# Modelling Economies of Scale and Imperfect Competition Using CGE: A Comparative Application to the Energy Sector of New Zealand, Canada, Singapore and Mozambique.

**Koli Fatai, Les Oxley and F. G. Scrimgeour**

University of Waikato, University of Canterbury

**Abstract:** The impact of exogenous policy shocks may have a significant impact on various sectors of the economy when certain features of industrial organizations are modeled. Features of industrial organizations such as economies of scale and imperfect competition may play a significant role in determining the extent of the effects of policy shocks. This paper presents Computable General Equilibrium (CGE) model results for New Zealand, Canada, Singapore and Mozambique focusing on the energy sector. The results are compared across countries to see if the impact of exogenous policy shocks are consistent. The energy sector is assumed to enjoy economies of scale and compete in an imperfect competitive environment. The simulations show the impact of economies of scale and imperfect competition on the analysis. The implications of the results for CGE models of climate change and emission trading are discussed.

***Keywords:*** *Economies of Scale, Imperfect Competition, CGE*

## 1. INTRODUCTION

The issue of whether economies of scale and imperfect competition in the energy sector significantly impact policy shocks has been debated by academics since the influential paper by Harris (1984). Recent literature is still inconclusive. Harris (1984) first suggested that economies of scale and imperfect competition do have a significant impact on the economy but in the context of trade liberalization. Although Harris argued that it does make a difference when one uses a general equilibrium model to assess the differences that economies of scale and imperfect competition make on the economy, others argued otherwise (see Cory and Horridge, 1985; Horridge, 1987, Wigle, 1988)[1]. The latter studies argued that there is only about 2% to 5% increase in GNP from trade liberalization. Harris argued, however, that the benefits are higher, in the order of 8% to 12%, when economies of scale and imperfect competition are taken into account and modeled in a general equilibrium framework (Abayasirisilva and Horridge, 1996).

This issue is important for modellers as two of the common assumptions for modelling the effect of climate change and energy related policies on the economy in a general equilibrium framework are that there is constant returns to scale and there is perfect competition in the economy. In reality, however, economies of scale seem to be the rule rather than the exception. Studies by Pratten (1971), and Buchanan and Yoon (1994) argued that economies of scale should be incorporated to energy and climate policy related models. In the energy sector, for example, many electricity-generating stations benefit from economies of scale. They may make use of resources that can be pooled such as voltage transformers, equipment maintenance and the network of grid connection. Despite the suggestions by the above studies, modelling economies of scale and imperfect competition has been largely neglected in the literature. To date, many if not most of the global models assume constant returns to scale and perfect competition (eg. DICE and RICE, G-Cubed, Global 2100, GREEN, GTEM and WorldScan etc.).

This paper will attempt to see if the impacts of a shock, to the energy sector are significantly different when economies of scale and imperfect competition are modeled in a computable general equilibrium model. We compare the energy sectors of New Zealand, Canada, Singapore and Mozambique. We chose these countries to represent various stages of development. We try to assess whether the results are consistent between industrialized, newly industrialized and developing economies when economies of scale and imperfect competition are present.

[1] Also more studies are mentioned in Abayasirisilva and Horridge (1996).

## 2. STANDARD CGE MODELS

This paper uses and extends the standard neo-classical model where, in the short-run, there is restriction of access to the market, but in the long run organizations are modeled as free agents who can enter or exit the market as they wish. The main agents in the market are domestic producers, investors, a single representative household and a government sector. Domestic producers are composed of 22 industries, which also produce 22 commodities. The 22 industries can produce either a single or several commodities. The industries are metals, transport, meat products, food products, housing, heavy manufactures, light manufactures, textiles, animals, services, crops, forestry, coal, oil, gas, minerals, chemical and plastic products, mineral products, electronic equipments, electricity and construction. There is also a representative foreign agent, who sells and buys aggregate imports and exports.

### 2.1 Structure of Production

Production uses inputs of labour, divided into skilled and unskilled, capital and land. Intermediate products, bought domestically or from abroad, are used with the inputs above to produce the commodities listed previously. We follow the structure of production used by Abayasiri-Silva and Horridge (1996). Because each industry can either produce multi-products or a single product with a number of different inputs, the task of modeling them is through a number of assumptions that allow for the separation of these products and inputs.

The separability assumption allows flexibility in the production sector. The production function in the 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 as it reduces the number of parameters to be estimated (Abayasiri-Silva and Horridge, 1996). 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 about 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 primary factors 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 the 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 22 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 (Abayasiri-Silva and Horridge, 1996). The other final demand sector is the government, which is assumed to have no substitution behaviour as in the household sector.

### 2.2 Extension to standard CGE model: Economies of Scale and imperfect competition

To model economies of scale we follow the CGE model of Abayasiri-Silva and Horridge (1996).. However, further discussion on incorporating scale economies in a CGE framework can be found in Devarajan and Rodrik (1988); Francois *et.al.* (1997); Harris (1984); Krugman (1980) and Melo and Tarr (1992). In the Abayasiri-Silva and Horridge (1996) CGE model, they made two additions to the standard neo-classical model namely, new technology and new pricing behaviours.

The simulations were undertaken using the standard neo-classical model with the addition of a new technology component and a new pricing component. Economies of scale are either modeled at the firm level or at the industry level. For the pricing part, Abayasiri-Silva and Horridge model it as being specified in the firm level and not at the industry level. The firms are modeled to enable the number of firms, in the short run, to be fixed, while in the long run, firms are determined by entry and exit to the market. That is, in the long run, the firms are modeled so that they are free to enter or exit the market depending on whether they can maximize their profits by either entering or exiting the market (for further discussions on modeling market entry/exit see Brown (1992); Lopez *et.al*. (1996); Markusen et.al. (1996); Melo and Tarr (1992))

Each of the firms are modeled to produce a single or multi-products, which are assumed to be imperfect substitute of products produced in other domestics firms or produced by other foreign firms. The firms are assumed to be price takers in the primary factor market while they are price makers in the final demand commodity market. To make things simpler, increasing returns to scale are restricted to the single product industries. The input functions are homogenous of degree 1, implying that production costs and the proportion of input used are flexible with respect to price, but are inflexible with respect to the level of output produced.

At the firm level the production function is formulated as follows: L(inputs) = Z' = H(inputs) – F, where F is the fixed costs of production. The fixed costs are modeled so that they are directly related to the number of firms in the industry. The firm's unit costs are given by the formula: Unit Cost = $(F + Z_f) * M / Z_f$. The formulation of the unit costs ensures that as output increases unit costs decrease to a minimum cost level, which is equal to the marginal cost. This minimum cost level is assumed to be the marginal cost of that product. The variable costs, on the other hand, are modeled so that they are proportional to the firm's output. This formulation of the unit costs ensures that marginal costs are independent of a firm's output.

### 2.3 Product Differentiation

In an environment of imperfect competition, it is likely that there is significant product differentiation when goods are close substitutes. In the CGE model used by Yasin-Silva and Horridge (1996), they simply add an extra layer of CES to show that consumers have a choice between imported and domestic produced products, and choice amongst a variety of close substitute domestically produced products. We follow the Yasin-Silva and Horridge model, but further discussion of product differentiation in a CGE setting can be found in Francois and Roland-Holst (1997) and Harrison *et. al.* (1993).

### 2.4 Two Pricing Rules and Imperfect Competition

There are two pricing rules that our CGE model follows, but we only present the Harris pricing rule results due to space limitations. The first is the Lerner pricing rule and the second is the Harris pricing rule. Both pricing rules are monopolistic pricing. In the Lerner pricing rule, the price set for an energy product depends on the elasticity of demand for that energy product. In particular, the price is set so that if the elasticity of demand is high, price will be lower. Conversely, the lower the absolute value of elasticity the higher the price. The Lerner price index is given by the formula $L = (P-MC)/P = 1/\varepsilon$ where P is the price, MC is the marginal cost of a given product, L is the Lerner index and $\varepsilon$ is the elasticity of demand for that product. If P = MC then L = 0 implying perfect competition. But if P> MC, the L > 0 implying monopolistic pricing. The mark-up factor is equal to $P = [1/(1-L)]MC$.

In the Harris pricing rule, the price of the energy commodity is a mixture of the monopolistic pricing rule and the price of the imported energy product substitute. The price is set so that the price is a mean of the sum of the monopolistic pricing rule and the Harris pricing rule. This pricing rule gives a weight to each of the two prices and the average of these pricing rules is based on the size of the weight[2]. Although there are other price setting rules discussed in the CGE literature (see Brown (1992); Lopez et.al., 1996; Melo and Tarr (1992); Roberts and Tybour (1996), the two pricing setting rules we use is enough to model imperfect competition behaviour in the market.

## 3. SIMULATION RESULTS

To assess the impact of shocks to the energy sector, we simulate a shock that would result in a reduction of output of the chosen energy commodities. The assumed shock is to *increase the import price of energy commodities*. One reason for choosing this shock is to assess the economic effect of trade liberalization in the energy sector.

We ran short-run and long-run simulations where, in the short-run to remind, there are a fixed number of industries. In the long-run, on the other hand, the number of industries can vary due to exit and entry. Firms can enter the market or exit depending on the profitability of the market. This ensures that there are zero pure profits, consistent with the neoclassical theory of short and long run behaviour of firms in the market. Furthermore, in each of these two cases we simulate both constant returns to scale and increasing returns to scale. Increasing returns to scale were divided into either economies of scale from internal economies

---

[2] For a more technical discussion of the Lerner and Harris pricing rules see Abayasiri-Silva and Horridge (1996).

in an industry or economies of scale caused by increased efficiency in the whole industry. The former is commonly known as internal economies of scale while the latter is known as external economies of scale.

In addition to the above simulations, we also made other assumptions by changing the prices that industries face. The change in prices are either a change in what has been described earlier as Harris pricing or prices are set according to the Lerner pricing rules. These two pricing rules ensure that competition in the market is imperfect, hence enabling us to study the outcomes of policy shocks in an industrial environment characterized by economies of scale and imperfect competition.

The reference case is the simulation where all industries are assumed to be perfectly competitive with constant economies of scale. The effects in the economy of the reference case simulations are compared with the impact of both external and internal economies of scale in the energy sector as well as monopolistic pricing by industries in the energy sector. We report the reference case (CMS) and he increasing returns to scale case with the Harris rule (HML).

### 3.1 Short-run Simulation

Table 1 reports the various price indexes (as represented by the macro variables such as GDP price index, investment price index, export price index and import price index) for the short-run simulation. They fall as a result of the decrease in the emission intensive products' prices for all of the four countries. Consequently output produced increases, which results in a boost to aggregate output produced in the economy. Real GDP increased by between 1.48 and 2.1% for New Zealand, while for Canada, Mozambique and Singapore, real GDP increased by 2.05 to 2.1%, 2.2 to 2.26%, and 2.32 to 3.07% respectively.

[Table 1]

However, some industries output fall as a result of the shock. This was especially true for import intensive industries such as metals. For New Zealand, the metals sector decreased by between 1.34 to 1.61 percentage. For Canada, Mozambique and Singapore, their mineral sectors decreased by 1.98 to 1.38%, 0.32 to 1.01%, and 0.98 to 1.25% respectively. Export intensive industries face a more elastic demand from overseas and also benefited from the reduction in its production cost caused by the shock to the energy intensive products. Hence, for most, production levels increased as shown by total exports in Table 1.

[Table 2]

It appears that there is not much difference between the constant returns to scale simulation results and the increasing returns to scale simulation results. This may be because of the use of the marginal costs rather than average costs in the pricing rules. The small differences evident in the simulations can be attributed to the use of resources where profitable sectors use more resources and non-profitable sectors use fewer resources than the constant returns to scale scenarios.

### 3.2 Long-run Simulation

Table 3 presents the results for the long-run simulations. The price indexes also fall as in the short-run simulations, but the fall in the long-run seems to be smaller than the percentage fall in the short-run simulations. This result seems to extend to all the price indexes. The increase in real GDP and import volume seems to be not very different from the short-run results. However, in the long-run the increase comes from increased capital use as labour is fixed in the long-run.

[Table 3]

In the output sectors, the same sectors that were losers in the short-run simulations were also losers in the long-run simulations regardless of whether it was constant return to scale or increasing return to scale.

[Table 4]

For example, in the petroleum products industries the average fall in output was about 0.1 percent. In the long-run, the fall in output seems to be at a higher percentage than in the short-run simulations. The fall was between 2 – 14 percent in the long-run simulations. This may be because of increased absorption in the long-run because the ratio of investment to capital was fixed in the short-run (Abayasiri-Silva and Horridge, 1996).

In the long-run the firms were free to enter or exit from the market. As a result the Lerner price change is smaller in the long-run than in the short-run (Abayasiri-Silva and Horridge, 1996). Another possible change because of the free entry or exit of firms, is that mark-ups may be very small so that the price faced by the firm is almost equal the marginal cost. For that reason, it is possible that firms now faces a scenario where returns to scale are almost constant.

## 5 SUMMARY AND CONCLUSION

In this paper we model the economy to reflect the reality that there are economies of scale in some industries and that imperfect competition also exists in the market. We have used a computable general equilibrium model to reflect the fact that there are economies of scale and imperfect competition in the market place. We model both short-run and long-run scenarios. In both the short and the long-run scenarios, we distinguish between constant returns to scale and increasing returns to scale. We distinguish the sources of increasing returns to scale – either internal economies of scale or external economies. We also distinguish between different types of pricing formulas that may exist in the market place by using three different price rules.

Our results for the reference case show that while import intensive sectors shrink, export intensive sectors seem to expand because of the increase in international competitiveness resulting from the induced shock to the economy. In the short-run, the change of resources to export intensive industries was slower. In the long-run, however, it was easier for firms to shift resources to the most profitable industries.

The results from the constant returns to scale case were often not very different from the results obtained from the increasing returns to scale scenario. This was especially true for the Lerner pricing rules and internal economies of scale. This observation was also true in the Abayasiri-Silva and Horridge (1996) study. Overall, however, we found that the shock introduced to the energy intensive sectors seems to have results that were not significantly different between the short and long-run and between constant return to scale and increasing returns to scale. Further work in this area, therefore, is still to be done.

## 6 REFERENCES


Abayasiri-Silva, K. and Horridge, M. (1996) "Economies of Scale and Imperfect Competition in an Applied G.E.Model of the Australian Economy" *Preliminary Working Paper* No. OP-84, March 1996.

Armington (1969) "A Theory of Demand for Products Distinguished by Place of Production," *International Monetary Fund Staff Paper* Vol. 16, pp. 159-176.

Brown, D.K. (1992). "Properties of Appllied General Equilibrium Trade Models with Monopolistic Competition and Foreign Direct Investment," in J.F. Francois and C.R. Shiells (eds.), *Economy-wide Modeling of the Economic Implications of an FTA with Indonesia and a NAFTA with Canada and Indonesia,* U.S. I.T.C, Washington.

Buchanan, James M; Yoon, Yong J, eds. (1994) *The Return to Increasing* Returns.University of Michigan Press, U.S. p. ix, 382.

Cory, P. and Horridge, M. (1985) "A Harris-Style Miniature Version of ORANI", Preliminary Working Paper, No. OP-54, Impact Project, Melbourne.

Devarajan, S., and D.Rodrik (1988), "Trade Liberalization in Developing Countries: Do Imperfect competition and Scale Economies Matter?" *American Economic Review,* Papers and Proceedings, 283-287.

Francois, J.F., and D. Roland-Holst (1997), "Industry Structure and Conduct in an Applied General Equilibrium Context," in J.F. Francois and K.A. Reinert (eds.), *Applied Methods for Trade Policy Analysis,* Cambridge: Cambridge University Press.

Horridge (1987) "Increasing Returns to Scale and the Long-run Effects of a Tariff Reform" *Preliminary Working Paper,* No. OP-62, IMPACT Research Centre, University of Melbourne and I. A. C.

Krugman, P.R. (1980), "Scale Economies, Product Differentiation, and the Pattern of Trade," *American Economic Review,* 70 (December), 950-959.

Lopez de Silanes, F., Markusen, J.R. and Rutherford, T.F. (1996). "Trade policy subtleties with multinational firms," *European Economic Review* 40: 1605-1627.

Melo, J. de and D.W. Roland-Holst (1991), "An Evaluation of Neutral Trade Policy Incentives Under Increasing Returns to Scale," in J. de Melo and A. Sapir (eds.), *Essays in Honor of Bela Balassa,* London: Basil Blackwell.

Pratten, C F. "Economies of Scale for Machine Tool Production," *Journal of Industrial Economics. Vol. 19 (2). p 148-65. 1971.*

Roberts, M.J., and J.R. Tybout (1996) *Industrial Evolution in Developing Countries,* Oxford UP.

Wigle, R. (1988), "General Equilibrium Evaluation of Canada-US Trade Liberalization in a Global Context", *Canadian Journal of Economics,* 21(3): 539-564.

**Table 1. Short run economy impacts**

| Macro Variables | Canada CMS | Canada HML | Mozambique CMS | Mozambique HML | New Zealand CMS | New Zealand HML | Singapore CMS | Singapore HML |
|---|---|---|---|---|---|---|---|---|
| Employment | 2.86 | 3.4 | 2.53 | 2.83 | 2.18 | 2.4 | 2.03 | 2.66 |
| Duty-paid Imp. P.I. | -0.45 | -0.43 | -0.62 | -1.62 | -0.43 | -0.43 | -0.43 | -1.33 |
| GDP P.I. | -2.86 | -2.96 | -1.34 | -2.26 | -1.35 | -1.46 | -2.13 | -2.61 |
| Investment P.I. | -1.59 | -1.73 | -2 | -2.92 | -0.72 | -1.77 | -2.13 | -2.78 |
| Consumer P.I. | -2.39 | -2.65 | -2.41 | -2.9 | -1.14 | -1.65 | -2.11 | -2.53 |
| Export P.I. | -1.35 | -2.58 | -2.43 | -2.52 | -1.14 | -2.58 | -1.06 | -1.18 |
| Real GDP | 2.05 | 2.1 | 2.2 | 2.26 | 1.48 | 2.1 | 2.32 | 3.07 |
| Export Volume | 2.98 | 3.15 | 2.22 | 2.67 | 2.44 | 3.35 | 2.77 | 2.93 |
| Import Volume | 2.71 | 3.04 | 2.11 | 2.88 | 3.5 | 3.4 | 2.04 | 2.50 |

**Table 2. Short run sectoral impacts**

| Commod. Output | Canada CMS | Canada HML | Mozambique CMS | Mozambique HML | New Zealand CMS | New Zealand HML | Singapore CMS | Singapore HML |
|---|---|---|---|---|---|---|---|---|
| Metals | -1.12 | -1.61 | -1.37 | -1.59 | -1.34 | -1.61 | -1.67 | -1.42 |
| Heavy Manu. | -1.15 | -1.97 | -1.62 | -2.29 | -0.33 | -1.17 | -1.25 | -1.65 |
| Coal | -0.61 | -1.57 | -2.08 | -2.84 | -0.23 | -1.57 | -1.04 | -1.04 |
| Oil | -0.43 | -0.33 | -1.17 | -1.42 | -0.06 | -0.33 | -0.83 | -1.67 |
| Gas | -0.37 | -0.16 | -0.31 | -0.7 | -0.03 | -0.16 | -0.53 | -0.99 |
| Minerals | -1.98 | -1.38 | -0.32 | -1.01 | -1.02 | -1.38 | -0.98 | -1.25 |
| Chemicals | -1.00 | -1.04 | -1.26 | -1.95 | -1.92 | -1.98 | -1.08 | -1.19 |
| Electricity | -1.12 | -1.88 | -1.19 | -1.64 | -1.49 | -1.88 | -1.35 | -1.90 |
| Construction | -1.13 | -1.81 | -1.15 | -1.26 | -1.02 | -1.81 | -0.15 | -0.52 |

**Table 3. Long run economy impacts**

| Macro Variables | Canada CMS | Canada HML | Mozambique CMS | Mozambique CMS | New Zealand HML | New Zealand CMS | Singapore CMS | Singapore HML |
|---|---|---|---|---|---|---|---|---|
| Employment | 1.86 | 1.9 | 1.53 | 1.66 | 1.96 | 1.40 | 1.66 | 1.96 |
| Duty-paid Imp. P.I. | -1.45 | -1.43 | -0.62 | -0.43 | -0.93 | -0.85 | -0.43 | -0.93 |
| GDP P.I. | -1.86 | -1.9 | -1.34 | -0.98 | -1.21 | -1.26 | -0.98 | -1.21 |
| Investment P.I. | -1.59 | -1.73 | -1.00 | -1.13 | -1.78 | -1.33 | -1.13 | -1.78 |
| Consumer P.I. | -1.39 | -1.65 | -1.41 | -1.61 | -2.53 | -1.65 | -1.61 | -2.53 |
| Export P.I. | -1.35 | -1.58 | -1.43 | -1.06 | -1.08 | -1.58 | -1.06 | -1.08 |
| Real GDP | 2.05 | 2.45 | 2.2 | 1.09 | 1.52 | 1.79 | 1.09 | 1.52 |
| Export Volume | 2.98 | 3.01 | 0.22 | 1.54 | 1.42 | 2.40 | 1.54 | 1.42 |
| Import Volume | 1.71 | 1.04 | 1.11 | 1.00 | 1.50 | 1.00 | 1.00 | 1.50 |

**Table 4. Long Run Sectoral Impacts**

| Commodities Output | Canada CMS | Canada HML | Mozambique CMS | Mozambique HML | New Zealand CMS | New Zealand HML | Singapore CMS | Singapore HML |
|---|---|---|---|---|---|---|---|---|
| Metals | -3.12 | -8.61 | 1.37 | 2.59 | -1.34 | -8.61 | -7.67 | -14.42 |
| Heavy Manufacturing | 1.15 | 2.97 | -5.62 | -9.29 | 0.03 | 1.97 | -5.25 | -8.65 |
| Coal | -0.61 | -1.57 | -1.08 | -1.84 | -0.23 | -1.57 | -1.04 | -1.08 |
| Oil | -0.43 | -0.33 | -1.17 | -1.42 | -0.06 | -0.33 | -0.83 | -1.67 |
| Gas | -0.37 | -0.16 | -0.31 | -0.7 | -0.03 | -0.16 | -0.53 | -0.99 |
| Minerals | -1.98 | -3.38 | -1.32 | -1.41 | -1.02 | -3.38 | -0.98 | -1.25 |
| Chemicals | -2.03 | -0.04 | -1.26 | -1.95 | -0.92 | -0.04 | -1.08 | -1.09 |
| Electricity | -1.12 | -1.88 | -1.19 | -1.64 | -0.49 | -1.88 | -1.35 | -1.20 |