Modeling a Method to Measure the Economic Impacts of Multiple Energy Price Changes

June 12, 2004

Suduk Kim**

Department of Energy Studies

Graduate School

Ajou University

Key Words: CGE Model, Input-Output Analysis, Multiple Energy Price Changes, Industrial Sectors, Price Elasticity

JEL Classification: C67; D58

This paper is sponsored by a project conducted as a joint research of Stanford Research Institute Consulting (SRIC) and Korea Energy Economics Institute (KEEI).

** Please correspond to him: Email: suduk@ajou.ac.kr, Address: Department of Energy Studies, Graduate School, Ajou University, Suwon, Korea, 443-749

Abstract

We investigate a practical method of calculating the impact of multiple domestic energy price change on the final demand, production, the export and import change, the change in the balance of payment of Korean economy. By combining an existing computable general equilibrium (CGE) model with the traditional input-output analysis with two additional assumptions on the price behavior, we provide a cost-effective method of analyzing the impact of multiple energy price changes on the domestic economy.

The energy price shock we used in this paper is 0.127% increase weighted by the sectoral productions. The total impacts on price level and GDP are 1.258% and -0.940%, respectively. The impact on the total output (GDP and intermediate goods) is about -1.580%.

I. Introduction

Energy prices in Korean economy have been designed and maintained to support the industrially growing economy. Korean government has played a major role in the pricing of energy. One of the main objectives of Korea's energy policies was to ensure the energy sectors managed to provide low cost of energy supplies for the economic development and growth. Keeping energy prices low was very essential to ensuring industrial competitiveness and social policy. This leads lot of distortions in energy prices. The energy prices have been kept lower than those without the government interventions.

In the dynamically interdependent economy and energy market, Korean economic and energy security interest can be obtained by energy prices based on market. The utility companies under the current pricing arrangements are unable to generate sufficient funds to meet their future investment needs. Besides, low energy prices will hinder the market from working efficiently.

There was a provision of the idea that the adjustment in distorted energy prices is one of the most important things to do in energy policy to achieve market-oriented economy. At this paper, we examine the economic impact of the price policy to provide information about the policy result. In order to make a balanced policy direction, we investigate various scenarios of the energy prices. Most of the policy makers agree to the necessity of the price changes in energy, but shows a deep concerns over the sudden consequences in the industries and economy. The purpose of this chapter is to show the experimental figure of the results of the policy changes.

A brief overview of the process is described in next chapter. In order to use demand elasticity, a computable general equilibrium model is introduced in third chapter. Price effects of each sector are followed in fourth chapter, using input-output analysis. At fifth chapter we combined the results of two analyses to get the effects in production, export, and import of the Korean economy.

II. Methodology and sector classification

Energy sector is an area of particular interest due to the strong linkage between this sector and economic and social well being of a country. Energy is closely related not only with final demand but also with the production of all goods as a factor of the production. This characteristic is well explained in the input-output table. In order to investigate the effect of energy price changes on economy, we decided to use two kinds of methods using input output relations. They are input output analysis and computable general equilibrium models.

Input-output analysis has many advantages for the purpose. It can handle various impacts of the price changes in sub-sectors at a reasonable computational cost. But the static situation it assumes has a limit that the analysis is restricted to only price level changes of other commodities. It cannot handle the demand or production of each industry.

The appropriate approach to evaluate the effects would be using a computable general equilibrium model. This model can handle the economy as complete system, though it has a lot of assumptions and high cost of computational efforts. In order to examine various scenarios of energy price changes, we have to build different CGE models for each individual scenario. And the additional problem is that it is very difficult to handle multiple shocks in a model simultaneously with a static model structure.

Under this circumstance, we have tried to combine two different approaches. We build an analytical tool using input output model first. After that we will combine this with a simulated result of other existing CGE model under some assumptions.

Classification of Industrial Sectors

In order to investigate the sectoral effects of the energy price adjustment, we need to classify the industry. It is summarized in table 1. The first column is ordinary classification (25 sectors) of the input output table of Korea. Next one is about new classification for the analysis of the impact on industries of the energy price shock. The Korean economy has been disaggregated into 29 industrial sectors with primary fossil fuels and energy sectors finely classified.

III. Summary of the CGE model used

We have investigated the impact of energy price adjustment on the price level of each industry. We expect that the price changes in each industry change the markets of each commodity continuously. In order to calculate the demand elasticity of each industry, we need some extra information from a model with the general economic structure. One standard static computable general equilibrium model of Korean economy (Sonn & Shin (1997)) is selected for this purpose.

Computable General Equilibrium Model

This model examines the economic effects on Korean economy, of an exogenous increase in importing price of oil. This model is constructed based on neo-classical theory like Robinson (1989) and Melo and Tarr (1992).

Table 1. Industrial Sectors Classification

Classification 25*	Classification 29	Code
Agriculture, forestry, and fisheries	Agriculture, forestry, and fisheries	1
Mining and quarrying	Anthracite coal	2
	Bituminous coal	3
	Crude petroleum	4
	Natural gas	5
	Quarrying	6
Food & kindred products, & tobacco	Food & kindred products, & tobacco	7
Textile mill products, apparel, & leather	Textile mill products, apparel, & leather	8
Paper & wood products	Paper & wood products	9
Petroleum & coal products	Coal products	10
	Gasoline	11
	Kerosene	12
	Light oil	13
	Bunker-c oil	14
	Liquefied petroleum gas	15
	Other petroleum products	16
Chemicals & chemical products	Chemicals & chemical products	17
Stone, clay, & glass products	Stone, clay, & glass products	18
Primary metal products	Primary metal products	19
Fabricated metal products	Metal products and machinery	20
General machinery & equipment		
Electric & electronic equipment	Electric & electronic equipment	21
Transportation equipment	Transportation equipment	22
Precision instruments		
Miscellaneous manufactured products	Miscellaneous manufactured products	23
Electric, gas, & water services	Electric power	24
	Piped gas supply	25
	Steam & hot water supply	26
Construction	Construction	27
Wholesale & retail trade	Wholesale, transportation, & finance	28
Transportation & warehouse		
Communications		
Finance & insurance		
Real estate & business services		
Public administration and defense	Public Adm. & other services	
Education and health services		
Social and personal services		29

* Classification 25 is standard industrial code of I/O 1993

Korea is assumed to be a small open economy and, so, it behaves as a price-taker in world markets. All domestic markets of commodity and factor are competitive with full employment of factors of production. All economic actors take market prices as given and maximize their objective function subject to their constraints.

The household's utility function is of a Cobb-Douglas type:

$$U = \prod_{i=1}^{n} CD_i^{\alpha_i}, \qquad \sum_{i=1}^{n} \alpha_i = 1, \qquad \alpha_i \geq 0$$

where CD_i is a consumption of composite good i. Government also consumes composite commodities, CG_i , which is assumed to be fixed in the model. The economy produces outputs, XD_i which is a Leontief function of value added, VA_i, and intermediate inputs of composite goods, IN_i:

$$XD_j = \min\left[\frac{VA_j}{v_j}, \frac{IN_{1j}}{io_{1j}}, \frac{IN_{2j}}{io_{2j}}, \ldots, \frac{IN_{nj}}{io_{nj}}\right]$$, where v_j ,io_{ij} : Leontief coefficient

Value added is produced by a constant elasticity of substitution (CES) technology, using labor, L_i, and capital, K_i, as inputs. Produced output is transformed into exports, E_i, and domestic goods, XS_i.

The model has no independent investment function and aggregate savings are equal to aggregate investment. It is assumed that there is a single capital good sector and this capital good, Z, is produced by a Leontief technology:

$$Z = \min\left[\frac{ID_1}{inr_1}, \frac{ID_2}{inr_2}, \ldots., \frac{ID_n}{inr_n}\right]$$ where inr_i = Leontief coefficient

where Z_i is an investment demand for composite good i. This capital good is demanded by household and government for the store of value.

The equilibrium system is described in the Appendix II. The model is composed of 4 blocks. They are price block, production block, demand block, and equilibrium conditions. The system includes optimization behavior of household, firms, and government, and equilibrium conditions for the commodity and factor markets. There are (18n+11) equations and same number of endogenous variables. Since we classified Korean industry by 23 sectors, the number of equations and endogenous variables are 425.

Data

The year 1993 has been chosen as the benchmark of the model. That was the latest available input output table for the CGE model. To calibrate the model, the 1993 input-output table, national income and product accounts and other tax data for the Korean economy have been consistently adjusted.

Results of the simulation

The simulation of the CGE model is conducted on the impact of the import price change of the crude oil. The exogenous impact is 30% increase in importing price. The simulation result is summarized in Table 2. The numbers in the table are followings:

- Final Demand change ($\frac{dY_i}{dP_4}$): final demand change for the 1% increase in oil price (P_4)
- Export change ($\frac{dE_i}{dP_4}$): export change for the 1% increase in oil price (P_4)
- Import change ($\frac{dM_i}{dP_4}$): import change for the 1% increase in oil price (P_4)

Table 2. Results of the simulation

Code	Industrial sectors	Final Demand change	Export change	Import chang
1	Agriculture, forestry, and fisheries	-126.66	16.85	-194.18
2	Anthracite coal	0.00	0.0	
3	Bituminous coal	0.00		-34.48
4	Crude petroleum	0.00		-553.33
5	Natural gas	0.09		-8.80
6	Quarrying	0.00	-0.10	16.22
7	Food & kindred products, & tobacco	-532.10	13.44	-213.85
8	Textile mill products, apparel, & leather	-202.91	93.12	-132.14
9	Paper & wood products	-16.81	3.54	-33.72
10	Coal products	-30.16	0.11	-0.63
11	Gasoline	-57.02	-249.43	-307.73
12	Kerosene	-23.65		
13	Light oil	-68.15		
14	Bunker-c oil	-44.74		

15	Liquefied petroleum gas	-18.87		
16	Other petroleum products	-69.67		
17	Chemicals & chemical products	-781.73	-36.19	44.09
18	Stone, clay, & glass products	-18.13	-2.35	52.73
19	Primary metal products	0.00	5.17	93.37
20	Metal products and machinery	353.47	37.79	15.13
21	Electric & electronic equipment	-48.63	72.25	-79.11
22	Transportation equipment	35.15	23.83	-55.33
23	Miscellaneous manufactured products	-60.10	14.75	-32.85
24	Electric power	-70.86	-0.06	-0.11
25	Piped gas supply	-20.98	-0.04	-0.1
26	Steam & hot water supply	-4.27		
27	Construction	1311.60	1.45	
28	Wholesale, transportation, & finance	-1005.62	21.95	-68.18
29	Public adm. & other services	-121.50	3.22	-25.43

IV. Input output analysis

Assume that the national economy can be aggregated into *n* industries and a sector of final demands that includes household and government purchases. The dollar values of transactions among sectors can be presented in the following transactions matrix S:

$$S = \begin{bmatrix} x_{11}p_1 & x_{12}p_1 & \cdots & x_{1n}p_1 & d_1 p_1 \\ x_{21}p_2 & x_{22}p_2 & \cdots & x_{2n}p_2 & d_2 p_2 \\ \vdots & \vdots & & & \\ x_{n1}p_n & x_{n2}p_n & \cdots & x_{nn}p_n & d_n p_n \\ v_1 & v_2 & \cdots & v_n & \end{bmatrix}, \qquad (1)$$

where p_i represents the price per unit of product i; d_i is the final demand for output i; and v_i represents the value added of the i-th industry. Each row shows the intermediate and final uses of input, and each column shows the intermediate and factor inputs of an industry. For example, x_{21} is the physical quantity of the output from industry 2 that is used by industry 1. With no loss in generality, the unit price convention defines the physical unit of each commodity as the amount that sells for $1. Since all prices are one, dollar volume in equation (1) can be used to derive the input coefficients. Let x_i be the sum of all demands in row *j* a measure of total output.

Then define a_{ij} as the "input coefficient," the input of the ith good as a fraction of total output of industry j:

$$a_{ij} = x_{ij} / x_j, \tag{2}$$

where

$$x_j = \sum_{i=1}^{n} x_{ji} + d_j$$

These input coefficients are assumed constant. This assumption is useful and appropriate for calculating first-order effects on the cost of output from variations in the cost of different inputs, as done here, but it does not account for second-order effects, such as changes in the mix of inputs. These second-order effects would be necessary to estimate efficiency effects from tax distortions or to estimate tax revenue after adjustments in behavior.

As long as profits are included in the value added, the sum of all inputs plus value-added is equal to the value of gross output. Also, the sum of all intermediate and final uses is equal to the value of gross output. Thus each column sum of matrix (1) is equal to the corresponding row sum:

$$\begin{aligned}
x_{11} p_1 + x_{21} p_2 + \cdots + x_{n1} p_n + V_1 &= x_1 p_1, \\
x_{12} p_1 + x_{22} p_2 + \cdots + x_{n2} p_n + V_2 &= x_2 p_2, \\
\vdots \qquad \vdots \qquad \cdots \qquad \vdots \qquad \vdots \quad &\vdots \\
x_{1n} p_1 + x_{2n} p_2 + \cdots + x_{nn} p_n + V_n &= x_n p_n,
\end{aligned} \tag{3}$$

Each of these equations is divided by total output of that industry x_i and then rearranged and reexpressed using the input coefficients to find

$$\begin{aligned}
(1 - a_{11}) p_1 \quad - a_{21} p_2 \quad - \cdots \quad - a_{n1} p_n \quad &= V_1 / x_1, \\
- a_{12} p_1 \quad + (1 - a_{22}) p_2 - \cdots \quad - a_{n2} p_n \quad &= V_2 / x_2, \\
\vdots \qquad \vdots \qquad \cdots \quad \vdots \qquad \vdots \quad & \\
- a_{1n} p_1 \quad - a_{2n} p_2 - \cdots + (1 - a_{nn} p_n) \quad &= V_n / x_n,
\end{aligned} \tag{4}$$

Using matrix algebra, these equations can then by represented by

$$\mathbf{(I - A')P = V} \tag{5}$$

Where

$$\mathbf{A} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix}, \quad \mathbf{P} = \begin{bmatrix} p_1 \\ p_1 \\ \vdots \\ p_n \end{bmatrix}, \quad \mathbf{V} = \begin{bmatrix} v_1 / x_1 \\ v_2 / x_2 \\ \vdots \\ v_n / x_n \end{bmatrix},$$

and where **I** is the identity matrix. If $\mathbf{(I - A)^{-1}}$ is nonsingular, the price vector can be derived as follows:

$$\mathbf{P} = \mathbf{(I - A')^{-1} V} \tag{6}$$

To analyze the external price change impact on other sector, we may have to modify the above equation (6). Let us decompose the price vector into internal (P^I) and external (P^E) price vector, and suppose k sectors prices change. Then P^E is (k x1) and P^I is ($n-k$) x 1 vector. From equation (3), we have the following equations.

$$\begin{aligned} a_{11}\ p_1 + a_{21}\ p_2 + \cdots + a_{n1}\ p_n + v_1 &= a_1\ p_1, \\ a_{12}\ p_1 + a_{22}\ p_2 + \cdots + a_{n2}\ p_n + v_2 &= a_2\ p_2, \\ \vdots \qquad \vdots \qquad \cdots \qquad \vdots \qquad \vdots \quad &\ \ \vdots \\ a_{1n}\ p_1 + a_{2n}\ p_2 + \cdots + a_{nn}\ p_n + v_n &= a_n\ p_n, \end{aligned} \tag{7}$$

By externalizing the price impact described above, we have

$$\mathbf{\tilde{A}'P^I + \hat{A}'P^E + \tilde{v} = P^I.} \tag{8}$$

Here, $\mathbf{\tilde{A}}$, $\mathbf{\tilde{v}}$ are input coefficient matrix and ratio of value added except the sectors of external price change. $\mathbf{\hat{A}}$ is ($n-k$) x k input coefficient matrix of the sectors of external price change. To get the impact of external price change, take total derivative on both side of equation (8) with the assumption that value added ratio doesn't change, i.e., $d\tilde{v} = 0$.

$$\mathbf{\tilde{A}'dP^I + \hat{A}'dP^E = dP}^I$$

With some arrangement, we get external price impact on other sectors such as

$$\mathbf{dP^I = (I - \tilde{A}')^{-1}\hat{A}'dP}^E \tag{9}$$

When $\mathbf{dP^E}$ is a vector of price changes as in this case of 30% increase of crude oil price change, $\mathbf{(I - \tilde{A}')^{-1}\hat{A}'}$ can be interpreted as the price elasticity of external price shock. Using equation (9), we calculated the impact of 30% price increase in sector 4, crude oil, on i-th sector (dP_i / dP_4) in Table 3.

V. Integration of the results

In order to get the output effect of price change, we have to combine the results from CGE and I/O model together. If we can find the price elasticity of final demand in all sectors, we may be able to analyze the economic impact of energy price change.

In this chapter, we show sectoral price elasticity, the simulation results of final demand change, total output change, sectoral price elasticity of import, export and their changes.

Basic structure of the process

In order to combine both results, we need two assumptions on well working price mechanism. In this economy, prices are so flexible that prices can absorb any shock in other price. The only way to change the output of the sector is through the own price.

Assumptions :

i) $Y_i = Y_i(P_i)$

ii) $P_i = P_i(P_1, P_2, ..., P_n) \qquad i = 1,2,...,n$

The first assumption is that final demand of each sector is a function of the own price of the sector. And second one is that price of each sector is function of the prices of all sectors.

We can decompose the effect of importing oil price change on final demand like followings:

$$\frac{dY_i}{dP_4} = \frac{dY_i}{dP_i}\frac{dP_i}{dP_4} \qquad i = 1,2,...,n$$

Table 3. Sectoral Price impact of Crude Oil Price change

Sector	Industrial sectors	dP_4	dP_i	dP_i / dP_4
1	Agriculture, forestry, and fisheries	0	0.00551	0.01836
2	Anthracite coal	0	0.00592	0.01972
3	Bituminous coal	0	0	0

4	Crude petroleum	0.3	0.3	1
5	Natural gas	0	0	0
6	Quarrying	0	0.00826	0.02752
7	Food & kindred products, & tobacco	0	0.00559	0.01864
8	Textile mill products, apparel, & leather	0	0.00824	0.02748
9	Paper & wood products	0	0.00784	0.02614
10	Coal products	0	0.00376	0.01254
11	Gasoline	0	0.07889	0.26296
12	Kerosene	0	0.18113	0.60375
13	Light oil	0	0.18207	0.60691
14	Bunker-c oil	0	0.19917	0.66391
15	Liquefied petroleum gas	0	0.17872	0.59574
16	Other petroleum products	0	0.15788	0.52628
17	Chemicals & chemical products	0	0.01742	0.05806
18	Stone, clay, & glass products	0	0.01127	0.03757
19	Primary metal products	0	0.00782	0.02606
20	Metal products and machinery	0	0.00614	0.02047
21	Electric & electronic equipment	0	0.00503	0.01677
22	Transportation equipment	0	0.00581	0.01936
23	Miscellaneous manufactured products	0	0.00610	0.02033
24	Electric power	0	0.02167	0.07223
25	Piped gas supply	0	0.02185	0.07282
26	Steam & hot water supply	0	0.03559	0.11864
27	Construction	0	0.00668	0.02226
28	Wholesale, transportation, & finance	0	0.00704	0.02347
29	Public Adm. & other services	0	0.00491	0.01636

Since we already obtained final demand change ($\frac{dY_i}{dP_4}$) and ($\frac{dP_i}{dP_4}$) from CGE and I/O analysis, respectively, price elasticity of each sector (η_i) can be easily obtained as follows:

$$\eta_i = \frac{dY_i}{dP_i}\frac{P_i}{Y_i} = \frac{dY_i}{dP_4}\frac{dP_4}{dP_i}\frac{P_i}{Y_i} \qquad (10)$$

Price changes scenarios

1) Base Scenario for the Price Impact Analysis (Unit: Won)

Sector	Industry	Price (P)	S*	Tax	dP
11	Gasoline	1089.90		-54.65	-0.05014
12	Kerosene	438.20		-14.19	-0.03238
13	Light oil	485.50		133.50	0.27497
14	Bunker-c oil	216.32		26.00	0.12019
15	Liquefied petroleum gas	516.10		-12.00	-0.02325
24	Electric power	71.10	7.96	3.00	0.15415
25	Piped gas supply	372.30	40.00	-11.00	0.07789

S* : Subsidy for production cost

dP = (S* + Tax) / P

2) Alternative Scenario for the Price Impact Analysis (Unit: Won)

Sector	Industry	Price (P)	S*	Tax	dP (Tax)
11	Gasoline	1045.64		99.39	0.09505
12	Kerosene	379.43		-74.07	-0.19521
13	Light oil	496.59		219.45	0.44191
14	Bunker-c oil	229.25		28.20	0.12301
15	Liquefied petroleum gas	542.60		-13.48	-0.02484
24	Electric power	71.93	11.87	3.29	0.21076
25	Piped gas supply	427.55	3.65	-12.39	-0.02044

S* : Subsidy for production cost

dP = (S* + Tax) / P

Simulation results of the alternative scenario are provided in **Appendix 3.** For the base scenario, we can obtain effects on the price vector, $\mathbf{dP^I}$, from the equation (9).

Impacts on final demand and total output

Given sectoral price elasticity as above, change of final demand in nominal term ($dY_i P_i$) can be obtained as below:

$$dY_i P_i = \eta_i dP_i Y_i \quad (11)$$

$$\frac{dY_i}{Y_i} = \eta_i \frac{dP_i}{P_i}$$

Table 4 reports the simulation results on final demand change, given the base scenario for sectoral price change.

From I/O analysis, we know the relationship between final demand and total output. That is,

$$X = (I - A)^{-1} Y$$

Taking total derivative on both sides, we get

$$dX = (I - A)^{-1} dY .$$

With dY_i for each sector obtained above, we get the amount of total output change given price change scenario. Table 4 summarizes the result.

Import, Export Change and Change in Balance of Payment

As was derived in equation (10), we can get the price elasticity of import (η_i^{IM}) and export (η_i^{EX}) as follows:

$$\eta_i^D = \frac{dD_i}{dP_i}\frac{P_i}{D_i} = \frac{dD_i}{dP_4}\frac{dP_4}{dP_i}\frac{P_i}{D_i} \qquad \text{where}$$

$D = IMPORT(IM), EXPORT(EX)$.

From CGE model, we have the import and export change given 30% crude oil price increase (dD_i / dP_4) and base year values (P_i / D_i). I/O analysis gives us its price impact on other sectors (dP_i / dP_4) as in equation (9). As in equation (11), nominal change ($dD_i P_i$) of import and export with the given scenario is

$$dD_i P_i = \eta_i^D dP_i D_i$$

$$\frac{dD_i}{D_i} = \eta_i^D \frac{dP_i}{P_i}.$$

Table 5 summarizes the simulation results. The resulting change of import and export on balance of payment is 479,192 mil.. Won surplus. Decreasing import can be easily understood. But the small increases (51,378 mil. Won) could be better understood with a closer examination of export in 1995. Considering the fact that I/O analysis uses base year of 1995 figure and some abnormal composition of export at that period (sector 8-Textile mill products, apparel, & leather, sector 17- chemicals & chemical products, sector 21 -Electric & electronic equipment), their effect on export might have been exaggerated. For a better understanding of this topic, a further examination of CGE model is required. This, however, will be out of the scope of our research at this time.

VI. Conclusion

We have tried to link the CGE model and I/O analysis to calculate the impact of pricing policy changes in energy sectors on industrial production and final demand. CGE model approach can show us the simulation result of the specific economic policy with strong theoretical background. However, it requires burdensome computational cost for multiple policy packages. I/O analysis is very efficient in handling multiple scenarios in computation and building models. But it has very restrictive limit to show the effects on industrial production or final demand, because it uses a static and fixed coefficient approach.

We tried to link these two approaches, under some assumptions. It has a strong limit in interpretation for the true impacts of the pricing policy. But we can evaluate it as an approximation of the true ones. The base scenario was written by synthesizing pricing policy that has been recommended for a long time by professionals. The direct impact on price level of the energy price shock is about 0.127% weighed by the sectoral productions. After the inter-industrial interactions, the total impact on price level is about 0.829%. Sectoral price impact is high in energy intensive industries, like chemicals and chemical products, cement industry, steel industry. Final demand of the energy changes oppositely to the changes in prices, which is consistent with the economic theory. The impact of the energy price shock on final demand (GDP) is about -0.656%, and the impact on the total output (GDP and intermediate goods) is about –0.792%. Sectoral effects show considerable amount changes in the energy mix. After the adjustment like energy mix changes, the social cost of the energy price adjustment can be predicted as –0.656% in GDP loss.

The most important advantage of the energy price adjustment can be found in energy savings and fuel mix changes. The effects are summarized in the table 6. The impact of the energy price shocks on imports and exports are about -427,825 Mil. Won, and 51,378 Mil. Won, respectively. The resulting change of import and export on balance of payment is 479,192 Mil Won.

Table 4. Simulation Result: Final Demand and total output Change Given the Base Price Change Scenario (Unit: Million Won)

Industrial sector	η_i	$\mathbf{dP^I}$ (%)	$(dY_i/Y_i)*100$ % Change	$(dX_i/X_i)*100$ % Change
Agriculture, forestry, and fisheries	-1.03026	0.63124	-0.65034	-0.96158
Anthracite coal	0	1.31005	0	-1.59431
Bituminous coal	0	0.00000	0	-1.60403
Crude petroleum	0	0.00000	0	-2.20371
Natural gas	0.03260	0.00000	0	-4.72161
Quarrying	0	1.40139	0	-0.26361
Food & tobacco	-1.45473	0.65947	-0.95935	-0.93908
Textile, apparel, & leather	-1.57637	0.77414	-1.22033	-1.30538
Paper & wood products	-0.52169	1.10541	-0.57669	-0.85675
Coal products	-3.29568	0.59354	-1.95611	-0.53859
Gasoline	-0.27395	-5.01422	1.37367	0.66115
Kerosene	-0.11932	-3.23825	0.38639	-0.22736
Light oil	-0.11870	27.4974	-3.26393	-1.40785
Bunker-c oil	-0.10851	12.0192	-1.30418	-2.01586
Liquefied petroleum gas	-0.12092	-2.32513	0.28116	-1.23279
Other petroleum products	-0.13688	0.60901	-0.08336	-3.43656
Chemicals & chemical products	-12.0696	1.03552	-12.4984	-6.09142
Stone, clay, & glass products	-2.00368	1.56879	-3.14335	0.09235
Primary metal products	0	1.56416	0	0.46020
Metal products and machinery	1.20667	0.87578	1.05677	0.61305
Electric & electronic equipment	-0.34791	0.62834	-0.21861	-0.19161
Transportation equipment	0.15228	0.71463	0.10883	0.03017
Misc. manufactured products	-1.44008	0.70395	-1.01374	-0.87754
Electric power	-0.82282	15.4149	-12.6837	-3.78786
Piped gas supply	-1.00698	7.78942	-7.84378	-4.61899
Steam & hot water supply	-0.61809	4.35003	-2.68872	-3.53368
Construction	1.48908	0.73790	1.09879	0.90035
Wholesale, transportation, finance	-1.19924	0.70833	-0.84946	-0.80676
Public Adm. & other services	-0.22129	0.55921	-0.12375	-0.32928
Total		0.829	-0.65507	-0.79172

1) $\eta_i = \frac{dY_i}{dP_i}\frac{P_i}{Y_i} = \frac{dY_i}{dP_4}\frac{dP_4}{dP_i}\frac{P_i}{Y_i}$: Price elasticity of each sector

2) $\mathbf{dP^I} = (\mathbf{I} - \tilde{\mathbf{A}}')^{-1}\hat{\mathbf{A}}'\mathbf{dP}^E$: Price changes in each sector for the base scenario

3) $(dY_i/Y_i)*100$: Final demand change in each sector for the base scenario

4) $(dX_i/X_i)*100$: Total output change in each sector for the base scenario

Table 5 Simulation Results: Import and Export Change Given the Base Price Change Scenario. (Unit: Million Won)

Industrial sector	**dP^I^** (%)	η_i^{IM}	η_i^{EX}	$\frac{dIM}{IM}\times 100$ (%)	$\frac{dEX}{EX}\times 100$ (%)
Agriculture, forestry, fisheries	0.63124	-3.20093	1.0908	-0.02021	0.006886
Anthracite coal	1.31005	0	0	0	0
Bituminous coal	0.00000	-0.03795	0	0	0
Crude petroleum	0.00000	-0.10736	0	0	0
Natural gas	0.00000	-0.02649	0	0	0
Quarrying	1.40139	0.52642	-0.0510	0.007377	-0.00071
Food & tobacco	0.65947	-4.18737	0.6144	-0.02761	0.004052
Textile, apparel, & leather	0.77414	-1.85853	0.2553	-0.01439	0.001976
Paper & wood products	1.10541	-0.79839	0.2507	-0.00883	0.002771
Coal products	0.59354	-3.15626	0.4910	-0.01873	0.002914
Gasoline	-5.01422	-0.45915	-1.1588	0.023023	0.058105
Kerosene	-3.23825	-0.19998	-0.5047	0.006476	0.016343
Light oil	27.4974	-0.19894	-0.5021	-0.0547	-0.13806
Bunker-c oil	12.0192	-0.18186	-0.4590	-0.02186	-0.05517
Liquefied petroleum gas	-2.32513	-0.20267	-0.5115	0.004712	0.011893
Other petroleum products	0.60901	-0.22942	-0.5790	-0.0014	-0.00353
Chemicals & chemical prod.	1.03552	0.10780	-0.1759	0.001116	-0.00182
Stone, clay, & glass products	1.56879	1.90786	-0.1504	0.02993	-0.00236
Primary metal products	1.56416	0.72855	0.0687	0.011396	0.001075
Metal products and machinery	0.87578	0.07382	0.3841	0.000647	0.003364
Electric & electronic equip.	0.62834	-0.56661	0.4367	-0.00356	0.002744
Transportation equipment	0.71463	-1.27929	0.3846	-0.00914	0.002748
Misc. manufactured products	0.70395	-2.93702	0.4266	-0.02068	0.003003
Electric power	15.4149	-0.20381	-0.0310	-0.03142	-0.00478
Piped gas supply	7.78942	-0.27225	-0.2284	-0.02121	-0.01779
Steam & hot water supply	4.35003	-0.16711	-0.1402	-0.00727	-0.0061
Construction	0.73790	0	0.6263	0	0.004621
Wholesale, transport, finance	0.70833	-1.01529	0.1043	-0.00719	0.000739
Public Adm. & other services	0.55921	-1.24171	0.2199	-0.00694	0.00123
Total	0.829			-0.3678	0.0451

Table 6. Summary of Energy Saving: Energy Sectors changes given the Base Price Change Scenario (Unit: %)

Gasoline	0.66
Kerosene	-0.23
Light Oil	-1.41
Bunker–C Oil	-2.02
Liquefied Petroleum Gas	-1.23
Other Petroleum Products	-3.44
Electric Power	-3.79
Piped Gas Supply	-4.62
Steam and Hot Water Supply	-3.53

References

Armington, P., 1969, A Theory of Demand for Products Distinguished by Place of Production, IMF Staff Papers 16, 159-178.

Bank of Korea , 1990, 1993, 1995, Input Output Table (I,II).

Fullerton, Don, 1995, Why Have Separate Environmental Taxes?, presented at the NBER conference on Tax Policy and the Economy, Washington, D.C., Nov. 7.

Lynch, R.G., 1986, An Assessment of the RAS method for Updating Input-Output Tables, in Ira Sohn (ed.) Readings in Input-Output Analysis – Theory and Applications, Oxford Press.

Mathiesen, L., 1985, Computational Experience in Solving Equilibrium Models by a Sequence of Linear Complementary Problems, Operations Research 33, 1225-1250.

Mathiesen, L., Computation of Economic Equilibrium Models by a Sequence of Linear Complementary Problems, Mathematical Programming Study 23.

Melo, Jaime de and David Tarr, 1992, A General Equilibrium Analysis of US Foreign Trade Policy, London.

Sonn, Y.H. and D.C. Shin, 1997, The Impact of Changes in Exchange Rate on Energy Industry: Computable General Equilibrium Model of Korea, Korean Economic Review, 45 (1).

Sonn Y.H., 1999, The Macroeconomic Impacts of Importing Oil Price Changes in Korea : Computable General Equilibrium Model, Korea Resources Economics Review 8 (2).

Uri, N.D. and Roy Boyd, 1997, An Evaluation of the Economic Effects of Higher Energy prices in Mexico' Energy Policy, 25 (2).205-215.

Appendix 1 : Information on the 29 Sector Classification

Sector	Original I/O Sector Number(1995)
1	1101 1102 1103 1104 1105 1106 1107 1108 1109 1110 1111 1112 1113 1114 1115 1116 1117 1121 1122 1123 1124 1125 1131 1132 1133 1134 1141 1142 1143 1144
2	2101
3	2102
4	2111
5	2112
6	2121 2122 2123 2124 2131 2132 2133 2134 2135 2136 2137
7	3101 3102 3103 3104 3105 3106 3111 3112 3113 3114 3115 3121 3122 3123 3131 3132 3133 3134 3141 3142 3143 3151 3152 3153 3154 3155 3156 3161 3162 3163 3164 3165 3166 3171 3172 3173 3174 3175 3176 3177 3178 3181 3191
8	3201 3202 3203 3204 3205 3206 3207 3211 3212 3213 3214 3215 3216 3217 3218 3219 3221 3222 3223 3224 3225 3226 3231 3232 3233 3241 3242 3243 3244 3245 3246
9	3301 3302 3303 3304 3305 3306 3311 3312 3313 3314 3315 3316 3317 3318 3319
10	3501 3502
11	3512
12	3514
13	3515
14	3516
15	3517
16	3511 3513 3518 3519 3735
17	3601 3602 3603 3604 3611 3612 3621 3622 3631 3632 3641 3642 3643 3651 3652 3653 3661 3662 3663 3664 3665 3666 3667 3668 3671 3672 3673 3681 3682 3683
18	3701 3702 3703 3711 3712 3713 3714 3721 3722 3723 3731 3732 3733 3734 3736
19	3801 3802 3803 3811 3812 3813 3814 3815 3816 3817 3818 3819 3820 3831 3832 3833 3834 3835 3836 3837 3838
20	3901 3902 3903 3904 3905 3906 3907 3908 3909 3910 3911 4001 4002 4003 4004 4005 4006 4007 4008 4009 4010 4021 4022 4023 4024 4025 4026 4027 4028 4029
21	4101 4102 4103 4104 4105 4106 4107 4108 4111 4112 4113 4114 4115 4116 4117 4118 4121 4122 4123 4124 4125 4126 4131 4132 4141 4142 4143 4144 4145 4201 4202 4203 4204 4205 4206
22	4301 4302 4303 4304 4305 4306 4307 4311 4312 4313 4321 4322 4323 4324
23	3401 3402 3403 3404 4401 4402 4403 4411 4412 4413 4414 4415 4416 4417
24	5101 5102 5103 5104
25	5111
26	5112
27	5113 5201 5202 5203 5204 5205 5211 5212 5213 5214 5215 5216 5217 5218 5219 5220 5221 5222
28	6101 6102 6201 6202 6301 6302 6303 6304 6305 6306 6307 6308 6309 6310 6311 6312 6313 6401 6402 6403 6404 6405 6501 6502 6503 6504 6505 6601 6602 6603 6611 6612 6613 6614 6615 6616 6617 6618 6619 6620
29	6701 6702 6801 6802 6803 6804 6805 6806 6807 6811 6812 6813 6814 6815 6816 6817 6901 6902 6903 6904 6905 6906 6911 6912 6913 6914 6915 6916 6917 6918 8101 8111 8121

Appendix 2: Equation structure of the CGE Model

A. Price Block

(1) $PM_i = (1 + t_i)PWM_i$

(2) $E_i = E_0 \left[\frac{PWE_i}{PE_i} \right]^{QE_i}$

(3) $P_i X_i = PS_i XS_i + PM_i M_i$

(4) $PD_i XD_i = PS_i XS_i + PE_i E_i$

(5) $PD_i [1 - intr_i] = PVA_i V_i + \sum_{j=1}^{n} IO_{ji} P_j$

(6) $PCG \; CG = \sum_{i=1}^{n} P_i ID_i$

(7) $F(P_1, P_2, ... P_n) = \overline{P}$

B. Production Block

(8) $VA_i = AD_i [L_i^{b_i}, K_i^{1-b_i}]$

(9) $P_L L_i = b_i PVA_i VA_i$

(10) $P_K K_i = (1 - b_i) PVA_i VA_i$

(11) $VA_i = V_i XD_i$

(12) $XD_i = AT_i [q_i E_i^{r_i} + (1 - q_i) XS_i^{r_i}]^{\frac{1}{r_i}}$

(13) $\frac{E_i}{XS_i} = [\frac{PE_i}{PD_i} \frac{1 - q_i}{q_i}]^{\frac{1}{r_i - 1}}$

(14) $X_i = AC_i [d_i M_i^{-a_i} + (1 - d_i) XS_i^{-a_i}]^{-\frac{1}{a_i}}$

(15) $\frac{M_i}{XS_i} = [\frac{PD_i}{PM_i} \frac{d_i}{1 - d_i}]^{\frac{1}{1 + a_i}}$

C. Demand Block

(16) $IOT_j = \sum_{i=1}^{n} IO_{ji} XD_i$

(17) $P_i CD_i = c_i (1 - mps) Y$

$$(18)\ Y = (1 - dtr)(\sum_{i=1}^{n} PVA_i VA_i)$$

$$(19)\ HS = mps\,Y$$

$$(20)\ GR = TR + IDT + (\frac{dtr}{1 - dtr})Y$$

$$(21)\ P_i GD_i = g_i (GR - GS)$$

$$(22)\ TR = \sum_{i=1}^{n} t_i PWM_i M_i$$

$$(23)\ IDT = \sum_{i=1}^{n} intr_i PD_i XD_i$$

$$(24)\ GS = gmps\,GR$$

$$(25)\ ID_i = inr_i CG$$

$$(26)\ PCG\ CG = HS + GS + FS$$

$$(27)\ FS = (\sum_{i=1}^{n} PWM_i M_i) - (\sum_{i=1}^{n} PWE_i E_i)$$

D. Equilibrium Conditions

$$(28)\ X_i = IOT_i + CD_i + GD_i + ID_i$$

$$(29)\ \sum_{i=1}^{n} L_i = L^*$$

$$(30) K_i = K^*$$

E. Variables

PM_i	=	domestic price of imports,	t_i	=	tariff rate,
PWM_i	=	international price of imports,	PE_i	=	domestic price of exports,
PWE_i	=	international price of exports,	P_i	=	price of composite good,
PS_i	=	price of domestic good,	PD_i	=	price of sectoral GDP,
$\bar{P}$	=	aggregate price index,	PVA_i	=	price of value added,
PCG	=	price of capital good,	P_L	=	wage rate,
P_K	=	capital cost,	X_i	=	composite goods,
XS_i	=	domestic goods,	XD_i	=	sectoral output,
M_i	=	imports,	E_i	=	exports,
$intr_i$	=	indirect tax rate,	IO_{ij}	=	input output coefficients,
VA_i	=	value added,	L_i	=	labor demand,
K_i	=	capital demand,			

AD_i , b_i = parameters of value added function,
AT_i , q_i , r_i = parameters of CET function,
AC_i , d_i , a_i = parameters of Armington function
IOT_i = intermediate good demand, CD_i = consumption demand,
c_i = parameter of Cobb-Douglas utility function,
mps = marginal rate of saving, Y = disposable income,
dtr = direct tax rate, HS = household savings,
GR = government revenue, TR = tariff revenue,
IDT = total indirect tax, GS = government savings,
gmps = marginal rate of saving of government,

CG = capital good,
GD_i = government consumption,
g_i = parameter of Cobb-Douglas utility function of government,
ID_i = investment demand,
inr_i = Leontief coefficient of capital good,
TS = total savings, FS = foreign savings,
L^* = labor supply, K_i^* = capital supply in i industry.

Appendix 3. **Simulation Result: Final Demand and total output Change Given the Alternative Price Change Scenario (Unit: Million Won)**

Industrial sector	η_i	$\mathbf{dP^I}$ (%)	$(dY_i/Y_i)*100$ % Change	$(dX_i/X_i)*100$ % Change
Agriculture, forestry, and fisheries	-1.03026	0.83098	-0.85612	-0.99908
Anthracite coal	0	0.70655	0.00000	-0.67220
Bituminous coal	0	0.00000	0.00000	-0.67755
Crude petroleum	0	0.00000	0.00000	-1.95796
Natural gas	0.03260	0.00000	0.00000	0.05947
Quarrying	0	1.58274	0.00000	-0.10557
Food & tobacco	-1.45473	0.68840	-1.00144	-0.93887
Textile, apparel, & leather	-1.57637	0.64430	-1.01566	-1.07628
Paper & wood products	-0.52169	0.78472	-0.40939	-0.65102
Coal products	-3.29568	0.36710	-1.20983	-0.24312
Gasoline	-0.27395	9.50518	-2.60399	-1.98922
Kerosene	-0.11932	-19.52139	2.32929	0.95793
Light oil	-0.11870	44.19139	-5.24550	-1.71825
Bunker-c oil	-0.10851	12.30098	-1.33475	-1.34211
Liquefied petroleum gas	-0.12092	-2.48433	0.30042	-0.44247
Other petroleum products	-0.13688	0.64148	-0.08781	-2.42875
Chemicals & chemical products	-12.0696	0.70988	-8.56798	-4.23453
Stone, clay, & glass products	-2.00368	1.32859	-2.66207	0.14522
Primary metal products	0	0.85410	0.00000	0.36159
Metal products and machinery	1.20667	0.58115	0.70126	0.42142
Electric & electronic equipment	-0.34791	0.44898	-0.15620	-0.13262
Transportation equipment	0.15228	0.51341	0.07818	0.01082
Misc. manufactured products	-1.44008	0.57157	-0.82311	-0.73075
Electric power	-0.82282	4.57390	-3.76351	-1.56737
Piped gas supply	-1.00698	-2.08980	2.10438	0.05818
Steam & hot water supply	-0.61809	4.20834	-2.60115	-2.90410
Construction	1.48908	0.65676	0.97797	0.81326
Wholesale, transportation, finance	-1.19924	0.81520	-0.97762	-0.80018
Public adm. & other services	-0.22129	0.51487	-0.11394	-0.27007
Total		0.78392	-0.54150	-0.61879

1) $\eta_i = \frac{dY_i}{dP_i}\frac{P_i}{Y_i} = \frac{dY_i}{dP_4}\frac{dP_4}{dP_i}\frac{P_i}{Y_i}$: price elastisticity of each sector

2) $\mathbf{dP^I} = (\mathbf{I} - \tilde{\mathbf{A}}')^{-1}\hat{\mathbf{A}}'\mathbf{dP}^E$: price changes in each sector for the alternative scenario

3) $(dY_i/Y_i)*100$: final demand change in each sector for the alternative scenario

4) $(dX_i/X_i)*100$: total output change in each sector for the alternative scenario