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Energy consumption and economic growth in New Zealand: Results of trivariate and multivariate models

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A B S T R A C T

This study examines the energy consumption–growth nexus in New Zealand. Causal linkages between energy and macroeconomic variables are investigated using trivariate demand-side and multivariate production models. Long run and short run relationships are estimated for the period 1960–2004. The estimated results of demand model reveal a long run relationship between energy consumption, real GDP and energy prices. The short run results indicate that real GDP Granger-causes energy consumption without feedback, consistent with the proposition that energy demand is a derived demand. Energy prices are found to be significant for energy consumption outcomes. Production model results indicate a long run relationship between real GDP, energy consumption and employment. The Granger-causality is found from real GDP to energy consumption, providing additional evidence to support the neoclassical proposition that energy consumption in New Zealand is fundamentally driven by economic activities. Inclusion of capital in the multivariate production model shows short run causality from capital to energy consumption. Also, changes in real GDP and employment have significant predictive power for changes in real capital.

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1. Introduction

The relationship between energy consumption and economic growth has received much attention in the recent economics literature. Economic theory is ambiguous regarding the direction of causality between these variables, as contrasting theoretical considerations suggest that energy consumption precedes economic growth and vice versa. Ecological economic theory asserts that energy resources are critical factors of production, such that energy consumption drives economic growth. Studies by Georgescu-Roegen (1975), Stern (1993), and Cleveland et al. (2000) raise questions about the theoretical feasibility of sustained economic growth given physical resource constraints, and the efficiency and equity implications of such growth. On the other hand, the growth models of the neoclassical school of thought imply that energy demand is a derived demand, so that energy consumption is a result of macroeconomic conditions (Lermit and Jollands, 2001). Central arguments of the proponents of neoclassical theory emphasise the role for substitution possibilities and technological progress to ameliorate resource scarcity and facilitate sustained growth in the presence of diminishing energy resources (see Stiglitz, 1974; Solow 1974; Dasgupta and Heal, 1974).

The causal relationship between energy consumption and economic growth has remained empirically elusive and controversial (Masih and Masih, 1996). Country-specific studies on the relationship between energy consumption and economic growth outcomes can provide valuable policy insights, as energy conservation policies may be more difficult to enact. This is particularly so where energy consumption causes economic growth rather than in a situation where economic growth causes energy consumption, or no causal relationship exists between these variables. Furthermore, the nature of the underlying relationship may differ according to countries' economic structures. This study examines the energy consumption–economic growth nexus for the case of New Zealand, utilising cointegration and causality methodologies to estimate specific relationships between these variables. Several models are used to test the competing hypotheses based on distinct demand-side and production-side relationships between energy and output.

The energy-growth literature is highly relevant for New Zealand given the current development of policy that seeks to balance national and international environmental imperatives with economic transformation objectives (Minister for Economic Development, 2006). Fatai et al. (2004) considered a bivariate relationship between energy resources and economic growth in New Zealand; however this study extends the analysis based on

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demand- and production trivariate and multivariate considerations. Trivariate and multivariate models incorporate other variables to ensure robust results that may alter the statistical relationship established in a bivariate framework. It also reflects on the policy implications suggested in the previous study to the findings of this paper.

The remainder of the paper is structured as follows: Section 2 reviews economic theory and empirical evidence on the energy consumption–economic growth relationship for various countries. Data, methodology and models are discussed in Section 3 followed by the estimated results in Section 4. These include unit root tests, bounds test of cointegration, and Wald *F*-tests of short run Granger-causality. Identifying the nature of key relationships between the variables in the alternative model specifications provide some implications that are relevant to the current policy context of emissions trading and sustainability on the one hand, and economic transformation on the other. The final section presents the conclusions.

2. Energy consumption–economic growth nexus: brief overview

With exogenous technological progress Solow (1956) model has been extended to account for the energy consumption–economic growth nexus. The subsequent developments in the theory highlight several mechanisms by which economic growth could theoretically persist despite a finite base of energy resources. Most often, these arguments have centred on the potential for technological change and the substitution of capital and labour inputs for energy to use existing energy resources more efficiently, and to deliver new energy resources that are not subject to binding supply constraints (Solow, 1974, 1997; Stiglitz, 1997; Brown and Wolk, 2000).

In light of these considerations the neoclassical theory predicts that energy resources are non-essential inputs into production. The implication is that, though energy resources contribute to production, causality runs from economic growth to energy consumption. Accordingly, energy supply constraints need not impact the growth path of the macroeconomy. The vital policy implication is that energy conservation and economic growth policies may be pursued simultaneously. Such an implication also suggests that global living standards need not decrease in the course of tackling pressing environmental issues like climate change and potential fossil fuel scarcity. However, an alternative theoretical perspective, commonly attributed to the ecological economics school of thought, asserts that energy resources are a limiting factor in the growth of modern economies (Stern and Cleveland, 2004). Implications of this argument for living standards are much less sanguine than the neoclassical approach if supply constraints of specific energy resources are assumed.

The ecological economics school of thought draws on various scientific laws and properties to argue that energy, broadly defined, is the sole factor of production in economic systems (Georgescu-Roegen, 1975). This theory focuses on the material basis of economic production, a perspective from which a number of limitations appear in the theoretical substitution and technological change arguments of the neoclassical theory. To the extent that these limits imply an ongoing dependence of economic growth on energy resource inputs, the prospects for sustained economic growth under a regime of energy resource scarcity (or energy conservation policies) differ widely to the predictions of the mainstream theory. Specific counter-arguments to the substitution and technological progress are noted below.

A crucial argument in the ecological economics literature suggests that factor-energy substitutability is limited by the physical interdependence of various inputs. To the extent that the construction and maintenance of capital items require a flow of energy and materials, production of the substitute goods therefore requires more of the input – energy – for which it is substituting (Stern and Cleveland, 2004).[1] Another line of enquiry suggests that thermodynamic restrictions can inhibit factor substitution possibilities. This argument applies the laws of thermodynamics to economic production, highlighting the possibility of limitations to the transformation of materials from one thermodynamic state to another, and on the use of energy to facilitate such transformations (Ruth, 1993). A more compelling critique of technological progress is that such progress simply reflects substitution from less efficient production techniques to more efficient production techniques, based on the acquisition of new knowledge, i.e. improved capital and more highly skilled workers. Stern and Cleveland (2004) argue that even improved capital and labour inputs still require energy and ecosystem services to produce economic outputs. Thus, the argument of thermodynamic restrictions to substitution (in this case, between knowledge and other factors of production) remains valid given that knowledge is only one of several factor inputs and the marginal productivity of knowledge remains constrained by the quantities of other inputs (Stern and Cleveland, 2004).

Despite the divergent views both perspectives of neoclassical and ecological economics schools of thought imply that a long run relationship may exist between energy resources and economic output. However, the direction of causality in both the short run and long run is disputed. Empirical studies that examine the relationship between these variables have utilised Granger-causality techniques to test for the existence and direction of a causal relationship for several developed and developing countries. However, these studies have failed to identify a robust and persistent causal relationship across different country contexts.[2] This may be because of, *inter alia*, inappropriate statistical methodologies being used, a failure to adjust for energy quality in the process of aggregation and the econometric problems associated with not considering time series properties of the data (Asafu-Adjaye, 2000; Stern, 1993, 2000; Zachariadis, 2006). As the central issue of causality remains largely unresolved, country-specific studies are necessary for drawing its implications given the lack of consensus in the empirical literature (Altinay and Karagol, 2004).

Studies by Fatai et al. (2001, 2004) test bivariate causality between disaggregated energy consumption components and economic variables for New Zealand and energy consumption and real GDP, respectively. Their (2001) study utilises the Johansen-Juselius (1990) approach (hereafter referred to as JJ) to examine cointegration properties of disaggregated total energy consumption of coal, electricity, gas, oil, commercial energy and total final energy (i.e. household plus commercial energy) with total employment for the period 1960–1999. The estimated results provide evidence of a cointegrating relationship for electricity consumption and employment, and oil consumption and employment, while the direction of causality shows that energy resources (i.e. electricity and oil) Granger-cause employment. These results hold for the Granger-causality test and the alternative Toda and Yamamoto (2005) (YT) test. The ARDL bounds test results show a similar significant causal relationship for the electricity and oil

[1] However, this argument only seems to apply at the macro-level; evidence from many regions (even nations, in the case of resource dependent countries such as Kuwait and Qatar) suggests that the depletion of natural resources can be augmented with manufactured capital to sustain economic growth.

[2] Several studies have reached conflicting conclusions on the nature of the causal relationship between these variables in the same country context. See Guttormsen (2004).

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