of the paper is organized as follows. Section 2 reviews the relevant literature; section 3 outlines methodology and data sources; section 4 discusses the results. Section 5 draws conclusion and offers some remarks on policy implications.

2. Literature Review

The literature on energy consumption and its interaction with other relevant macroeconomic variables is discussed under three broad headings: (a) economic growth; (b) financial development; and (c) international trade. We discuss them in turn.

2.1 Economic Growth and Energy Consumption

Four hypotheses have been identified to describe energy-growth nexus: growth hypothesis; conservation hypothesis; feedback hypothesis; and neutrality hypothesis. The growth hypothesis considers energy critical to economic growth. Under conservation hypothesis causality runs from economic growth to energy. If reduction in energy use slows GDP then economy is energy dependent– unidirectional causality runs from economic growth to energy use. The feedback hypothesis assumes interdependence of the two series. In neutrality hypothesis, lower energy consumption does not affect economic growth, and conversely (Belke et al. 2011).

Kraft and Kraft (1978) first studied the economic growth-energy nexus. Using US data from 1947 to 1974 they found unidirectional causality from GNP growth to energy use. However, using a different dataset (1947-1972), Akarca and Long (1980) did not find any link. They argue that the 1973-1974 data might have been contaminated by the oil crisis. Erol and Yu (1988) used data from six developed countries from 1952-1982 and found bidirectional causality for Japan; unidirectional causality from energy to economic growth for Canada; from economic growth to energy for Germany and Italy; and none for France and England. Masih and Masih (1996) found causality from energy consumption to economic growth in India; there verse for Pakistan and Indonesia; and none for Malaysia, Singapore and the Philippines. Soytas and Sari (2003) found that economic growth Granger causes energy use in Italy and Korea, and unidirectional causality runs from energy use to economic growth in France, Germany, Japan and Turkey. Huang et al. (2008) found none for the low-income countries. However, they found unidirectional causality from economic growth to energy use for the middle and high-income countries. Comparable studies include Aqeel and Butt (2001) for Pakistan; Lee (2006) for France; Italy and Japan; and Lee and Chien (2010) for France and Japan. The reverse causality is reported by Lee, (2006) for Canada, UK, Germany Sweden and Switzerland; Narayan and Smyth (2008) for G-7 countries and Bowden and Payne (2009) for the US. The lack of consensus in these papers can be traced to the differences in methodology, time periods, and possibly country heterogeneity with respect to stages of economic growth and energy use patterns.

2.2 Financial Development and Energy Consumption

Financial development implies financial sector reforms that favor inflow of more foreign direct investment (FDI), more domestic credit to private sector, sound stock market and better banking services. Developed financial infrastructure enhances economic growth and boosts demand for energy (Sadorsky, 2010, 2011; and Shahbaz and Lean, 2012). Financial development lowers CO_2 emissions (Tamazian et al. 2009, p. 246); increases economic efficiency (Xu, 2000; Bell et al. 2001); lowers borrowing cost; and facilitates investment. Mielnik et al. (2002) found inverse relationship between FDI and energy intensity.

Dan and Lijun (2009) applied the Karanfil (2009) model to examine the effect of financial development on primary energy use in China. They found unidirectional Granger causality from energy consumption to financial development. Xu (2012) employed GMM approach to 29 Chinese provinces to examine a relationship between financial development and energy use. He documented cointegration when he used the ratio of loan by financial institutions to measure the former. Sadorsky (2010) applied different indicators of financial development to 22 emerging economies. He reported that the impact of financial development on energy demand is positive and small, but significant. Kaker et al. (2011) used production function approach to examine the relationship between economic growth, financial development and energy consumption in Pakistan. They find support for neutrality effect between economic growth and energy consumption but energy use Granger causes financial development.

Shahbaz and Lean (2012) document bidirectional causality between energy consumption and financial development; financial development and industrialization; and industrialization and energy consumption for Tunisia. Tang and Tan (2012) examine the relationship between energy consumption and financial development by incorporating relative prices and foreign direct investment (FDI) in the energy demand function in Malaysia. They report bidirectional causality between in the short and long runs[1]. Islam et al. (2013) document bidirectional causality between financial development and energy use in the long run; but in the short run, the former Granger causes the latter[2].

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[1]Their estimates may be biased for ignoring the role of population. They constructed financial development index using money and quasi money; liquid liabilities; domestic credit claims on private sectors; and domestic credit from the banking sector, each as a percentage of GDP. For the index, they ignored the role stock market capitalization.
[2] Islam et al. (2013) incorporated population in energy demand function. The coefficient of financial development for energy consumption is more meaningful than Tang and Tan, (2012).

2.3 International Trade and Energy Consumption

The link between international trade and energy consumption is based on the idea that export requires more production and thus more energy use. However, exports boost income and thus imports, which includes more machinery, transportation and luxury goods; and thus higher energy demand. The link has been explored by several authors. Narayan and Smyth (2009) used multivariate approach to investigate causality among energy use, exports and economic growth for some Middle Eastern countries[3]. They did not find causality. Erkan et al. (2010) applied Johansen-Juselius cointegration and VECM approaches to Turkish data. They document a long run relation; and causality from energy consumption to exports. Halicioglu (2011) found short run causality the other way around; while Lean and Smyth (2010a, b) reported none for Malaysia.

Using Japanese data, Sami (2011) found causality running from exports and economic growth to energy consumption[4]. Sultan (2011) found that energy consumption and exports cause economic growth in Mauritius. Sadorsky (2011b) applied panel cointegration method to Middle Eastern[5] countries and found causality from exports to energy consumption, and feedback relation between import and energy consumption in the short-run. In the long run the effect of exports and imports on energy consumption was positive.

Hossain (2012) examine causality between economic growth, exports, remittances and energy consumption for the SAARC countries[6]. The results confirm cointegration but the effect of exports on energy use was neutral. Sadorsky (2012) finds a long run relationship between energy and exports; energy and imports and energy and trade (exports + imports) using data from

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[3]Iran, Israel, Kuwait, Oman, Saudi Arabia and Syria

[4]He incorporated income per capita to examine the impact of exports on energy consumption.

[5]Bahrain, Iran, Jordan, Oman, Qatar, Saudi Arabia, Syria, United Arab Emirates

[6]Bangladesh, India and Pakistan

7 South American countries[7]. He documents feedback relationship between energy consumption and exports in the short run; and the former Granger causes imports. Shahbaz et al. (2012) finds that energy consumption Granger causes exports in Pakistan.

3. Data and Methodological Framework

Annual data from 1965 to 2009, used in the paper, is taken from the World Development Indicators (WDI-CD-ROM, 2011). The series are: GDP, energy consumption (kg of oil equivalent), domestic credit to private sector, exports, real imports and capital stock; each in per capita real terms. We employ the extended Cobb-Douglas production function[8] where technology is endogenously determined by the level of financial development and trade. The framework is written as follows[9]:

$$G = AE^{\alpha_1} K^{\alpha_2} L^{\alpha_3} e^{u} \tag{1}$$

where, G is real domestic output; E, K and L denote respectively, energy, real capital and labor. The term A refers to technology and e to error term, assumed *N(iid).* The output elasticity with respect to energy use, capital and labor is α_1, α_2 and α_3 respectively. When ($\alpha_1 + \alpha_2 + \alpha_3 = 1$) we have constant returns to scale. Financial development promotes economic growth via its positive effect on capital formation, efficient resource allocation; FDI inflows; transfer of superior technology and managerial skill. International trade helps diffusion of technological advances. Entrepreneurs are the main actors in a free market who set the stage for implementing innovation into actual technological progress. The model thus can be written as:

$$A(t) = \phi.TR(t)^{\alpha} F(t)^{\delta} \tag{2}$$

[7] Argentina, Brazil, Chile, Ecuador, Paraguay, Peru, Uruguay

[8] See Shahbaz, (2012) for details

[9] We have used consumer price index series to convert all the series into real terms except energy consumption.

Where ϕ is time-invariant constant, TR is indicator of trade openness and F is financial development[10]. Substituting equation-2 into equation-1:

$$G(t) = \phi . E(t)^{\delta_1} F(t)^{\delta_2} TR(t)^{\delta_3} K(t)^{\beta} L(t)^{1-\beta} \quad (3)$$

Following Lean and Smyth, (2010); Shahbaz and Lean, (2012) we divide both sides by population and get each series in per capita terms; leaving the impact of labor constant. The linearized Cobb-Douglas production function in log is written as:

$$\ln G_t = \beta_1 + \beta_E \ln E_t + \beta_F \ln F_t + \beta_{TR} \ln TR_t + \beta_K \ln K_t + \mu_t \quad (4)$$

where, $\ln G_t$, $\ln E_t$, $\ln F_t$, $\ln TR_t$ and $\ln K_t$ represent GDP, energy consumption, real domestic credit to private sector as a proxy for financial development, trade openness and capital use, respectively, each in real, per capita terms; expressed in natural logarithm. The μ_t is a random error term. We use three indicators of trade openness: exports, imports, and (export + import)[11]. We specify and estimate each trade model separately in an effort to captures the relationship between energy use and economic growth where technology works through financial development and international trade.

Prior to testing for cointegration, we check for stationarity of each series[12]. The study period is hallmarked by major changes in the global landscape. These exogenous shocks can potentially cause structural breaks and distort the relation. We check the stationarity properties using ADF with intercept and trend keeping in mind that such test is not appropriate in the presence of structural break in the series. So, finesse the problem, we implement the Zivot-

[10]We use three indicators of trade openness: (a) exports, imports, and trade (exports+imports), each measured in real per capital terms.

[11] Trade intensity equals exports plus imports as share of GDP.

[12]The ARDL bounds test works regardless of whether or not the regressors are I(1) or I(0) / I(1), but the presence of I(2) or higher order makes the F-test unreliable (See Ouattra, 2004).

Andrews (ZA) (1992) and Clemente et al. (1998) unit root tests. The former is used for one; and latter for two unknown structural breaks. The Clemente et al. (1998) test has more power compared to the ZA (1992) test.

We choose the ARDL bounds testing approach due it its advantages. (a) The approach applies regardless of the order of integration of the regressors. (b) It has better small sample properties (Pesaran and Shin, 1999). (c) A dynamic unrestricted error correction model can be derived from the ARDL model using a simple linear transformation which integrates short run dynamics with long run equilibrium without losing any long run information. For purposes of estimation, we implement the following the ARDL models:

$$\Delta \ln G_t = \alpha_1 + \alpha_T T + \alpha_D D + \alpha_G \ln G_{t-1} + \alpha_E \ln E_{t-1} + \alpha_F \ln F_{t-1} + \alpha_{TR} \ln TR_{t-1} + \alpha_K \ln K_{t-1} + \sum_{i=1}^{p} \alpha_i \Delta \ln G_{t-i}$$
$$+ \sum_{j=0}^{q} \alpha_j \Delta \ln E_{t-j} + \sum_{k=0}^{r} \alpha_k \Delta \ln F_{t-k} + \sum_{l=0}^{s} \alpha_l \Delta \ln TR_{t-l} + \sum_{m=0}^{t} \alpha_m \Delta \ln K_{t-m} + \mu_t \quad (5)$$

$$\Delta \ln E_t = \alpha_1 + \alpha_T T + \alpha_D D + \alpha_G \ln G_{t-1} + \alpha_E \ln E_{t-1} + \alpha_F \ln F_{t-1} + \alpha_{TR} \ln TR_{t-1} + \alpha_K \ln K_{t-1} + \sum_{i=1}^{p} \beta_i \Delta \ln E_{t-i}$$
$$+ \sum_{j=0}^{q} \beta_j \Delta \ln G_{t-j} + \sum_{k=0}^{r} \beta_k \Delta \ln F_{t-k} + \sum_{l=0}^{s} \beta_l \Delta \ln TR_{t-l} + \sum_{m=0}^{t} \beta_m \Delta \ln K_{t-l} + \mu_t$$

(6)

$$\Delta \ln F_t = \alpha_1 + \alpha_T T + \alpha_D D + \alpha_G \ln G_{t-1} + \alpha_E \ln E_{t-1} + \alpha_F \ln F_{t-1} + \alpha_{TR} \ln TR_{t-1} + \alpha_K \ln K_{t-1} + \sum_{i=1}^{p} \beta_i \Delta \ln F_{t-i}$$
$$+ \sum_{j=0}^{q} \beta_j \Delta \ln G_{t-j} + \sum_{k=0}^{r} \beta_k \Delta \ln E_{t-k} + \sum_{l=0}^{s} \beta_l \Delta \ln TR_{t-l} + \sum_{m=0}^{t} \beta_m \Delta \ln K_{t-m} + \mu_t$$

(7)

$$\Delta \ln TR = \alpha_1 + \alpha_T T + \alpha_D D + \alpha_G \ln G_{t-1} + \alpha_E \ln E_{t-1} + \alpha_F \ln F_{t-1} + \alpha_{TR} \ln TR_{t-1} + \alpha_K \ln K_{t-1} + \sum_{i=1}^{p} \vartheta_i \Delta \ln TR_{t-i}$$
$$+ \sum_{j=0}^{q} \vartheta_j \Delta \ln G_{t-j} + \sum_{k=0}^{r} \vartheta_k \Delta \ln E_{t-k} + \sum_{l=0}^{s} \vartheta_l \Delta \ln F_{t-l} + \sum_{m=0}^{t} \vartheta_m \Delta \ln K_{t-m} + \mu_t$$

(8)

$$\Delta \ln K_t = \alpha_1 + \alpha_T T + \alpha_D D + \alpha_G \ln G_{t-1} + \alpha_E \ln E_{t-1} + \alpha_F \ln F_{t-1} + \alpha_{TR} \ln TR_{t-1} + \alpha_K \ln K_{t-1} + \sum_{i=1}^{p} \rho_i \Delta \ln K_{t-i}$$
$$+ \sum_{j=0}^{q} \rho_j \Delta \ln G_{t-j} + \sum_{k=0}^{r} \rho_k \Delta \ln E_{t-k} + \sum_{l=0}^{s} \rho_l \Delta \ln F_{t-l} + \sum_{m=0}^{t} \rho_m \Delta \ln TR_{t-m} + \mu_t \quad (9)$$

where, Δ is difference operator, T, time trend and D refers to structural break identified by the ZA (1992) test. The test of cointegration involves comparing the computed F-statistic with the critical bounds. The null hypothesis of no cointegration $H_0: \alpha_G = \alpha_E = \alpha_F = \alpha_{TR} = \alpha_K = 0$ is tested against the alternate of cointegration[13] $H_1: \alpha_G \neq \alpha_E \neq \alpha_F \neq \alpha_{TR} \neq \alpha_K \neq 0$. The series are cointegrated if the F-statistic exceeds the upper critical bound (UCB). They are not cointegrated if the F falls below the lower critical bound (LCB). However, if the F-statistic lies between then UCB and LCB, the test is inconclusive[14]. We use are the critical bounds from Narayan (2005) which are appropriate for small sample, 45 in this case[15]. The parameter stability is checked by applying the CUSUM and CUSUM_{SQ} tests proposed by Brown et al. (1975).

For the long run relation among the series we use the following equation:

$$\ln G_t = \theta_0 + \theta_1 \ln E_t + \theta_2 \ln F_t + \theta_3 \ln TR_t + \theta_4 \ln K_t + \mu_i \quad (10)$$

where, $\theta_0 = -\beta_1 / \alpha_G, \theta_1 = -\alpha_E / \beta_1, \theta_2 = -\alpha_F / \beta_1, \theta_3 = -\alpha_{TR} / \beta_1, \theta_4 = -\alpha_K / \beta_1$ and μ_t the error term assumed normally distributed. Once the long run relationship is established among the series, we test the direction of causality using the following error correction representation[16]:

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[13]Pesaran et al. (2001) provide two critical values - when the regressors are *I(0)* and *I(1).*

[14]Here the error correction model is appropriate method to investigate the cointegration (Bannerjee et al. 1998). This indicates that error correction term will be a useful way of establishing cointegration between the variables.

[15] The critical bounds by Narayan, (2005) are appropriate for small sample (30 – 80). The critical bounds by Pesaran et al. (2001) are significantly smaller (Narayan and Narayan, 2005).

[16]If cointegration is not detected, the causality test is performed without an error correction term (*ECT*).

$$(1-L)\begin{bmatrix}\ln G_t\\ \ln E_t\\ \ln F_t\\ \ln TR_t\\ \ln L_K\end{bmatrix}=\begin{bmatrix}a_1\\ a_2\\ a_3\\ a_4\\ a_5\end{bmatrix}+\sum_{i=1}^{p}(1-L)\begin{bmatrix}b_{11i}b_{12i}b_{13i}b_{14i}b_{15i}\\ b_{21i}b_{22i}b_{23i}b_{24i}b_{25i}\\ b_{31i}b_{32i}b_{33i}b_{34i}b_{35i}\\ b_{41i}b_{42i}b_{43i}b_{44i}b_{45i}\\ b_{51i}b_{52i}b_{53i}b_{54i}b_{55i}\end{bmatrix}\times\begin{bmatrix}\ln G_{t-1}\\ \ln E_{t-1}\\ \ln F_{t-1}\\ \ln TR_{t-1}\\ \ln K_{t-1}\end{bmatrix}+\begin{bmatrix}\alpha\\ \beta\\ \delta\\ \phi\\ \varphi\end{bmatrix}ECT_{t-1}+\begin{bmatrix}\varepsilon_{1t}\\ \varepsilon_{2t}\\ \varepsilon_{3t}\\ \varepsilon_{4t}\\ \varepsilon_{5t}\end{bmatrix}\quad(11)$$

where, $(1-L)$ is the lag operator and ECT_{t-1} is the lagged residual obtained from the long run ARDL relationship; $\varepsilon_{1t}, \varepsilon_{2t}, \varepsilon_{3t}, \varepsilon_{4t}$, and ε_{5t} are error terms assumed $N(0,\sigma)$. Long run causality requires a significant t-statistic on the coefficient of ECT_{t-1}. A significant F-statistic on the coefficients of first differences of the variables suggests short run causality. Joint long-and-short runs causality can be obtained from joint significance of the ECT_{t-1} and the estimated lagged independent variables. For instance, $b_{12,i} \neq 0 \forall_i$ suggests that energy consumption Granger causes economic growth. Causality runs from economic growth to energy consumption if we have $b_{21,i} \neq 0 \forall_i$.

4. Results and Discussions

The ADF and PP unit root test results with intercept and trend, presented in Table-1 show that each series is I(1). The ZA (1992) [Table-2] and Clemente et al. (1998) [Table-3] test results suggest that each series is I(1) with intercept and trend; and contains structural breaks. For stationarity, we use the results from the Clemente et al. (1998) test[17] as reported in Table-3.

Table-1: ADF and PP Unit Root Analysis

Variables	ADF Test with Intercept and Trend		PP Test with Intercept and Trend	
	T-statistics	Prob. Values	T-statistics	Prob. Values

[17] The test does so by using two models (a) additive outliers (AO) model for an abrupt change; and (b) innovational outliers (IO) model for gradual shift in mean.

$\ln G_t$	-2.7694 (1)	0.2231	-2.2815(3)	0.4347
$\Delta \ln G_t$	-3.5675(2)	0.0454**	-5.5471(3)	0.0002*
$\ln E_t$	-2.9797 (1)	0.1495	-3.1108 (3)	0.1165
$\Delta \ln E_t$	-6.2960 (1)	0.0000*	-8.9865(6)	0.0000*
$\ln F_t$	-2.1391(1)	0.5101	-1.6360 (0)	0.7744
$\Delta \ln F_t$	-4.7291 (1)	0.0024*	-4.4264 (3)	0.0053*
$\ln K_t$	-1.1231 (1)	0.9131	-0.7025 (3)	0.9666
$\Delta \ln K_t$	-5.4844 (1)	0.0003*	-5.8474 (3)	0.0001*
$\ln EX_t$	-2.8859 (2)	0.1772	-0.2671 (3)	0.9215
$\Delta \ln EX_t$	-5.6097(1)	0.0002*	-6.9225(3)	0.0000*
$\ln IM_t$	-2.9680 (2)	0.1530	0.3419 (3)	0.9780
$\Delta \ln IM_t$	-4.8668 (2)	0.0018*	-7.0990 (3)	0.0000*
$\ln TR_t$	-2.7570 (3)	0.2207	0.1922	0.9622
$\Delta \ln TR_t$	-5.1075 (2)	0.0009*	-6.5597 (3)	0.0000*
Note: * and ** represent significance at 1% and 5% levels, respectively. Lags of ADF (PP) test are in parentheses.				

Table-2: Zivot-Andrews Structural Break Trended Unit Root Test

Variable	At Level		At 1st Difference	
	T-statistic	Time Break	T-statistic	Time Break

$\ln G_t$	-4.394 (1)	1998	-6.520 (0)*	1971
$\ln E_t$	-5.519 (0)	1983	-4.665 (2)***	1987
$\ln F_t$	-5.065 (1)	1985	-6.594 (1)*	1985
$\ln K_t$	-4.618 (0)	1991	-5.976 (1)*	1995
$\ln EX_t$	-4.101 (0)	1996	-7.100 (0)*	2002
$\ln IM_t$	-4.292 (0)	1974	-7.529 (1)*	1974
$\ln TR_t$	-4.138 (0)	1995	-5.882 (1)*	2002
Note: * and *** represent significance at 1%, and 10% level respectively. Lag order is shown in parenthesis.				

Table-3: Clemente-Montanes-Reyes Structural Break Unit Root Test

Variable	Innovative Outliers			Additive Outlier		
	t-statistic	TB1	TB2	t-statistic	TB1	TB2
$\ln G_t$	-3.601 (2)	1982	1993	-6.672 (2)*	1982	1991
$\ln E_t$	-3.949 (2)	1986	1994	-8.279 (1)*	1979	1985
$\ln F_t$	-4.297 (3)	1983	1996	-8.848 (3)*	1983	1988
$\ln K_t$	-2.257(3)	1983	2001	-6.992 (1)*	1994	2000
$\ln EX_t$	-2.720 (1)	1983	1991	-7.482 (1)*	1982	2000
$\ln IM_t$	-3.802 (1)	1972	1991	-8.195 (5)*	1972	1982
$\ln TR_t$	-2.659 (2)	1983	1991	-7.402 (2)	1982	2000

Note: * indicates significance at 1% level.

Armed with information about stationarity, we apply the ARDL bounds testing approach to cointegration. For the optimal lag orders, we use the AIC criteria (column-2, Table-4). Appropriate lag length is helpful in capturing the dynamic link among the series (Lütkepohl, 2006). The ARDL bounds test results, based on Narayan, (2005) are reported in Table-4. In the exports model we find four cointegrating vectors (F-statistics exceeds the UCB). For other models, when we use imports and trade as indicators of trade openness the results are similar. We find cointegration among economic growth, energy use, financial development, trade openness and capital for Australia. We now report the results of Johansen and Juselius, (1990) cointegration test. The results presented in Table-5 confirm one cointegrating vector when we use exports, imports and trade as indicators of trade openness. The results thus appear robust.

Table-4: The Results of ARDL Cointegration Test

Bounds Testing to Cointegration				Diagnostic tests			
Estimated Models	Optimal lag length	Structural Break	F-statistics	χ^2_{NORMAL}	χ^2_{ARCH}	χ^2_{RESET}	χ^2_{SERIAL}
$F_G(G/E,F,K,EX)$	2, 1, 1, 1, 2	1998	5.951**	0.6979	[1]: 1.9823	[1]: 1.5081	[1]: 0.9330; [2]: 1.6206
$F_E(E/G,F,K,EX)$	3, 2, 1, 1, 1	1983	5.351***	0.7288	[1]: 0.0013	[1]: 0.1736	[1]: 0.1113; [2]: 1.6369
$F_F(F/G,E,K,EX)$	3, 2, 2, 1, 2	1985	6.194**	4.2222	[1]: 1.0248	[2]: 2.1298	[1]: 0.1678; [2]: 0.4386
$F_K(K/G,E,F,EX)$	2, 2, 1, 2, 1	1991	1.415	0.9875	[1]: 0.8641	[2]: 2.753	[1]: 1.8578; [2]: 1.0781
$F_{EX}(EX/G,E,F,K)$	1, 0, 1, 0, 3	1996	5.997**	0.2879	[1]: 0.6234	[1]: 0.3915	[1]: 0.1475; [2]: 2.4983
$F_G(G/E,F,K,IM)$	2, 2, 2, 2, 2,	1998	11.645*	1.5056	[1]: 0.0759	[5]: 3.2188	[1]: 1.5680; [2]: 2.0343
$F_E(E/G,F,K,IM)$	2, 2, 1, 2, 2	1983	6.416**	0.0286	[1]: 0.3333	[1]: 0.0069	[1]: 0.7395; [2]: 2.4246
$F_F(F/G,E,K,IM)$	2, 1, 1, 2, 2	1985	5.898**	4.0567	[1]: 0.0414	[4]: 3.1653	[1]: 2.1326; [2]: 1.0130
$F_K(K/G,E,F,IM)$	2, 2, 1, 2, 1	1991	1.563	10.5194	[1]: 0.3779	[1]: 0.5778	[1]: 1.1437; [2]: 0.5957
$F_{IM}(IM/G,E,F,K)$	2, 2, 2, 2, 2,	1974	9.062*	0.0283	[1]: 0.6923	[2]: 2.7683	[1]: 0.1578;[2]: 1.2704

$F_G(G/E,F,K,TR)$	2, 2, 2, 2, 2	1998	10.131*	0.0711	[1]: 0.6228	[1]: 1.9141	[1]: 0.5848; [2]: 2.0446
$F_E(E/G,F,K,TR)$	2, 2, 1, 1, 2	1983	5.587**	0.3257	[1]: 0.1944	[1]: 0.5539	[1]: 0.5633; [2]: 3.2566
$F_F(F/G,E,K,TR)$	3, 2, 2, 1, 1	1985	6.656**	4.1223	[1]: 1.6893	[4]: 1.8452	[1]: 0.1920; [2]: 0.1039
$F_K(K/G,E,F,TR)$	2, 2, 2, 2, 2	1991	1.120	0.2671	[1]: 1.5535	[4]: 2.01163	[1]: 0.6148; [2]: 0.8465
$F_{TR}(TR/G,E,F,K)$	2, 2, 2, 2, 2	1995	6.2997**	0.5594	[1]: 0.0736	[1]: 0.8912	[1]: 0.0635; [3]: 2.1557
Significant level	Critical values(T= 45)§						
	Lower bounds $I(0)$	Upper bounds $I(1)$					
1% level	6.053	7.458					
5% level	4.450	5.560					
10% level	3.740	4.780					

Note: *, ** and *** denote the significance at 1%, 5% and 10%levels, respectively. The optimal lag length is based on AIC. [ ] is the order of diagnostic tests. §Critical values are from Narayan (2005).

Table-5: Results of Johansen Cointegration Test

Hypothesis	Trace Statistic	Maximum Eigen Value
$G_t = f(E_t, F_t, K_t, EX_t)$		
$R = 0$	78.9610*	42.1823*
$R \leq 1$	36.7786	21.8443
$R \leq 2$	14.9343	11.6114
$R \leq 3$	3.3228	2.8917
$R \leq 4$	0.4310	0.4310
$G_t = f(E_t, F_t, K_t, IM_t)$		
$R = 0$	81.2336*	39.2562**
$R \leq 1$	41.9774	25.4069
$R \leq 2$	16.5705	10.3030
$R \leq 3$	6.2674	4.9147
$R \leq 4$	1.3526	1.3526
$G_t = f(E_t, F_t, K_t, TR_t)$		
$R = 0$	79.9799*	42.6671*
$R \leq 1$	37.3128	21.8477
$R \leq 2$	15.4651	10.5328
$R \leq 3$	4.9323	4.1491
$R \leq 4$	0.7831	0.7831
Note: * and ** denote significance at 1% and 5% levels, respectively.		

We now report the long and short run impacts of energy consumption, trade openness, financial development and capital on economic growth in Australia. Recall that we used three different measures of trade openness: export, import and trade (export + import) in estimating the respective equations. This generated different coefficient values depending on the particular measure used. To make things simpler, we report each coefficient (Table-6) within a range of values; as obtained under alternative model. We find that energy consumption is positively related to economic growth and is statistically significant at the 1% level. All else same, a 1% growth in energy consumption is expected to boost economic growth between (0.5384 and 0.5886) % (under alternative specifications) suggesting that the former plays a vital role in promoting domestic production in Australia. The effect of financial development on economic growth is positive and significant at the 1% level. A 1% increase in financial development raises economic growth on an average in the range of (0.0861 - 0.1008)%, ceteris paribus. Capital boosts economic growth, as theory predicts, and the relation is significant at the 1% level. The results suggest that a (0.1610-0.1848) % economic growth is associated with a 1% increase in capital accumulation in the country, on an average, all else same. The impact of exports, imports and trade openness (taken separately) on economic growth is positive and significant at the 5 and 10% levels, respectively. A 1% increase in exports, imports and trade openness is expected to boost economic growth by 0.1123, 0.0592 and 0.0846%, respectively, ceteris paribus. The elasticity of economic growth with respect to export is the highest, almost twice, compared to imports and about 30% higher, compared with trade openness.

Table-6: Long Run Analysis

Dependent variable = $\ln G_t$						
Variables	Coefficient	T-statistic	Coefficient	T-statistic	Coefficient	T-statistic
Constant	2.6955*	6.8730	2.4484*	4.5748	2.4618*	6.4348
$\ln E_t$	0.5384*	8.2197	0.5886*	7.1675	0.5567*	9.0479
$\ln F_t$	0.0861*	4.3897	0.1008*	9.9394	0.0908*	5.1139
$\ln K_t$	0.1610*	6.2089	0.1763*	6.5548	0.1848*	6.1385
$\ln EX_t$	0.1123**	2.6719	…	…	…	…
$\ln IM_t$	…	…	0.0592***	1.7947	…	…
$\ln TR_t$	…	…	…	…	0.0846**	2.0860
R^2	0.9556		0.9955		0.9855	
$Adjusted-R^2$	0.9551		0.51*		0.949*	
F-statistic	22.62*		20.22*		21.65*	
Diagnostic Tests						
Test	F-statistic	P-value	F-statistic	P. value	F-statistic	P-value
χ^2 *NORMAL*	0.9164	0.6323	1.0304	0.5973	0.8605	0.6503
χ^2 *SERIAL*	1.6430	0.1913	1.8960	0.1577	2.1290	0.1336
χ^2 *ARCH*	0.4276	0.6157	1.2411	0.2414	0.8840	0.3524
χ^2 *WHITE*	1.2164	0.2171	1.2413	0.3041	1.3724	0.2420
χ^2 *REMSAY*	2.1742	0.1565	2.3527	0.1088	2.2202	0.1253
CUSUM	Stable	5%	Stable	5%	Stable	5%

$CUSUM_{SQ}$	Stable	5%	Stable	5%	Stable	5%
Note: *, ** and *** show significance at 1%, 5% and 10% level, respectively.						

Table-7: Short Run Analysis

Dependent variable = $\Delta \ln G_t$						
Variables	Coefficient	T-statistic	Coefficient	T-statistic	Coefficient	T-statistic
Constant	0.0067**	2.4389	0.0073**	2.3219	0.0068**	2.4507
$\Delta \ln E_t$	0.2335*	2.8069	0.2873*	2.9930	0.2618*	3.1931
$\Delta \ln F_t$	0.0632***	1.7338	0.0762***	1.6869	0.0698***	1.9515
$\Delta \ln K_t$	0.1398*	3.5246	0.1079**	2.6321	0.1142*	3.0960
$\Delta \ln EX_t$	0.0696**	2.2189	...	...	...	...
$\Delta \ln IM_t$	...	...	0.0281	1.1200	...	...
$\Delta \ln TR_t$	...	...	...	...	0.0661***	1.7977
ECM_{t-1}	-0.2663**	-2.1605	-0.2494**	-2.1832	-0.2570**	-2.1544
R^2	0.5942		0.5631		0.5867	
$Adjusted-R^2$	0.5052		0.4402		0.4963	
F-statistic	11.1311*		9.7976*		10.7904*	
Short Run Diagnostic Tests						
Test	F-statistic	P-value	F-statistic	P-value	F-statistic	P-value
$\chi^2 NORMAL$	0.0658	0.9676	0.1120	0.9455	0.0486	0.9759

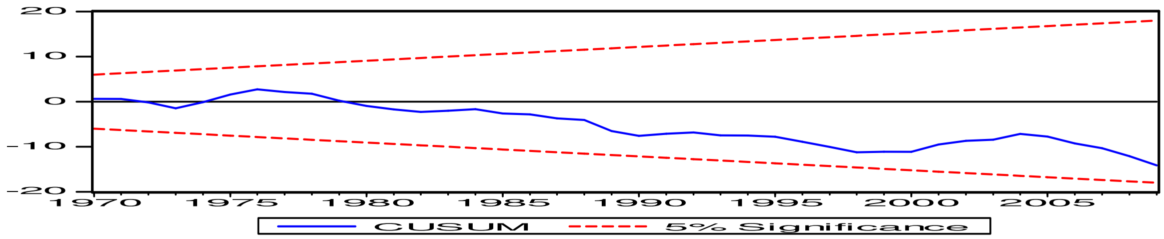
χ^2 *SERIAL*	1.8530	0.1713	1.6960	0.1977	2.1290	0.1336
χ^2 *ARCH*	0.4328	0.5142	1.2745	0.2654	1.3338	0.2548
χ^2 *WHITE*	0.4253	0.9238	1.2267	0.3107	0.7796	0.6474
χ^2 *REMSAY*	2.2743	0.1400	2.4648	0.1249	2.3302	0.1353
Note: *, ** and *** show significance at 1%, 5% and 10% level, respectively.						

Table-7 reports the short run results. The impact of energy consumption, capital, exports trade and financial development on economic growth is positive, and significant except imports. The estimates for ECM_{t-1},-0.2663, -0.2494 and -0.2570 (for exports, imports and trade, respectively) are negative and significant at the 5% level. The results lend support to a long run relationship among the series. The short run deviations from the long run equilibrium are thus corrected by 26.63% (export), 24.94% (import) and 25.70% (trade) towards the long run equilibrium path each year. The diagnostic tests show that error terms of short run models are normally distributed; free of serial correlation, heteroskedasticity, and ARCH problems for each model. The Ramsey reset test suggests that the functional form for the models is well specified.

The cumulative sum (CUSUM) and the cumulative sum of squares (CUSUMsq) tests suggest stability of the long and short run parameters (Figures 1–6). The graphs of CUSUM and CUSUMsq test lie within the 5%critical bounds which confirm stability (Brown et al. 1975).

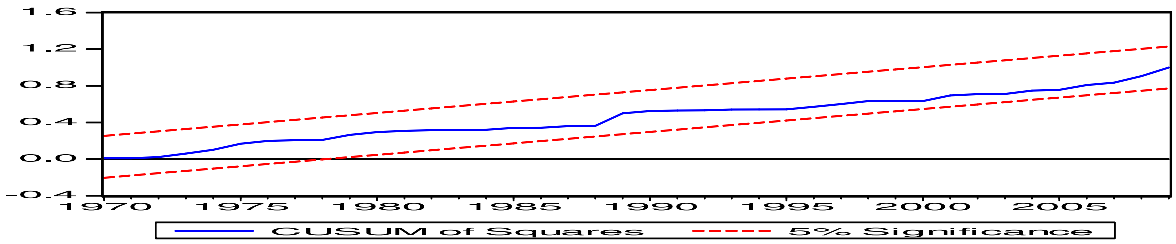
Exports Model

Figure 1: Plot of Cumulative Sum of Recursive Residuals



The straight lines represent critical bounds at 5% significance level.

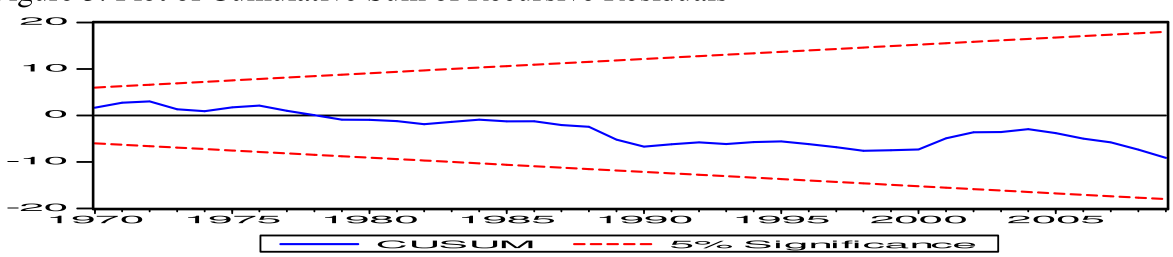
Figure 2: Plot of Cumulative Sum of Squares of Recursive Residuals



The straight lines represent critical bounds at 5% significance level.

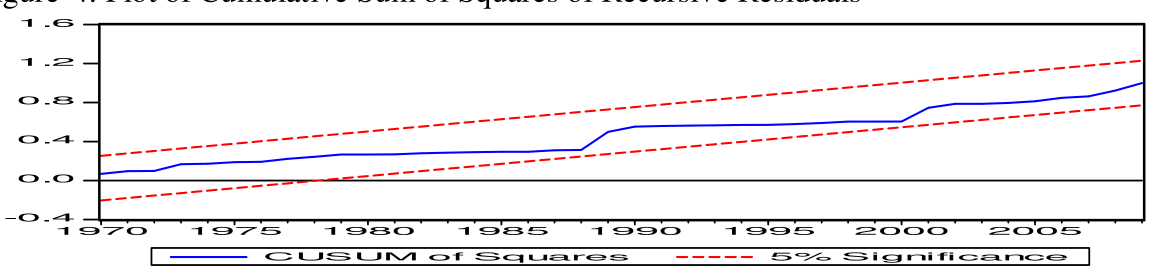
Imports Model

Figure 3: Plot of Cumulative Sum of Recursive Residuals



The straight lines represent critical bounds at 5% significance level.

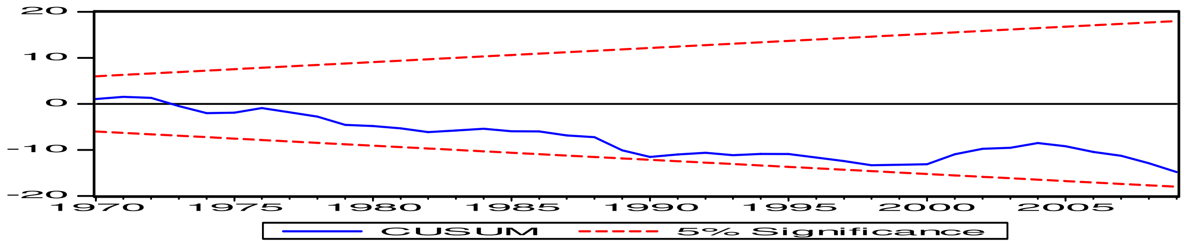
Figure 4: Plot of Cumulative Sum of Squares of Recursive Residuals



The straight lines represent critical bounds at 5% significance level.

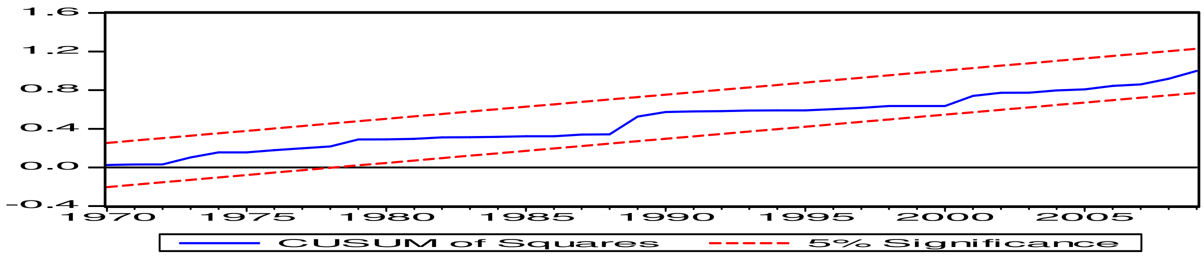
Trade Model

Figure 5: Plot of Cumulative Sum of Recursive Residuals



The straight lines represent critical bounds at 5% significance level.

Figure 6: Plot of Cumulative Sum of Squares of Recursive Residuals



The straight lines represent critical bounds at 5% significance level.

The VECM Granger Causality Analysis

The confirmation of cointegration assures the existence of uni- or bidirectional causality between/among the series and we examine causality using the VECM framework. Knowledge about causality can help to craft appropriate energy policies for sustainable economic growth. The long run causality (Table-8) test shows feedback relation between energy consumption and economic growth; exports and economic growth; imports and economic growth; trade and economic growth; financial development and energy consumption; economic growth and financial development; exports and financial development; import and financial development; and trade openness and financial development in Australia. The causality from energy consumption, financial development, capital, exports, imports and trade to economic growth lends supports to the energy-led-growth, finance-led-growth, capital-led-growth, exports-led-growth, imports-led and trade-led-growth hypotheses. We find that economic growth, financial development, capital, exports, imports and trade corroborate growth-led-energy, finance-led-energy, exports-led-energy, imports-led-energy, trade-led-energy and capital-led-energy hypotheses. The bidirectional causality for the pairs of financial development and exports; imports, and trade openness lends support to the idea that financial development and trade openness complement each other and thus may be sustainable in the context of Australia.

Table-8: The VECM Granger Causality Analysis

Dependent Variable	Type of causality					
	Short Run					Long Run
	$\sum \Delta \ln G_{t-1}$	$\sum \Delta \ln E_{t-1}$	$\sum \Delta \ln F_{t-1}$	$\sum \Delta \ln K_{t-1}$	$\sum \Delta \ln EX_{t-1}$	ECT_{t-1}
$\Delta \ln G_t$	…	4.4689** [0.0194]	2.1652 [0.1312]	3.7607** [0.0341]	2.5422*** [0.0945]	-0.3746** [-2.7285]
$\Delta \ln E_t$	3.4242** [0.0449]	…	0.9503 [0.3972]	0.4956 [0.6138]	1.9241 [0.1625]	-0.3599** [-2.2182]
$\Delta \ln F_t$	0.6264 [0.5409]	0.1778 [0.8379]	…	2.3347 [0.1131]	0.3655 [0.6966]	-0.1582** [-2.2569]
$\Delta \ln K_t$	6.6742* [0.0037]	0.4371 [0.6496]	3.5892** [0.0389]	…	4.9997** [0.0127]	…
$\Delta \ln EX_t$	3.2818** [0.0505]	1.1283 [0.3361]	2.5831*** [0.0912]	2.2195 [0.1251]	…	-0.7380* [-5.2328]

	$\sum\Delta\ln G_{t-1}$	$\sum\Delta\ln E_{t-1}$	$\sum\Delta\ln F_{t-1}$	$\sum\Delta\ln K_{t-1}$	$\sum\Delta\ln IM_{t-1}$	
$\Delta\ln G_t$	…	5.7208* [0.0075]	2.0146 [0.1499]	5.2424** [0.0107]	0.1471 [0.8637]	-0.3444* [-2.7783]
$\Delta\ln E_t$	9.8850* [0.0005]	…	0.8331 [0.4439]	0.0128 [0.9872]	2.0207 [0.1491]	-0.3494** [-2.1256]
$\Delta\ln F_t$	0.9428 [0.4001]	0.6608 [0.5233]	…	1.5100 [0.2362]	1.0626 [0.3574]	-0.1339*** [-1.6919]
$\Delta\ln K_t$	4.2891** [0.0221]	0.4613 [0.6344]	4.5234** [0.0184]	…	1.6019 [0.2168]	…
$\Delta\ln IM_t$	1.6879 [0.2011]	0.9255 [0.4067]	0.4494 [0.6420]	1.5445 [0.2289]	…	-0.4773* [-3.3678]
	$\sum\Delta\ln G_{t-1}$	$\sum\Delta\ln E_{t-1}$	$\sum\Delta\ln F_{t-1}$	$\sum\Delta\ln K_{t-1}$	$\sum\Delta\ln TR_{t-1}$	
$\Delta\ln G_t$	…	5.8737* [0.0067]	2.8223 [0.1184]	5.9283* [0.0065]	0.7449 [0.4828]	-0.4594* [-2.7423]
$\Delta\ln E_t$	9.7753* [0.0005]	…	1.0975 [0.3459]	0.1207 [0.8667]	4.4270** [0.0201]	-0.3639** [-2.0725]
$\Delta\ln F_t$	1.0640 [0.3569]	0.3513 [0.7064]	…	1.8153 [0.1791]	0.4793 [0.6236]	-0.1490*** [-1.9662]
$\Delta\ln K_t$	3.7552** [0.0339]	0.5405 [0.5867]	4.5372** [0.0182]	…	0.3975 [0.6751]	…
$\Delta\ln TR_t$	2.7811*** [0.0770]	1.1954 [0.3157]	0.1631 [0.8501]	0.1985 [0.8209]	…	-0.5239* [-3.8702]

Note: *, ** and *** denote significance at 1%, 5% and 10% level, respectively.

We also find short run, bidirectional causality between energy consumption and economic growth, and exports and economic growth; and feedback hypothesis between economic growth and capital. Financial development Granger causes capital and exports. Economic growth Granger causes of financial development. The unidirectional causality flows from exports to capital. Finally, trade openness Granger causes economic growth. Trade openness Granger causes energy consumption in the trade openness model. The findings are intuitively appealing.

5. Conclusion and Policy Implications

The paper uses the extended Cobb-Douglas production function model to examine long run equilibrium relation and the direction of causality among energy consumption, financial development, trade, capital and economic growth in Australia using data from1965 to 2009. Stationarity properties have been examined by ADF and PP tests, supplemented by Zivot-Andrews (1992) and Clemente et al (1998) unit root tests. The latter test can capture potential structural breaks which may be caused by major changes at global landscape. For a long run relation, we use both the ARDL bounds testing and the Johansen-Juselius, (1990) approaches to cointegration; and for the direction of causality we apply the VECM method. The results confirm cointegration for the three indicators of trade openness – exports, imports and (export + import) which appear to be robust.

The results suggest that energy consumption boosts economic growth, as does each of the series: financial development, exports, imports, trade openness and capital. The causality test shows feedback relation between energy consumption and economic growth exports/imports and economic growth; economic growth and trade openness; financial development and energy consumption; energy consumption and trade openness (also exports + imports), and financial development and economic growth. Finally, capital Granger causes economic growth, energy consumption, financial development, exports, imports and trade openness.

Though both production and domestic energy consumption have increased over the past 20 years, the rate of growth of production has exceeded that of consumption triggered by fast growing energy demand in Australia. As such, the share of domestic consumption in Australian energy production has declined. Our findings suggest that energy positively contributes to Australia's economic growth which implies that the use of energy will continue to grow. However, to minimize the environmental damages of energy use, a smart national policy must emphasize use of some kind of alternative e.g., renewable energy. The aim should be to increase dependence on secure, reliable, clean, cost effective and sustainable energy. Australian federal and state governments must work together towards further regulatory and institutional reforms to ensure efficient supply of energy to meet the growing needs.

Our results point to the need for careful scrutiny of the nexus of financial development and trade openness. Further research will help to better assess the role Australia may play by contributing to sound trade relations with her partners. To expand trade, Australia should work with trading partners towards lowering of trade barriers. Bi- and multilateral trade negotiations can be initiated for trade diversification. Organizing export fairs can be helpful. Some of the areas that can help are: import of modern and efficient capital goods rather than consumer goods to increase domestic production, and also add to export capacity. Appropriate trade policy may be crafted to achieve these objectives both in the short and the long run. A major challenge is to find a balance among the use of energy, environmental protection, production and export; noting that they all add to the global emissions of greenhouse gases. Fossil fuel is the single largest contributor to greenhouse gas. As with many other nations, high energy consuming projects are taking their toll on Australia's environment (Energy Matters, 2012). Given that the projected demand for energy in Australia will increase by 50% by 2020 (Energy Matters, 2012), the challenges are likely to get more complex and possibly worsen.

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