Energy Efficiency and the New Zealand Economy: A Dynamic CGE Analysis

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Abstract: This paper develops a dynamic CGE model of the New Zealand economy to analyze the impact of energy efficiency improvements and other energy shocks. The dynamic CGE model focuses on the energy sector, which is modeled using a technological bundle approach and a bottom-up framework. Alternative energy efficient policies and energy shocks are simulated. The model and results are useful for energy policy analysis including policy development to maximize the potential benefits of advancing to a more energy efficient economy.

Keywords: *Energy Efficiency, Dynamic CGE, Economy*

1.0 INTRODUCTION

A shock to the energy sector or a policy that affects energy efficiency would have significant impact on the rest of the economy. Hence, the use of a dynamic general equilibrium model to model the economy wide impact of energy efficiency practice is logical as there is a significant interaction between the energy sector and the rest of the economy. This paper develops a dynamic CGE model of the New Zealand economy to analyze the dynamic impact of energy efficiency improvements and discuss issues related to modeling energy efficiency. The dynamic CGE model focuses on the energy sector, which is modeled using a 'technological bundle' approach and a 'bottom-up' framework. Alternative energy efficient policies are simulated. The dynamic model may help to develop policies that can maximize the potential benefits of advancing to a more energy efficient economy.

2.0 LITERATURE

2.1 Modelling Energy Efficiency Impact

The most common approaches to modeling energy efficiency in the CGE literature are either to use the bottom-up (engineering) model or the top-down (economic) model (see Hertel, 1997, chapter 2 for details). The bottom-up approach is commonly known as an ideal approach to estimate the minimum costs of technical and input factors to meet demand for energy, while the top-down economic approach commonly begins with the macro-economy divided into its main sectors and from there the modeler derives the demand for energy inputs, as well as other inputs such as labour and capital, to be used by selected sectors in the macro-economy). Energy efficiency can be modeled in bottom up models by introducing technical improvements that may both reduce costs and be environmentally friendly. Top-down models, however, usually assume that the market's decisions on which technology to use are already optimal (Edmonds *et al.* 2000). Technologies, which are not optimal in energy efficiencies, for example, may not be employed as they may be optimal. However, most CGE models eliminate the above assumption and introduce technical progress parameters that reflect energy saving technologies progress in the economy. Some CGE models introduce a "costless energy saving" through the autonomous energy efficiency improvement parameter. One rationale for CGE models' introduction of the energy efficiency parameter can be the persistence in technological improvements even if these technological improvements are not stimulated by price changes (see Edmonds *et. al.,* 2000). For example, price changes may be one of the important drivers of technological improvements but usually these price changes stop or slow down, but technological improvements usually continue. In CGE models, especially those that follow the top-down economic approach, both the technological improvements and energy efficiency parameters are exogenous. However, endogenizing them may be preferable, as in new growth theory (Romer, 1989), thus allowing technology to respond not only to price changes, but also to other determinants of technological progress such as research and development and innovations. (See Forssell, 2000 for evidence of relationship between energy efficiency and research and development for European Union countries). There is a need for better empirical evidence on the likely success of new technology and this is hard to obtain given the uncertainty of the likely success of new technologies. The other problem of top-down economic models is the algorithm for solving the non-convex optimization model, where technological improvement and learning is endogenized

3.0 MODEL STRUCTURE

The model used in this study is a recursive dynamic model in the sense that the evolution of the model over time is a sequence of connected single period equilibria. The model follows closely those discussed in Dixon *et al.* (1982) and its various enhancements in McDougall (1993) and Hertel (1997), Dixon *et al.* (1998) and especially Abayasiri-Silva and Horridge, (1996). As the model is recursive, it can be described in two parts. First, the static component with its single equilibria and second, the dynamic component.

3.1 Static Component

The starting point of the static component is the neoclassical model. In this paper's standard neo-classical CGE model, each producer is assumed to maximize profit, the difference between total revenue and factor costs plus intermediate input, subject to a production technology. Specifying the production technology is usually undertaken in a number of different ways but a popular choice is the Leontief production function and the constant elasticity of substitution (CES) function. The Leontief function, $F(V) = \min_i(V_i/a_i)$ where V is a vector of inputs V_i and a_i are the constant per unit input requirements, specifies the aggregate factors of production and disaggregate intermediate inputs.

The alternative to the Leontief function is the CES function, which is the preferred production function in this paper for the disaggregate factors of production and the source of intermediate inputs. The model used here has 23 commodities and industries with the CES production function having the form:

$$Q_i = A_i\left(a_{h_i}H_i^{(\sigma_i-1)/\sigma_i} + a_{k_i}K_i^{(\sigma_i-1)/\sigma_i} + a_{l_i}L_i^{(\sigma_i-1)/\sigma_i}\right)^{\sigma_i/(\sigma_i-1)}$$

where i = 1…23. This is expanded from the common CES functional form:

$$Q_i = A\left(a_{hi}H^{ui} + a_{ki}K^{ui} + a_{li}L^{ui}\right)^{1/ui}$$

The CES function allows the mix between the sources of intermediate inputs and the disaggregate factors of production to vary in the production process.

The main agents in the market include domestic producers, divided into 23 industries, investors and a single representative household, who received income and either spend or save the income. Imports are bought from a representative foreign agent, who purchases the imports. A 'minor' agent in the model is the government, which is modeled, but does not have a significant role in the economy unlike the other agents (industries and households).

The inputs are from the labour sector, which is divided into either skilled or unskilled, additionally, there are also other production inputs of other commodities, which are either imported or bought domestically. The main other inputs are from the 'sluggish factor' land and both mobile and immobile capital. Because each industry can either produce multi-products or a single product with a number of different inputs, the task of modeling is to allow for the separation of products and inputs. The separability assumption allows flexibility in the production sector. The production function in some industries can be modeled as, H(inputs) = Y = H(outputs) rather than the traditional production function H(inputs, outputs) = 0 (Abayasiri-Silva and Horridge, 1996). The separability assumption makes it easier to estimate the parameters, because it reduces the number of parameters to be estimated.

In this model, the separable function of the output is derived from a constant elasticity of transformation aggregation function. The input separable function is divided into a number of nests. At the top of the nests for the input function, there is a composite commodity, which is a combination of the primary factor and 'other' costs. The composite commodities are combined by using a Leontief production function. This implies that all inputs are demanded in proportion to Y, an index defining the activity in that industry. Like many other CGE models, the Armington (1969) assumption is used. This means that the composite commodity produced is a constant elasticity of substitution function of either a domestic good or its imported equivalent. The composite input of a primary factor is a constant elasticity of substitution combination of land, capital and composite labour. The composite labour is a constant elasticity of substitution of skilled and unskilled labour. This combination of composite primary input is the same across industries. However, this does not imply the same composite input and labour combination for every product produced because the input combination and the behavioural parameters are not the same across the industries.

The household sector in the model is assumed to have a Stone-Geary utility function, which is used to aggregate the composite commodity demanded by the household sector. All other nests are the same as that for the primary-factor input nesting function (Yasin-Silva and Horridge, 1996). The other final demand sector is the government, which is assumed to have no substitution behaviour unlike the household sector.

3.2 Dynamic Extensions and Inter-period Linkages.

In developing the Neo-classical model, we extend it by adding the dynamic components, which consist of changes in capital, investment and wages mainly following the work of Horridge (2002).

Capital stocks in this model can either grow at a constant, or flexible, rate of growth. The amount of investment determines the rate of capital growth. Investment, on the other hand, is determined by its rate of return (Horridge, 2002). The database of 23 by 23 sectors and industries is the initial data source, which then changes every year when the end of the year database becomes the beginning of the year database for the next year, as in a recursive model.

Capital is expected to grow annually and the rate of growth is equal to net investment defined as the rate of investment at the beginning of the year less the rate of depreciation for that year. The rate of depreciation in this model is assumed to be 5 percent. The change in annual capital, for each of the 23 industries, therefore is equal to:

$$\Delta K = I_o - \delta K_o$$

or

$$\Delta K\theta_o = I_o\theta_o - \delta K_o\theta$$

where I is investment at the beginning of the year, K is the amount of capital, d is the depreciation rate and θ is the price of a capital unit (Horridge, 2002). The investment equation is the macroeconomic equation that shows that the change in investment in this period would affect the amount of capital in the next period.

To help computation time, the capital equation is transformed into percentage form. Investment comprises two components. The first is the investment-to-capital ratio and the second is the expected rates of return which is assumed to adjust gradually to its actual rate of return via an adjustment mechanism (to be described later). The investment-to-capital ratio is assumed to be (positively) proportional to the expected rates of return. The actual rate of return to investment is defined as $R = P_k/\theta$ where R is the per unit rental price of capital while θ is the per unit capital price (Horridge, 2002). Conversely, the growth rate of capital for the next period is equal to the investment capital ratio. Via theory, the rates of growth of the capital stock depends on the expected rate of return G = F(E) where E is the expected rate of return. Both G and E are assumed to be greater than zero. The expected rate of return is not expected to rise without limit as it is bounded by the normal rate of return, which in this paper, is assumed to be 0.95 percent. Because the expected rate of return is bounded, the gross rate of capital growth is also bounded. The model is constructed so that when the expected rate of return rises to the maximum expected rate of return, capital growth reaches its maximum growth rate, which is assumed to be its normal or long-run rate of growth.

The expected rate of growth function is assumed to have a logistic form:

$$G = Q.G_t M^a/(Q-1+M^a)$$

where G is the gross rate of capital growth, M is the ratio of expected rate of return to long-run or normal rate of return while Q is the investment capital ratio. In this specification, when M is equal to 1 the expected rate of growth is equal to the long-run or normal rate of growth and if M is 0 then the expected rate of growth is also equal to zero.

The function G is showed in Figure 1 with different values for M and the parameter a.

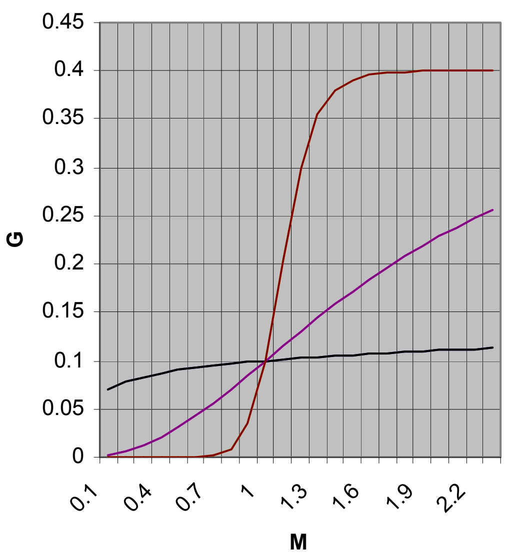

Figure 1: Logistic investment function.

In percentage form the logistic equation becomes:

$g - g_t = [1\text{-}g/g_r/g_{max}]am$

The end of the period expected rates of return are an average of the beginning expected rate of return and the end of the period actual rate of return. This implies that investors are quite conservative as only the past and current rates of return affect their expectation of the rate of return for the next period.

The other important inter-period linkage component is the real wage. In this model, real wages can also adjust in response to changes in the employment levels. The adjustment mechanism is such that if the end of the year employment level is above a certain trend level, real wages may adjust by some percentage equal to a parameter multiplied by the percentage change in the employment level. Given that the rate of employment rises when wages increase and falls when real wage decreases, the adjustment mechanism ensures that the level of employment will adjust towards the trend changes in employment. In this regard, the adjustment follows the NAIRU mechanism of employment level changes. The adjustment is controlled by the equation:

$$\Delta W/W_o = \gamma[(L_O/T_O)\text{-}1]+\Gamma\delta(L/T)$$

where W is the real wage, L is the actual rate of employment, T is trend employment. L_0 and T_0 are the initial rate of employment and trend employment respectively. Gamma and delta are both adjustment parameters.

4.0 SIMULATION DESIGN

4.1 Simulation

Three sets of simple scenarios were designed. The first was an energy efficiency scenario for industries and the second was an energy efficiency scenario for households and the third was a combination of the first two scenarios plus the incorporation of forecasts of other economic variables. For industries, we assume that they are more energy efficient so that every unit of output requires less fuel input resulting in a decrease in the price of fuel input by 1%. We simulate both a temporary and a permanent increase in energy efficiency. In the second set of simulations, we assume that households are saving by being more energy efficient resulting in a decrease in the petrol price for households also by 1%. Again we simulate both a temporary and a permanent change in energy efficiency. In the third simulation we incorporate forecasts of various economic variables by specialists in the field of economics, and simulate the likely path of the economy assuming it is more energy efficient in the sense defined above.

5.0 SIMULATION RESULTS

5.1 Scenario I: Industries are temporarily more energy efficient

In this scenario industries are more efficient in their use of inputs now that there is less energy required to produce a unit of output. As a result of the temporary change, both real GDP and real wage increase from zero to about 2.5% for real GDP and about 1.5% for real wages (Figure 2). However, because the shock is reversed in the next period, the temporary rise in price resulting from the reversed shock, drives real wages and real GDP down to about 0.8 and 0.2 for real wage and real GDP, respectively. As the reversed shock is only a one period shock, as soon as the reversed shock ends, both real GDP and real wage rises slightly because of the persistent technological effect of energy efficiency. As there are no more shocks, real GDP and real wages slowly reverts back to the long term path over the rest of the simulation period.

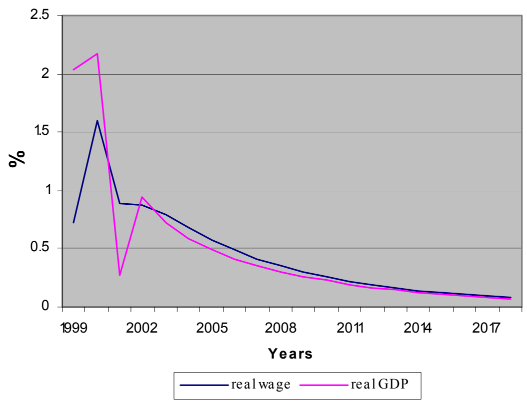

Figure 2. Temporary increases in industries energy efficiency

Various price indices, such as CPI, the export price index, the GDP price index, all initially decrease, thus driving up real wages, real GDP and other commodities' output. It is noted that the energy sector contracts as industries becomes more energy efficient. However, this is only temporary. When the shock is reversed, the energy sector slowly starts to expand before it reverts to its original position. However, at the end of the energy efficiency period, the price indexes start to rise again when the energy efficiency period is removed.

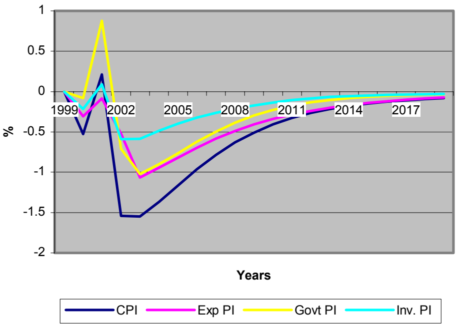

Figure 3. Temporary impact on some price indexes of a temporary increase in energy efficiency

However, as the reversal is a one period shock only, the various price indexes decline as soon as the reversal shock ends. The rate of price increases slowly returns to zero. Consumption of commodities also increases due to the decrease in price, the benefits which are passed-on to consumers (not discussed here due to space limitations.)

5.2 Scenario II: Industries are permanently more energy efficient

A typical example of industries being permanently more energy efficient is shown as Figure 4. In this simulation, there is a decrease in the cost of energy per unit of output. The decrease is 1.5 percent.

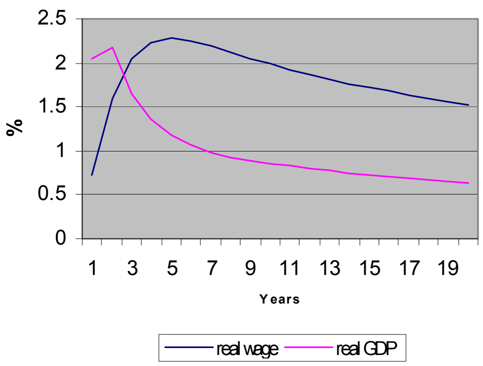

Figure 4. Permanent increase in industrial energy efficiency

With a permanent increase in industrial energy efficiency, there is an initial increase both in real wages and real GDP of approximately 2.3 and 2.1 percentages respectively and, over time it settles back to a new long-run growth rate of about 1.5 and 0.8% for real wage and real GDP, respectively. This demonstrates that a small permanent improvement across industry can have a very significant effect on the economy.

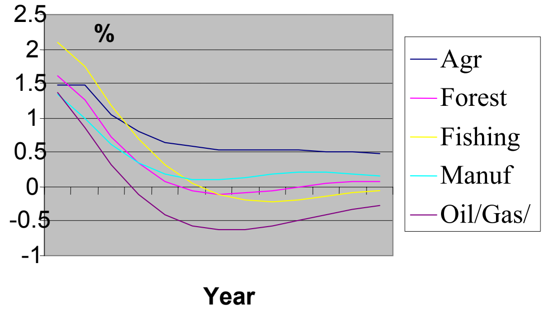

Figure 5. Effect of permanent increase in energy efficiency on some commodities prices

Price indices for a range of commodities are shown as Figure 5. In general all the price indices decrease and stabilize. The greatest percentage reduction in price is in the oil, gas and petroleum sector combined, while other sectors follow closely.

5.3 Scenario III: Industries and Households are more energy efficient and forecasts of economic variables are incorporated

In the last scenario, we combine both our forecasts of various economic variables from specialists with the effects of energy efficiency in both the industry and household sectors. We forecast GDP, etc., to grow by an average of 3 percent given the latest official government forecast (see New Zealand Treasury website). We also assume that there is a government policy that increases energy efficiency by 1.5% in the energy intensive sectors and a government policy that increases energy efficiency by 1.5% in the household sector. The increase in energy efficiency in the household sector allows households to save, which is directed to buying other goods. As before, there is an effective reduction in fuel prices when the energy efficiency policy in shocked compared to when the policy is not shocked. Real wages for households increase by about 2% leading to a slight increase in labour supply of about 1.5% compared to the forecast case. Household savings from fuel costs are now spent on other commodities such as food, manufacturing goods etc.

6.0 CONCLUSION

This exercise modeled the dynamic effects of a shock that improves energy efficiency in both the industrial and household sector. We start by simulating the possible effects of a temporary shock that improves energy efficiency in the industrial sector. Then we simulate a dynamic effect of a permanent improvement in the industrial sector's energy efficiency. We then incorporate our forecasts of various economic variables in the New Zealand economy with the shock that induce energy efficiency in both the household and the industrial sectors.

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