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Imperfect competition in the international coal industry – does it matter?

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Abstract

The market for coal is of increasing significance in policy discussions on carbon reduction. Because the coal market has become increasingly internationalized, and because of the importance of coal in energy generation for industrial purposes and the limitations and costliness of alternative cleaner technologies, the use of multi-country, multi-sectoral computable general equilibrium (CGE) economic models is very popular for the evaluation of policies. These types of models frequently contain generic market structure assumptions that enhance the general applicability of the models but may limit their value for specific issues. This article evaluates the effects of imperfect competition in the international coal market under the CGE modeling framework. The results generated under various market structure scenarios are very similar, indicating that the structure of the international coal market does not play a significant role in determining the policy simulation outcomes. It can be concluded that coal-related CGE analyses can make use of the simple but robust perfect competition assumption and priority can be given to issues other than the underlying international coal market structure.

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1. Introduction

With volatile primary energy prices and political instability in oil and gas producing countries, coal has again gained prominence in the international energy sector. The abundance and stability in supply, diversity in supplying nations, relatively cheap prices and continuous advancement in clean coal technology have all contributed to make coal a reliable primary energy resource. Due to the growing import demand for coal and associated development of seaborne coal trade, the number of coal exporters has increased and the dominance of any single supplier has decreased. These developments may lead to a more competitive market for coal.

The market structure of coal was examined in a number of studies under the partial equilibrium modeling framework. For example, in 1984, Kolstad and Abbey (1984) found that their World Coal Trade Model produces trade patterns that most accurately simulate the actual patterns under the Australia-South Africa duopoly assumption. The competitive formulation performed poorly. Graham, Thorpe and Hogan (1999) simulated coking coal trade patterns in 1996 and also found that the international coking coal market was non-competitive. By 2008, Haftendorn and Holz (2008) found that their modeling results appear to be closer to reality under the perfect competition assumption than the Cournot oligopoly assumption. Despite the differences in the modeling strategies of these studies, these results suggest that the structure of the international coal market may have changed in the last 20 years.

The market for coal is of increasing significance in policy discussions on carbon reduction. Evidence-based evaluation of policies at an international level in this context arguably requires the use of multi-country, multi-sectoral computable general equilibrium (CGE) economic models. CGE models are particularly useful when it is essential to account for the substitution possibilities that exist among the primary energy sources. Also, CGE models are commonly used to analyze the inter-industry effects of various policy shocks. In most CGE applications, it is a customary practice to employ the assumption of perfect competition. Various studies have examined the sensitivity of CGE model outcomes to the market structure specification. However, the conclusions from these studies are not unified. For example, Willenbockel (2004) finds in a stylized prototype CGE model that the simulated responses to a trade policy shock are not sensitive to the specification of market conduct. On the other hand, Roson (2006) finds in an agricultural trade liberalization simulation that imperfect competition does matter for the CGE simulation results. In a CGE model for the German economy, Böhringer, Löschel and Welsch (2008) find that the effects of a carbon tax, in terms of induced structural change, are more pronounced under imperfect competition than perfect competition.

The aim of this article is to evaluate the effects of imperfect competition in the international coal industry under the CGE modeling framework with various assumptions about the underlying market structure. The conjectural variation approach is adopted for the specification of the market structures. An advantage of this approach is that it accommodates a wide continuum of market structures in one single formulation.

This article is structured as follows. Section 2 provides a brief overview of international steam coal trade. Section 3 discusses the modeling methodology and policy shocks. Section 4 presents the results and Section 5 concludes.

2. International Coal Trade

The changes in demand and supply conditions in the international coal market have underpinned the development of international coal trade. In both Europe and the Asia-Pacific (for example Japan and South Korea), high cost mines had been shut down as domestic coal lost its competitiveness against imported coal from low cost producers. In the last three decades, domestic production in Europe has decreased significantly and imports have increased gradually. In Japan, production has declined gradually to virtually zero in 2002 while imports have surged.

We can see from Figure 1 that consumption growth for the US is just moderate but the growth in Asian coal consumption has been very strong, mainly due to the high energy demand in China and India. While imports have been rising, consumption in Europe has actually been diminishing slowly. The growth in Asian consumption clearly outweighs the reductions in Europe. Figure 2 shows the import volume of the major coal importers. It can be observed that imports of Japan, South Korea and Taiwan have all increased steadily in the past two decades. The USA and China have recently become significant importers.

The upsurge in Asian consumption and European imports required the development of new supplies. In the Asia-Pacific market, it led to the expansion of Australian, Chinese and Indonesian exports. In the Europe-Atlantic market, it stimulated the growth of coal export industries in Colombia, South Africa and Venezuela. The US and Poland were already major exporters of coal before the other countries expanded their exports.

Figure 1. Coal Consumption (thousand tonnes)

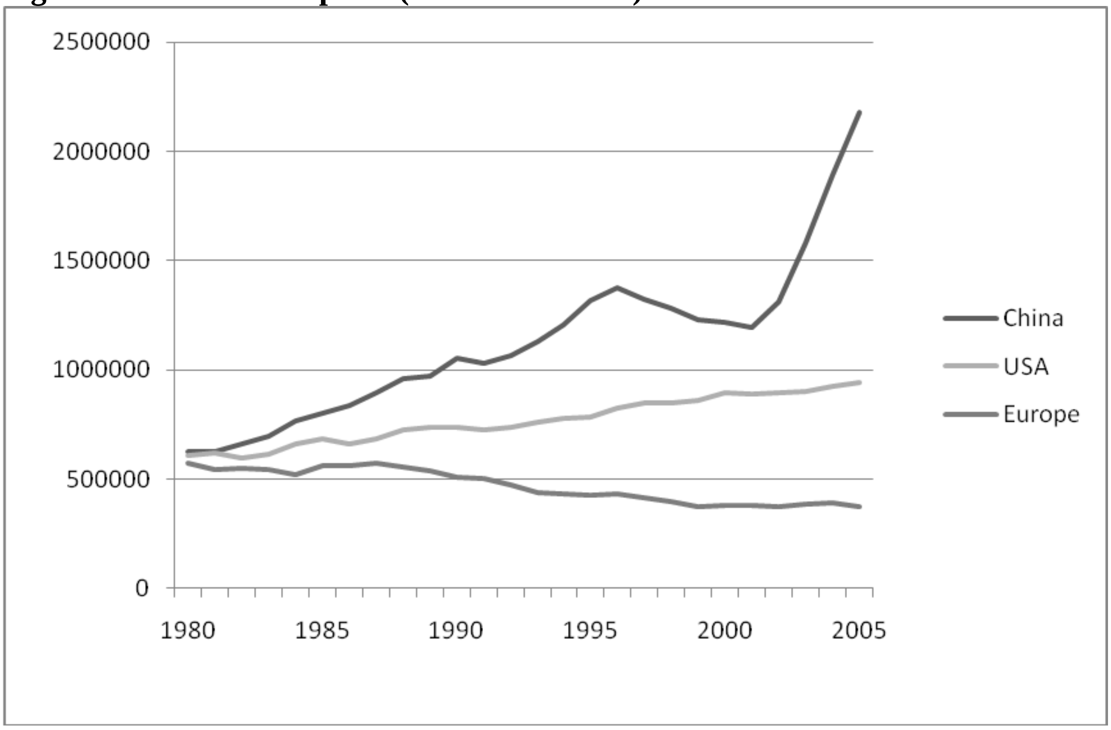
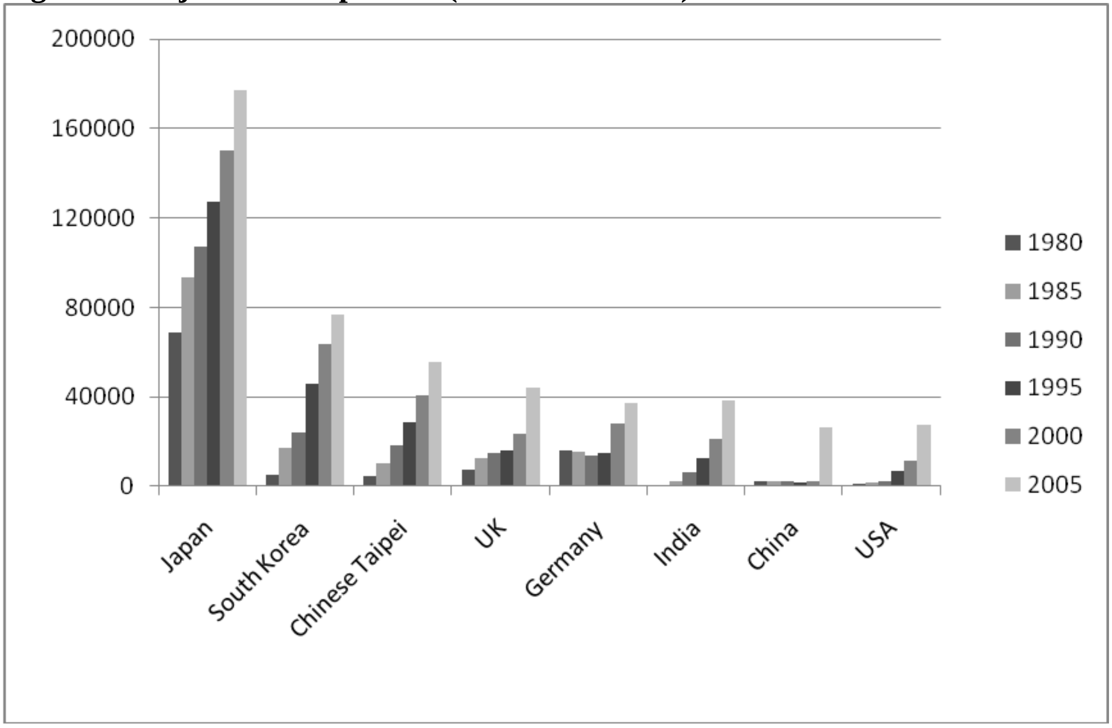


Figure 2. Major Coal Importers (thousand tonnes)



3. Methodology

3.1 Modeling Imperfect Competition in the GTAP-E framework

The standard GTAP-E model assumes that all markets are perfectly competitive. As pointed out by Roson (2006), there is no single way of implementing imperfect competition in CGE models. Depending on the assumed market structure and the type of strategic interaction between agents, the specification method will differ. In order to encompass imperfect competition in the model, the approach suggested by Francois (1998) is adopted in this paper.

There is a wide range of possible market structure assumptions between the two extremes of perfect competition and monopoly. In this paper, the Cournot conjectural variations model is adopted to represent the oligopolistic interactions between suppliers. Under this specification, firms anticipate or "conjecture" the output responses of their competitors. Firms choose how much to produce and let the inverse demand functions determine the price. Firm *i*'s conjecture of the change in industry output with a change in its output is:

$$\Omega_i = \frac{dQ}{dQ_i} \tag{1}$$

where Ω_i is the conjectural variation, dQ is the change in total industry output ($Q=\Sigma Q_i$) and dQ_i is the change in firm *i*'s output. The profit function, first-order condition and mark-up equation for the oligopolists are:

$$\Pi_i = P_i Q_i - TC_i \tag{2}$$

$$\frac{d\Pi_i}{dQ_i} = P_i + Q_i \frac{dP_i}{dQ} \frac{dQ}{dQ_i} - \frac{dTC_i}{dQ_i} = 0 \tag{3}$$

$$\frac{P_i - MC_i}{P_i} = \frac{\Omega_i}{\varepsilon_i} \frac{Q_i}{Q} \tag{4}$$

Equation (4) embraces a wide spectrum of market structure assumptions. For a perfectly competitive industry, the output of any single firm is too small to affect the industry output, hence dQ and Ω_i both equal zero. Therefore, equation (4) will collapse to the marginal cost pricing equation. For a perfectly collusive market, equation (4) will simplify to the monopoly pricing equation. This is because in a perfectly collusive market, all firms act together and a change in firm i's output will lead firm k to change its output by $(Q_k/Q_i)dQ_i$. Considering the actions of all firms together, $\Omega_i=Q/Q_i$. For the standard Cournot-Nash equilibrium model, $\Omega_i=1$. This is because each firm conjectures that the other firms will not respond to changes in the output of the others and hence the change in industry output is the same as the change in the firm's own output, i.e. $dQ = d\mathrm{Q}_i$. In this case, the mark-up varies inversely with the firm-perceived market demand elasticity and positively with the conjectural variation and the ratio of the firm's output to industry output.

The calculation of the market elasticity of demand is crucial in the determination of the mark-up. Following Francois (1998), the market elasticity of demand for coal from region i to region r, $\varepsilon_{i,r}$, is given by:

$$\varepsilon_{i,r} = \sigma + (1-\sigma)\zeta_{i,r} \tag{5}$$

and

$$\zeta_{i,r} = \left[\sum_{k=1}^{R} \left(\frac{\alpha_{k,r}}{\alpha_{i,r}} \right)^{\sigma} \left(\frac{P_{k,r}}{P_{i,r}} \right)^{1-\sigma} \right]^{-1} \tag{6}$$

where σ is the elasticity of substitution of coal between different regions, $\alpha_{i,r}$ is the demand share of coal from region i in region r and $P_{i,r}$ is the price of coal from region i to region r. If we assume that firms with market power do not practice price discrimination, a single mark-up will be charged for each firm and the demand elasticity is:

$$\varepsilon_i = \sigma + (1-\sigma)\zeta_i \tag{7}$$

and

$$\zeta_i = \sum_{r=1}^{R} \frac{Q_{i,r}}{Q_i} \left[\sum_{k=1}^{R} \left(\frac{\alpha_{k,r}}{\alpha_{i,r}} \right)^{\sigma} \left(\frac{P_{k,r}}{P_{i,r}} \right)^{1-\sigma} \right]^{-1} \tag{8}$$

where $Q_{i,r}$ is the quantity of coal from region i consumed in region r, Q_i is the total output of coal in region i. The perceived market demand elasticity for a particular supplier is the elasticity of substitution modified by its global market share as measured by $\zeta_{,i}$. As limiting cases, $\varepsilon_i = \sigma$ when $\zeta_i = 0$ and $\varepsilon_i = 1$ when $\zeta_i = 1$. In general, ζ_i will have a large value when (1) region *i* produces a large quantity of coal, (2) coal output of region *i* constitutes a high share in the demand of the other regions, (3) region *i* does not import a large amount of coal, and (4) the coal price of region *i* is relatively lower than the others. The oligopoly pricing equation can now be written as:

$$\frac{P_i - MC_i}{P_i} = \frac{\Omega_i}{n}\left[\sigma + (1-\sigma)\zeta_i\right]^{-1} \tag{9}$$

To implement this type of market structure in the GTAP-E framework, it requires the calculation of the mark-up and adding it to the supply price equation in the model. This is accomplished by adding an extra module to the standard GTAP-E model to calculate the market demand elasticities and mark-ups and including the new pricing equation in the standard model.

3.2 Database and Aggregation

The GTAP database version 7 is used for the simulations in this article. The reference year of the database is 2004 and it represents the world economy as a system of flows of goods and services measured as money values in millions of US dollars. The CO_2 emissions database prepared by Lee (2008) is integrated into the main GTAP database in order to provide the GTAP-E model with information on CO_2 emissions. The original database contains 113 regions and 57 commodities. For the purpose of this article, the database is aggregated into 12 regions and 8 commodities.

Table 1 provides a summary of the aggregation. The selection of regions is mainly based on the importance of the countries in the international coal market. In particular, Australia, South Africa, China, Indonesia, Colombia, Russia and the USA are the key exporters of coal, while the European Union (EU), Japan, South Korea, Taiwan, China and the USA are the key importers of coal in the international market. The sectoral aggregation is inherited from the standard GTAP-E model.

Table 1. Aggregation of Regions and Sectors

Regions	Sectors
Australia (AUS)	Agriculture
South Africa (SA)	Coal
China (CHN)	Oil
Indonesia (IDN)	Gas
USA	Petroleum and coal products
Colombia (COL)	Electricity
Russia (RUS)	Energy intensive industries
European Union (EU)	Other industries and services
Japan (JPN)	
South Korea (KOR)	
Taiwan (TWN)	
Rest of the World (ROW)	

3.3 Assumptions and Shocks

Table 2 displays the share of individual exporters to total exports. It can be observed that while none of the exporters has a significantly high share of the world export market, the major exporters together accounted for about 85.5% and 83.9% of total world exports in 2000 and 2005, respectively. Although there is a large number of exporters in the world market, the big players are still dominating the market. A second observation from the figures is that from 2000 to 2005, the distribution of shares amongst the major exporters have become more even. It appears that the playing field has become more level amongst these players.

Table 2. Share in Total Exports (%)

	2000	2005
Australia	32.6	29.1
Indonesia	9.9	13.9
Russia	6.0	9.9
South Africa	12.2	9.2
China	9.6	9.1
Colombia	6.0	7.0
USA	9.2	5.7
Other	14.5	16.1

The conjectural variation approach for modeling imperfect competition requires *a priori* knowledge or assumption of the underlying market structure of the industry. In order to achieve the objective of this paper, three alternative market structure assumptions are used. The assumptions include perfect competition (PC), Australia-Indonesia duopoly (DUO) and Cournot oligopoly (CO) in which six key coal exporters (Australia, South Africa, China, Indonesia, Colombia and Russia) are given market power.

The debates and discussions on global warming, emissions reduction and emissions trading are ongoing. Since coal is highly carbon-intensive and it accounts for a large share of greenhouse gas emissions, emissions reduction-related policies will likely have significant impact on the international coal industry. The simulations in this article are designed to help illustrate the potential effects of imperfect competition in the international coal industry on emissions policy outcomes. The policy shock requires all advanced economies in the model (namely, Australia, EU, USA, Japan and South Korea) to reduce their CO_2 emissions by 30% and all other countries to reduce their CO_2 emissions by 10%.

4. Results

As the most carbon intensive fossil fuel, CO_2 reductions impose significant negative impact on the consumption of coal. Referring to Figure 3, the reductions in coal consumption are estimated to be in the range of 35% to 40% for countries with high abatement level and 10% to 16% for those with low abatement level. For all countries with high abatement level, the percentage reduction in coal consumption is higher than the CO_2 reduction percentage. This implies that a heavier burden of CO_2 reduction is imposed on coal in general and there is substitution away from the use of coal to other primary energy sources.

The percentage changes in coal production, exports and imports are reported in Figures 4, 5 and 6, respectively. The changes in coal production can be explained by the changes in domestic demand and demand from other countries. Depending on the demand structure (i.e. domestic or export-oriented), the production responses of the key coal producers will differ. In addition, the changes in coal consumption, especially of the major coal importers, will significantly influence the international trade of coal. As the largest coal exporter in the world, Australia suffers from 24% shrinkage in the volume of exports. With a closer look at the percentages, we can observe that the percentage reduction in Australian production is higher than the percentage reduction in its exports. This is because Australian production diminishes through two channels – on top of the cutback in import demand as a result of CO_2 emission reductions, Australian domestic demand for coal also decreases. For the same reason, coal production of South Africa, China, Russia and Colombia decreases in the range of 12% to 19%. The situation of Indonesia is different. Indonesian coal consumption decreases by 16% while its production decreases by only 12%. This difference can be explained by the rather low percentage fall (11%) in its exports.

Figure 3. Percentage Change in Coal Consumption

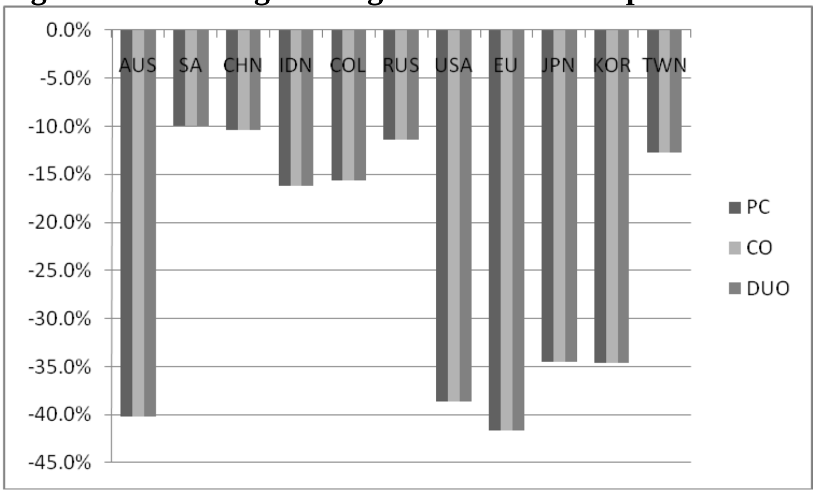


Figure 4. Percentage Change in Coal Production

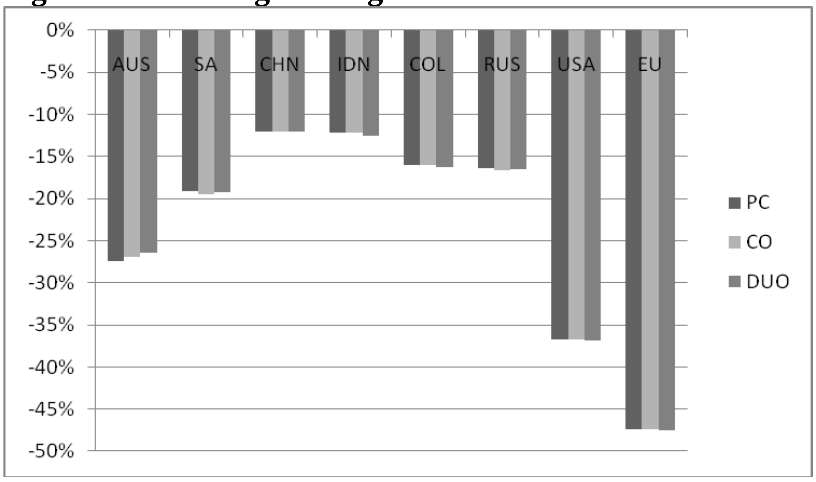


Figure 5. Percentage Change in Coal Exports

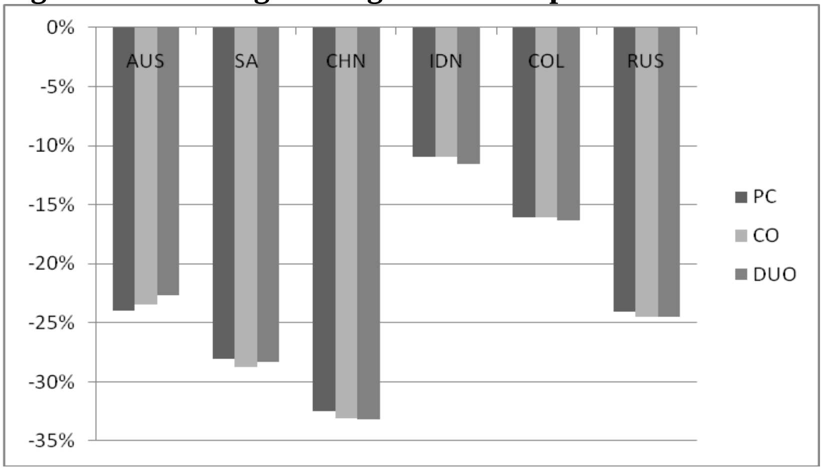
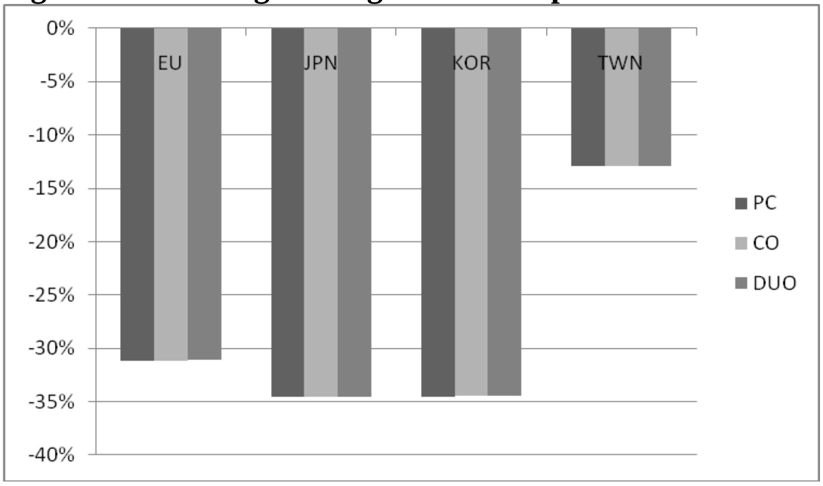


Figure 6. Percentage Change in Coal Imports



EU coal production contracts by 47%, which is more than the region's reduction in consumption. Assessed in combination with the 42% reduction in coal consumption and 31% reduction in imports, these results indicate that there is a moderate degree of substitution towards imports in the EU. Since the EU is a principal destination of South African and Russian exports, these two countries are vulnerable to circumstances in the EU. South African and Russian exports are estimated to drop by 28% and 24%, respectively. Lower import demand from the EU is the main reason for these declines. Because Japan satisfies almost 100% of its demand for coal by imports, in all scenarios the percentage fall in its imports matches the percentage fall in its consumption. A similar situation can also be observed for Korea and Taiwan.

Overall, the simulation results under the three market structure scenarios are almost the same. For all scenarios and all countries being studied, the extents of consumption reductions are strongly influenced by the CO_2 reduction requirement. The international trade and production of coal are in turn strongly affected by the consumption reductions. Apparently, the key driving force of the model outcomes is the specification of the policy shocks in the simulations rather than the underlying market structure assumptions.

5. Conclusion

This article examines the effect of the international coal market structure on policy modeling outcomes. The GTAP-E model was augmented with an imperfect competition module and used as a platform for running the policy simulations. Emissions reduction policy simulations were performed under various market structure scenarios and the outcomes of coal production, consumption, exports and imports were compared. The differences in the simulation results under various scenarios are negligible. The results indicate that the structure of the international coal market may not significantly alter the outcome of carbon emissions policies. Therefore, when using CGE models (or the GTAP-E model in particular) to analyze policy issues relating to the international coal market, the modeler can focus on the specification of the policy shocks and benchmark data calibration instead of the specification of the “correct” market structure. Future research may explore further the possible effects of uneven emissions reduction targets across the advanced economies and other policy shocks.

References

Böhringer, C, A. Löschel and H. Welsch (2008) “Environmental taxation and induced structural change in an open economy” *German Economic Review* **9(1)**, 17-40.

Burniaux, J.M. and P.T. Truong (2002) “GTAP-E: an energy-environment version of the GTAP model” GTAP Technical Paper No.16.

Francois, J. (1998) “Scale economies and imperfect competition in the GTAP model” GTAP Technical Paper No. 14.

Graham, P, S. Thorpe and L. Hogan (1999) “Non-competitive market behavior in the international coking coal market” *Energy Economics* **21**, 195-212.

Haftendorn, C. and F. Holz (2008) “Analysis of the world market for steam coal using a complementarity model” DIW Berlin Discussion Papers no.818.

Kolstad, C.D. and D.S. Abbey (1984) “The effect of market conduct on international steam coal trade” *European Economic Review* **24**, 39-59.

Lee, H.L. (2008) “The Combustion-based CO2 Emissions Data for GTAP Version 7 Data Base” Accessed online 17 May 2010.
https://www.gtap.agecon.purdue.edu/resources/download/4470.pdf.

Roson, R. (2006) “Introducing imperfect competition in CGE models: technical aspects and implications” *Computation Economics* **28**, 29-49.

Truong, P.T. (2007) “GTAP-E: an energy-environment version of the GTAP model – User’s Guide” Accessed online 20 Jan 2010.
https://www.gtap.agecon.purdue.edu/resources/download/3552.pdf

Willenbockel, D. (2004) “Specification choice and robustness in CGE trade policy analysis with imperfect competition” *Economic Modelling* **21**, 1065-99.