에너지경제연구 제 11 권 제 1 호
Korean Energy Economic Review
Volume 11, Number 1, March 2012 : pp. 1~31

Economic Effects of Oil Price Shocks on Biodiesel Production: The Complementarity of Biodiesel and Petroleum

Jeong Hwan Bae*

Abstract

The increasing volatility of international crude oil prices has induced petroleum-addicted countries to increase the production of alternative fuels. In the initial stage of alternative fuel promotion, a careful institutional mechanism is crucial for the commercial success of alternative fuels. Koreahas successfully commercialized biodiesel as an alternative to petrodiesel. Most of the biodiesel distributed in Korea has been in the formof BD5 (blend of maximum 5% biodiesel), not BD20 (blend of 20% biodiesel and 80% petroleum diesel). Whereas BD5 is used as intermediate inputs to petrodiesel, BD20 is directly consumed by car drivers.

This study attempts to quantify the economic effects of increases in international oil prices on Korea's energy and biodiesel industry by using a small open computable general equilibrium (CGE) model for Korea. The results indicate that increases in oil prices would dramatically reduce GDP and consumer welfare. Biodiesel and petroleum production as well as the transportation sector could decline dramatically because biodiesel (BD5) would be consumed mainly as intermediate inputs to petrodiesel. These

* Assistant Professor, Department of Economics, Chonnam National University, 300, Yongbong-dong, Buk-gu, Gwangju, Korea, 500-757, Tel.: +82-62-530-1542; E-mail address: jhbae@jnu.ac.kr

results suggest that because the Korean economy is vulnerable to the volatility of crude oil prices, an independent and separate alternative fuel industry should be fostered to improve the substitutability of alternative fuels.

Key Words : Biodiesel, Volatility of oil price, Complementarity, CGE modeling
JEL Codes : Q42, Q48, Q54

1. Overview

After a period of technological demonstrations and on-site testing from 2002 to June 2006, the Republic of Korea (hereafter “Korea”) began commercially producing biodiesel. BD20(blend of 20% biodiesel and 80% petroleum diesel), which was used during the testing period, was found to be both technologically and institutionally inadequate for commercial use (Korean Research Association of Biodiesel, 2006). As a result, BD5 (blend of maximum 5% biodiesel) has been used by passenger car drivers, whereas BD20 has been used exclusively by truck and bus drivers who have their own garage for repair. In 2007, total biodiesel consumption was greater than 100,000 kiloliters, of which 99% was BD5. Because biodiesel is more expensive than petrodiesel, biodiesel blenders have been exempted from fuel taxes. In 2007, the exemption was 497~528 won[1)] per liter, which was about half the retail price of petrodiesel (Ministry of Commerce, Industry, and Energy, 2007). The total amount of tax exemptions for biodiesel was approximately 53~56 billion won in 2007.

1) The average exchange rate for 2007 was 929 KRW/USD.

Biodiesel has been promoted by the government because it is renewable, clean, and carbon-neutral and exhibits higher cetane, combustion efficiency, and biodegradability (Ma & Hanna, 1999; Speidel et al., 2000; Knothe et al., 2006). The push for biodiesel has also been driven by agricultural development and the diversification of transport fuels to address the upward volatility of crude oil prices (Faaij, 2006; Rejinders, 2006; Charles et al., 2007). Despite several disadvantages associated with its physical attributes, biodiesel is safe because of its high flash point, and the combustion of biodiesel is more efficient than that of petrodiesel (Prakash, 1998). It is well known that the most common blending ratio of biodiesel to petroleum is 20% (Demirbas, 2007). BD20 in a conventional diesel engine can dramatically reduce emissions of SO_2, CO, particulate matter, and volatile organic compounds (Morris et al., 2003).

By contrast, there has been increasing awareness of negative aspects of biofuel production, including reduced food security and environmental degradation (Anderson & Fergusson, 2006; Energy Intelligence, 2008) and the inefficiency of first-generation biofuels (van der Laaka et al., 2007). Recently, concurrent hikes in international crude oil prices and international prices of major grains such as soybeans, corn, and wheat have raised concerns over the government's policy supporting the promotion of first-generation biofuels, which use major grains as feedstocks (Charles et al., 2007). Moreover, previous studies have found that biofuels have limited role for replacing petroleum with respect to potential production possibility (Akinci et al., 2008), although others have presented contradictory findings (Mathews, 2007). Further, tropical forests have been deforested to increase the available land for producing feedstocks, which worsens climate change and destroys ecosystems for endangered species (UN-Energy, 2007).

The recent increases in the volatility of international crude oil prices have stimulated petroleum-addicted countries to accelerate the substitution of alternative fuels for fossil fuels. Korea, one of the major petroleum consumers in the world, plans to increase its production of biodiesel to 3% of its total transportation demand for petroleum diesel by 2012 and maintain the existing fuel tax exemption for biodiesel blends through 2010. One of the controversial issues surrounding the promotion of biodiesel is the growing demand for the extension of BD20. Advocates of BD20 have argued that low-blend biodiesel does not offer more environmental benefits than high-blend biodiesel (Demirbas, 2007) and that the former is a complement to petroleum diesel, which can reduce the demand for biodiesel when oil prices increase.

It is generally expected that the demand for alternative fuels would rise as oil prices increase. However, Tokgoz and Elobeid (2006) argued that the relationship between oil prices and ethanol consumption relies on the composition of vehicle fleets and demonstrated by partial equilibrium analysis using an international ethanol model that high gasoline prices are likely to reduce ethanol consumption in the U.S. run on gasoline blended with 10% ethanol, those in Brazil consist of vehicles running on gasohol (anhydrous ethanol) at the mandated blending ratio as well as FFVs (flex fuel vehicles) running on 85% ethanol and 15% unleaded gasoline (E85). Hence, because FFVs outnumber gasohol vehicles, ethanol is used more as a substitute for than as a complement to gasoline in Brazil.

In Korea, BD5 is provided mainly by petroleum firms, whereas BD20 is provided by biodiesel firms. However, BD20’s market share is less than 1%. This is because government regulates that general stations should not provide BD20 but only biodiesel firms satisfying rigorous requirements for opening BD20 stations should be allowed. BD5 is different from BD20 in several institutional aspects. First, BD5 is sold in general gas stations, whereas BD20 is delivered to a limited number of stations owned by biodiesel firms. In addition, drivers of general passenger cars are not allowed to purchase BD20 but only those drivers who have the ability to repair their own vehicle are allowed to buy BD20 (e.g., when vehicles running on petroleum diesel blended with BD20 have mechanical problems in cold winter). Second, according to the “Petroleum and Alternative Fuel Business Act,” BD5 is an additive to petroleum diesel, whereas BD20 is a substitute for petroleum diesel (Ministry of Commerce, Industry, and Energy, 2008).

Accordingly, as in the U.S., it is very likely that increases in oil prices would reduce biodiesel consumption in Korea because biodiesel is used as an intermediate input to petro-diesel. The purpose of this study is to investigate whether and how the increases of international crude oil prices will affect production of biodiesel applying a static computable general equilibrium (CGE) model for Korea combined with bottom up model on economic production costs of biodiesel. Furthermore, given that biodiesel is regarded as a complement to petroleum diesel, the present study examines the effects of international crude oil price shocks on various microeconomic variables related to the energy and biodiesel industries and explores the macroeconomic consequences.

Section 2 describes the overall structure of the CGE model for Korea, specifying the basic assumptions and equations. Section 3 presents data, calibration methods, and scenarios for the CGE modeling. Section 4 summarizes the simulation results for the counterfactual scenarios, and Section 5 presents the major findings and policy implications and concludes.

2. CGE Model

A static CGE model for Korea, a small open economy, was constructed to evaluate the impacts of international oil price shocks on industrial output, factor demand, prices, trade, and macroeconomic variables. CGE models have been widely used for quantifying the effect of government policies or external shocks on a specific economy (Ballard et al., 1985; Thissen, 1998).

There are several studies that examine economic impact of oil price shocks applying the CGE model. Doroodian and Boyd (2003) investigated whether oil price shocks are inflationary in the US. They simulated increases of oil prices consistent with the oil price shock of 1973~1974 and let the economy experience a Hicksian technological change. Applying a dynamic CGE model, they analyzed the oil price impact on gasoline and refinery prices, CPI and PPI for regular and low economic growth scenarios. Roeger (2005) examined the short and long run quantitative impact of a permanent oil price increase for output and inflation in the EU area employing an open economy DSGE (Dynamic Stochastic General Equilibrium) model, called as ‘QUEST’ model. The study showed that there is no severe inflation risk.

Concerning impact analysis of the oil price shock on the Korean economy, Lee et al. (2007) employed a global CGE model for different oil price changes (14%~71%). According to the results, GDP declined by 0.23~1.54%p, consumer price index inclined by 0.16~1.07%. Kim (2008) simulated Korean economic impact of high oil price increase scenario predicted by AEO (Annual Economic Outlook) report using the KEEI CGE model. For 2030, the GDP of Korea decreased by 1.03%, export declined but import increased for Korea.

Contrary to the previous studies, this study attempts to examine the impact of oil price shock on petroleum industry and other economic variables as well as renewable fuel industry such as biodiesel. In this regard, biodiesel industry explicitly entered the CGE model, which shows how the oil price shock would affect output, intermediate demand, and factor demands for biodiesel industry.

The benchmark data were drawn from the Korean input-output table for 2003. Industrial sectors were aggregated into 10 sectors: agriculture, livestock, feed, wood, petroleum, biodiesel, electricity, transportation, manufacturing, and services. A GAMS (General Algebraic Modeling System) / CONOPT solver was used to construct and simulate the CGE model.[2)]

In this study, the CGE model makes several assumptions with respect to the biodiesel industry. First, the model explicitly integrates data on economic production costs of biodiesel. Second, there exists only intermediate input demand for biodiesel (i.e., no final demand for biodiesel) because biodiesel is regarded as an additive to petroleum diesel. Third, biodiesel is assumed to be a complement to petroleum diesel because the CGE model assumes that only BD5 is used commercially. Finally, the model assumes that crude soybean oil, a major feedstock for biodiesel, is imported. Since the total amount of soybean oil for biodiesel is relatively small, soybean oil is aggregated into the agricultural sector in the model.

Although the CGE model has advantages in evaluating economic impacts of a government policy, it has several limitations. First, the model assumes a highly simplified aggregation scheme for industries, households, and the government, which may limit the model's ability to capture more realistic effects of external shocks. Second, the financial flow of the biodiesel sector depicted in the model does not represent the entire industry. Third, some of the important parameters, including the elasticity of substitution and the elasticity of transformation, may be dependent on external sources, and hence, a further research should estimate such parameters directly by using econometric measures.

2.1 Consumption

Household demand for commodity i (CD_i)is derived by maximizing the utility subject to disposable income(HH_{EXP}): labor income (LY) and capital income (CY)

2) As an alternative to the MINOS, the GAMS/CONOPT solver can address nonlinear problems. More information can be found in the GAMS website (www.gams.com/solvers).

less household savings (HH_{SAV}). Household consumption is determined by shares of the Cobb-Douglas utility function (θp_i), disposable income, and prices of the Armington combined commodity (PAi). Household savings are determined by share of household savings (θs_i) relative to total household (HHY).

Because owners of passenger cars are not allowed to buy BD20 in general gas stations and over 99% of biodiesel produced in 2007 was used as additives to petroleum, this study assumes no household consumption in the biodiesel sector, and thus, only the intermediate demand for biodiesel is reflected in the model:

$$CD_i = (\theta p_i / PA_i) HH_{EXP} \quad (1)$$

$$HH_{EXP} = HHY - HH_{SAV} \quad (2)$$

$$HHY = LY + CY \quad (3)$$

$$HH_{SAV} = \theta s_i HHY \quad (4)$$

2.2 Production

Producers in a competitive market maximize profits, which are constrained by the Cobb-Douglas production technology. Output (Y_i) is a function of technological progress coefficient (αv_i), labor demand (LD_i), and capital demand (KD_i). From this maximization problem, labor demand (LD_i) and capital demand (KD_i) for industry I are derived. LDi is determined by net value-added prices (PF_i), the labor income share (θL_i) of total revenues, and the total output (Y_i) and wage (PL) of industry i. KD_i is a function of the net value-added price, the capital income share(θK_i) of total revenues, and the total output and capital price (PK) of industry i. Intermediate input demand for industry i is determined by sum of Leontief input-output coefficient ($lc_{j,i}$) for sector j and output level. Value-added prices are determined by output prices, production tax rates, input-output coefficients, and Armington commodity prices (PA_j).

$$Y_i = \alpha v_i LD_{i_i}^{\theta L_i} KD_{i_i}^{\theta L_i} \, (\theta L_i + \theta K_i = 1) \tag{5}$$

$$LD_i = PF_i \, \theta L_i \, Y_i / PL \tag{6}$$

$$KD_i = PF_i \, \theta K_i \, Y_i / PK \tag{7}$$

$$MD_i = \sum_{j=1}^{n} lc_{j,i} \, Y_i \tag{8}$$

$$PF_i = PY_i (1 - tyr_{i)} - \sum_{j=1}^{n} (lc_{j,i} \, PA_{j)} \tag{9}$$

2.3 Trading

A composite Armington good (A_{im})of an industry, except for the biodiesel sector (im), is formulated from the Constant Elasticity of Substitution (CES) function, where domestic and imported commodities are treated as the "input" (Ballard et al., 1985). This composite Armington good reflects the imperfect substitution between domestically produced commodities and imported ones (Armington, 1969). Import demand (M_{im}) and domestic demand (D_{im}) are determined through the cost minimization of the composite Armington commodity (A_{im}) subject to the CES technology (Equation 10). Coefficients such as and are calibrated while elasticities (σ_{im}) of substitution are given from exogenous data.

Relative ratio of import demands and domestic demands are determined by relative ratios of domestic prices (PDD_{im}) and import prices (PM_{im}), and elasticity of substitution as shown in Equation (11).

On the other hand, domestic products are sold to domestic as well as foreign consumers. Firms maximize the output of commodity i (Y_{im}) subject to the CET (Constant Elasticity of Transformation) function reflecting the imperfect substitution between domestic demand and export demand(X_{im}) (Equations 12). Coefficients such as at_{im} and γ_{im} are determined by calibration while elasticity of transformation (τ_{im}) are given by exogenous data. Relative ratio of export demands and domestic demands are determined by relative ratio of export prices and domestic prices, and elasticity of transformation (Equation 13).

$$A_{im} = ac_{im}\left[\delta_{im} M_{im}^{(\sigma_{im}-1)} + (1-\delta_{im}) D_{im}^{\frac{\sigma_{im-1}}{\sigma_{im}}}\right]^{\sigma_{im}/(\sigma_{im}-1)} \tag{10}$$

$$\frac{M_{im}}{D_{im}} = \left[\frac{PDD_{im}}{PM_{im}}\right]^{\sigma_{im}}\left[\frac{\delta_{im}}{1-\delta_{im}}\right]^{\sigma_{im}} \tag{11}$$

$$Y_{im} = at_{im}\left[\gamma_{im} X_{im}^{\frac{(\tau_{im}+1)}{\tau_{im}}} + (1-\gamma_{im}) D_{im}^{\frac{(\tau_{im}+1)}{\tau_{im}}}\right]^{\frac{\tau_{im}}{\tau_{im}+1}} \tag{12}$$

$$\frac{X_{im}}{D_{im}} = \left(\frac{PX_{im}}{PDD_{im}}\right)^{\tau_{im}}\left(\frac{\gamma_{im}}{(1-\gamma_{im})}\right)^{\tau_{im}} \tag{13}$$

The production structure of composite Armington goods of the biodiesel sector (zm) is different from that of other sectors because all imported goods are regarded as the "intermediate" demand (MM_{zm})for biodiesel production [Figure1]. In the other industries, Armington goods consist of “final” imported goods and domestically produced goods (Figure 2).

Figure 1 Production structure of the biodiesel sector

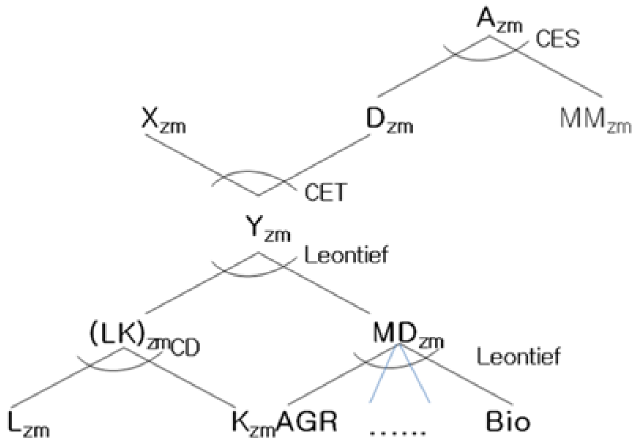
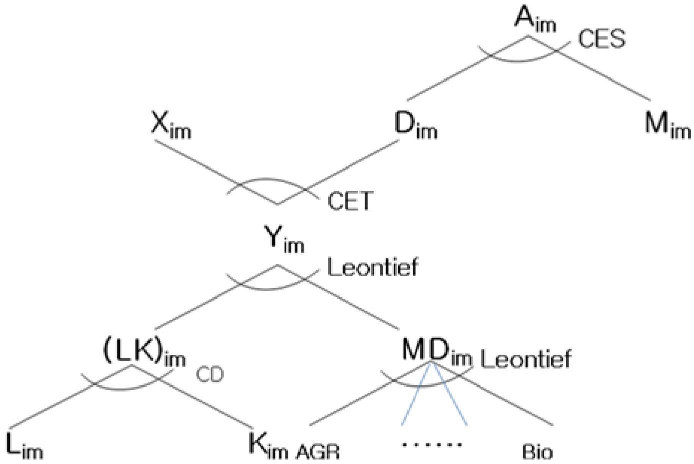


Figure 2 Production structure of industrial sectors (except for the biodiesel sector)



In addition, there is no import or export of biodiesel in the model, and there is a technological barrier. Although biodiesel firms meet international standards such as EN14214 or ASTM-D6751 (Van Gerpen et al., 2004), monopsonic petroleum firms require the distillation of biodiesel (which is yellow) for its decolorization. The distillation process makes it difficult for biodiesel firms to make profits because of the high cost of the distillation process. Thus, it has been difficult for foreign biodiesel firms to meet Korea's stringent biodiesel standards.

2.4 Government

Although Korea imposes various taxes, including capital and labor income taxes and value-added taxes, the model assumes that government revenues (GOV_{REV}) consist of production taxes (tyi) and import tariffs (tm_i) for simplicity and that government expenditure(ED_i) is determined by the government expenditure share(θ_g), government revenue, and the price of the composite Armington good i:

$$GOV_{REV} = \sum_{i}^{n}(tm_i + ty_{i)} \tag{14}$$

$$ty_i = tyr_i \cdot PY_i \cdot Y_i, tm_i = tmr_i \cdot M_i \tag{15}$$

$$GD_i = \theta_g GOV_{REV} / PA_i \tag{16}$$

$$GOV_{sav} = (1 - \theta_g) \cdot GOV_{REV} \tag{17}$$

2.5 Investment

Investment supply (IS) is composed of household savings (HH_{sav}), government savings (GOV_{sav}), and exogenous savings (EXO_{sav}); investment demand (ID_i) is determined by the investment share(θ_{inv}), output, and the price of the composite Armington commodity i; and exogenous savings are determined by the difference between total investment demand and the sum of household and government savings in order to balance investment demand and supply:

$$IS = HH_{SAV} + GOV_{SAV} + EXO_{SAV} \qquad (18)$$

$$ID_i = (\theta_{inv} Y_i)/PA_i \qquad (19)$$

$$EXO_{SAV} = \sum_i^n ID_i - HH_{SAV} - GOV_{SAV} \qquad (20)$$

2.6 Market equilibrium conditions

In the commodity market, a composite Armington commodity of industry i is the sum of intermediate demand, household demand, investment demand, and government demand for commodity i. In the investment market, total investment demand is the sum of household, government, and exogenous savings. In terms of the balance of the factor market, total labor supply is the sum of the labor demand of industries, and total capital supply is the sum of the capital demand of industries. In terms of the balance of trade, the sum of import demand should equal the sum of export and foreign savings.

$$A_i = MD_i + CD_i + ID_i + GD_i \qquad (20)$$

$$\sum_i^n ID_i = HH_{SAV} + GOV_{SAV} + EXO_{SAV} \qquad (21)$$

$$LS = \sum_i^n LD_i, KS_i = \sum_i^n KD_i \qquad (22)$$

$$\sum_i^n M_i = \sum_i^n X_i + ROW_{SAV} \qquad (23)$$

2.7 Macro-closure rule

It is necessary to match the number of equations with the number of endogenous variables in the model to close the model (Sen, 1963). The total number of equations was 193, and that of endogenous variables was 206. Because the model was under-identified, 13 of the 206 endogenous variables were converted into fixed variables under the default assumption of macroeconomic balances[3] (Lofgren et al., 2002): total labor supply (1), total capital supply (1), foreign savings (1), foreign exchange (1), and world export prices(9).

Following the neo-classical assumption, total investment demand equals whatever is saved (Swan, 1970), and macroeconomic variables such as GDP and the consumer price index do not affect total employment (Lofgren et al., 2002).

3. Data, Calibration and the Scenario

3.1 Data and calibration

The data[4] for constructing a CGE model for Korea were drawn from the Korean input-output table for 2003 (Bank of Korea, 2008), and the production cost of biodiesel was determined based on financial reports submitted by 12 biodiesel firms in Korea (Korean Biodiesel Association, 2007). Industries were aggregated into 8 sectors from 77 industrial sectors in the original input-output

3) The IFPRI's standard CGE model makes default assumptions about macroeconomic balances such as the government balance, the external balance, and the savings-investment balance. For more information, the reader is referred to Lofgren et al. (2002).

4) SAM (Social Accounting Matrix) for this model can be found in the appendix.

data. In addition to the 8 sectors, the biodiesel industry was added to the aggregated input-output table by rebalancing the sums of rows and columns of each transaction, following the rebalancing method suggested by Rutherford and Paltsev (1999). The standard industrial code (SIC) for each production cost item of the biodiesel industry is shown in Table 1.

Table 1. Industrial Classification of Biodiesel Production Costs

Biodiesel Production Cost Items	*Corresponding SIC in the Input-Output Table*	*Value (Million KRW)*
Soybean Imports	Agriculture	61,135
Methanol	Manufacturing and Services	4,761
Other Catalysts		2,489
Conversion		6,402
Labor and Administration	Labor	5,253
Transportation	Transportation	2,618
Profits	Capital	4,213
Byproduct Credits		7,358
Depreciation		1,915
	Total	96,143

According to the benchmark data, GDP was 767 trillion won, which was approximately equal to total expenditure (763 trillion won). The aggregated intermediate demand and final demand of households were 974 trillion won and 449 trillion won, respectively. Total value added, which includes labor income, capital income, and production taxes, was approximately 767 trillion won. Total imports and exports were 255 trillion won and 272 trillion won, respectively. Import tariffs and excise taxes were 6.9 trillion won and 6.3 trillion won, respectively. Livestock and feed products had the highest import tariff rates (17.5% and 11.4%, respectively). The petroleum industry had the highest production tax rate (27.4%).

Other sources of data included the elasticity of substitution between imports and domestic goods and that of transformation between exports and domestic goods.[5] The elasticity of biodiesel was not included because there were no trade data on the biodiesel industry.

The shift and share parameters of production and demand－Armington and CET functions－were calibrated by solving the target parameters for endogenous variables with initial values and external parameters [Table 2].

Table 2. Elasticity of substitution/transformation

sector	*Elasticity of substitution between imports and domestic goods**	*Elasticity of transformation between exports and domestic goods***
Agriculture	0.5	0.729
Livestock	1.8	0.729
Wood	1.4	0.729
Feed	2.0	0.729
Petroleum	1.4	0.31
Electricity	0.4	3.476
Transportation	1.9	0.85
Manufacturing & Services	0.4	1.04

Source: * The elasticity was modified from the GTAP (Hertel, 1998) and Jung (2001);
** the elasticity was modified from Jung (2003))

5) Sensitivity analysis on the CES and CET parameters showed that macro variables are affected significantly by the changes in these parameters. Although it is important to estimate theses parameters for this reason, the estimation itself remains an independent research for further study.

3.2 Scenarios

The simulation involved three scenarios. The first scenario assumed that there was a small increase in the international crude oil price. Consumer welfare and GDP were quantified to determine how the whole economy would respond to the external shock. Consumer welfare was quantified using a compensating variation (CV). The CV can be measured throughout the difference between expenditure function before the oil price shock and that after the oil price shock as shown in the following formula.

$$CV_h = M_h(Pa_i^1, V_h(Pa_i^1, HH_{\mathrm{EXP}}^1)) - M_h(Pa_i^1, V_h(Pa_i^0, HH_{\mathrm{EXP}}^0)) \qquad (24)$$

Hereby, M_h is expenditure function for household h, Pa_1 is price of a Armington combined good i, V_h is indirect utility function for household h, HH_{EXP} is a household disposable income which is equal to the household expenditure. The superscript 0 denotes a condition before the change (oil price shock) and the superscript 1 stands for the condition after the change.

Similar to the first scenario, moderate and high oil prices were simulated in the model. Increases of 10%, 30%, and 50% in international crude oil prices corresponded to small, medium, and large oil price shocks, respectively.

4. Results

4.1. Production

As international oil prices increased by 10%, 20%, and 30%, the decline in the absorption (the sum of domestic demand and import demand) was sharper for the petroleum, transportation, and biodiesel sectors than for the other sectors. Among the energy sectors, the electricity sector was affected the least. The overall impact patterns in the output level for most of the industries were similar to those in the absorption level. Noteworthy is that the output of the transportation sector was affected more severely than absorption of it by the increase in crude oil prices. This implies that the import demand from the transportation sector may increase because domestic prices of transportation services are less competitive than those in other countries. In the next section, we discuss this issue in greater detail. Absorption and output of agriculture, wood, and manufacturing & service sectors increase slightly. This result can be interpreted as a result of substitution effects among energy intensive sectors and energy less intensive sectors. This intuition will be clarified in comparison between consumer demands and intermediate demand changes in section 4.2.

An increase in international oil prices leads to an increase in the production cost of petroleum, resulting in higher production costs in the transportation sector. Consequently, the demand for petroleum as well as transportation is likely to fall as well. On the one hand, decreases in the demand for transportation are likely to reduce the demand for biodiesel. On the other hand, decreases in petroleum demand are likely to depress the demand for biodiesel as an additive to petroleum.

Therefore, as long as biodiesel is used as an additive to petroleum, it is unlikely to substitute for petroleum when international oil prices are high [Table 3].

Table 3. Effects of oil price shocks on the absorption and output (% Change)

Item	Absorption			Output		
Oil price shock	10%	20%	30%	10%	20%	30%
Agriculture	0.02	0.02	0.02	0.04	0.08	0.11
Livestock	-0.06	-0.13	-0.20	-0.05	-0.11	-0.17
Feed	-0.05	-0.10	-0.17	-0.04	-0.10	-0.16
Wood	0.01	0.02	0.02	0.02	0.04	0.04
Petroleum	-3.57	-6.37	-8.63	-5.39	-9.45	-12.62
Electricity	-0.05	-0.11	-0.17	-0.05	-0.11	-0.17
Transportation	-0.32	-0.64	-0.95	-0.38	-0.76	-1.15
Manufacturing & Service	0.04	0.08	0.11	0.05	0.09	0.12
Biodiesel	-0.38	-0.77	-1.15	-0.38	-0.77	-1.16

4.2 Consumer Demand and Intermediate Demand

Consumer demand decreased for all commodities as the price of imported oil increased, while the intermediate demands except for the petroleum, biodiesel, transportation, feed sectors increased slightly. As oil prices increase, consumers reduce demands for all commodities as household income decreases due to the fall of wages and capital prices with holding total labor and capital supply. Meanwhile, there are substitution effects among intermediate demands for different sectors, which lead to increases in the intermediate demand for sectors such as agriculture, livestock, wood, and manufacturing and services.

There was no change in consumer demand for the biodiesel sector because it was assumed that there was no final demand for biodiesel. The decrease in the intermediate demand for biodiesel was between 0.38%~1.15%. As the final demand for petroleum declined by 10.45%~26%, the intermediate demand for biodiesel as an additive to petrodiesel declined slightly. The results suggest that biodiesel remains as a complement to petrodiesel and that increases in oil prices would not lead to the substitution of biofuels for petroleum [Table 4].

Table 4. Effects of oil price shocks on the final demand and the intermediate demand (% Change)

Item	*Consumer Demand*			*Intermediate Demand*		
Oil price shock	10%	20%	30%	10%	20%	30%
Agriculture	-0.09	-0.18	-0.28	0.04	0.08	0.11
Livestock	-0.42	-0.85	-1.28	0.01	0.02	0.02
Feed	-0.28	-0.56	-0.85	-0.04	-0.09	-0.15
Wood	-0.61	-1.21	-1.81	0.03	0.06	0.08
Petroleum	-10.45	-18.95	-26.00	-2.26	-3.97	-5.32
Electricity	-0.02	-0.12	-0.36	-0.06	-0.11	-0.15
Transportation	-1.47	-3.04	-4.63	-0.12	-0.22	-0.31
Manufacturing & Service	-0.62	-1.24	-1.86	0.02	0.04	0.06
Biodiesel	-	-	-	-0.38	-0.77	-1.15

4.3 Primary Factor Demand

Labor demand and capital demand of the livestock, feed, petroleum, electricity, transportation, and biodiesel sectors declined. Without a doubt, substantial declines in the output and final demand associated with these sectors led to such decreases in primary factor demand. The biodiesel sector ranked second in terms of job losses and decreases in capital demand. Interestingly, for most sectors (except for manufacturing/services), the decline in labor demand was slightly greater than that in capital demand [Table 5].

Table 5. Effects of oil price shocks on labor demand and capital demand (% Change)

Item	*Labor Demand*			*Capital Demand*		
Oil price shock	10%	20%	30%	10%	20%	30%
Agriculture	0.01	0.02	0.03	0.05	0.09	0.12
Livestock	-0.07	-0.15	-0.22	-0.03	-0.08	-0.14
Feed	-0.08	-0.15	-0.23	-0.04	-0.09	-0.14
Wood	0.00	0.00	0.00	0.04	0.07	0.09
Petroleum	-5.42	-9.50	-12.68	-5.38	-9.44	-12.60
Electricity	-0.09	-0.16	-0.24	-0.05	-0.10	-0.15
Transportation	-0.39	-0.79	-1.19	-0.36	-0.73	-1.10
Manufacturing & Service	0.03	0.06	0.08	0.07	0.12	0.17
Biodiesel	-0.40	-0.80	-1.20	-0.36	-0.74	-1.12

4.4 Macroeconomic Variables

The simulation results indicate that increases in crude oil prices can have negative effects on the macro variables of Korean economy. All of the macro variables are nominal. Korea’s GDP fell by 0.09%~0.24%, aggregated final consumption of households declined by 0.65%~1.94%, the consumer price index rose by 0.4%~1.3%, and consumer welfare declined by 4.21 trillion won to 12.3 trillion won. This indicates that the increase in the consumer price index (as a result of higher oil prices) led to the decrease in final consumption. The diminishing final demand had a negative impact on the overall output level, which led to decreases in primary factor demand. The adverse effects of decreases in the final demand as well as primary factor demand resulted in dramatic declines in consumer welfare and GDP [Table 6].

Table 6. Changes in macroeconomic variables from high crude oil prices (*%change,trillion won)**

Oil price shock	GDP*	Aggregated household expenditure*	Laspayres price index*	Consumer welfare**
10%	-0.09	-0.65	0.42	-4.21
20%	-0.17	-1.30	0.86	-8.3
30%	-0.24	-1.94	1.32	-12.3

5. Conclusions

This study examined the economic effects of increases in crude oil prices on energy and non-energy industries by paying close attention to Korea's biodiesel industry. A static CGE model for a small open economy was developed to quantify the effects of international oil price shocks on the economic relationship between various industries' supply and demand sides.

The results obtained using the proposed CGE model have several important implications. First, increases in oil prices can devastate the industrial output, primary factor demand, final demand, intermediate demand, and imports/exports of the petroleum and transportation industries. Korea depends completely on imported petroleum to fuel its transportation sector. Thus, the petroleum and transportation sectors are the sectors most likely to be affected by increases in petroleum prices. Second, the CGE modeling shows that there exist substitution effects among energy intensive (petroleum, electricity, transport, and biodiesel) and less intensive industries (agriculture, wood, other manufacturing and services). It is supposed that there will be substitution effects within the other manufacturing and services. But we did not disaggregate the other manufacturing and services more specifically because those sectors are not the objectives of interests for this study.

Third, the macroeconomic variables indicate that the Korean economy is vulnerable to high crude oil prices and that increases in oil prices can reduce Korea's GDP and consumer welfare considerably. However, any interpretation of this result should be grounded in reality. The average price of crude oil (Dubai) was $26.8 per barrel in 2003, but it climbed to $68.4 in 2007 (Korea Energy Economics Institute, 2008). However, despite the 255% increase in the crude oil price, the Korean economy did not experience an economic recession during this period. In fact, the Korean economy grew 5% in 2007, outperforming the 3.1% increase in 2003. It is likely that there are dynamic factors that influence the flexibility of the Korean economy, making it more resilient to the volatility of crude oil prices. Therefore, the proposed model may overestimate the macroeconomic response to increases in crude oil prices.

Finally, the results indicate that the biodiesel sector is not likely to replace the petroleum sector. Increases in crude oil prices reduced the biodiesel sector's total absorption, output, intermediate demand, and primary factor demand. This is because biodiesel serves as a complement (intermediate input) to petroleum. The primary reason behind subsidizing biodiesel is the "substitution effect" of biodiesel for petrodiesel. This substitution can occur in the initial stage of biodiesel commercialization, but the simulation results show that the substitutability can be overpowered by complementarity when oil prices increase.

Ultimately, Korea's biodiesel promotion policy should take into account the extensive penetration of BD20 as a substitute for petrodiesel. Up to now, over 99% of biodiesel which has been produced in Korea enter as intermediate demand of petroleum industry. Therefore there is no way of avoiding complementarity effect between petroleum and biodiesel industries. However, as BD20 can be released throughout sales to the final consumers, substitution effect between the two sectors is expected. Further, in terms of its alternative fuel policy, providers of alternative fuels should be given the blending responsibility, and passenger car drivers should be allowed access to alternative fuels. For further study, it would be necessary to consider comparing the economic impacts of the high oil price shock when BD20 can replace BD5 in the CGE model. Besides, more sophisticated disaggregation scheme should be considered in order to reflect substitution effects between energy intensive industries and others in the manufacturing and service sector.

접수일(2012년 1월 10일), 수정일(2012년 2월 28일), 게재확정일(2012년 3월 14일)

◎ References ◎

Akinci, B., Kassebaum, P., Fitch, J.V., and Thompson, R.W., 2008. The role of bio-fuels in satisfying US transportation fuel demands. Energy Policy 36, 3485-3491.

Anderson, G.Q.A., Fergusson, M.J., 2006. Energy from biomass in the UK: sources, processes and biodieversity implications. Ibis 148, 180-183.

Armington, P., 1969, A theory of demand for products distinguished by place of production. IMF Staff Papers, vol. 16. Washington.

Ballard, C.L, Fullerton, D., Shoven, J.B., and John Whalley, 1985. A General Equilibrium Model for Tax Policy Evaluation. The University of Chicago Press.

Bank of Korea, 2008. Input-Output table for 2003. <http://ecos.bok.or.kr/>

Charles, M. B., Ryan, R., Ryan, N., and Oloruntoba, R., 2007. Public Policy and Biofuels: the way forward?. Energy Policy 35, 5737-5746.

Demirbas, A., 2007. Importance of biodiesel as transportation fuel. Energy Policy 35, 4661-4670.

Doroodian, K, Boyd, R., 2003, The linkage between oil price shocks and economic growth with inflation in the presence of technological advances: a CGE model, Energy Policy 31, 989-1006.

Energy Intelligence, 2008. Biofuels: fuels of the future? . <http://www.energyintel.com/DocumentDetail.asp?document_id=240795>

Faaij, A.P.C., 2006. Bio-energy in Europe: changing technology choices. Energy Policy 34(3), 322-342.

Freeman, A. M., 1999. The measurement of environmental and resource values: Theory and methods. Resources for the Future, Washington. D.C.

Hertel, T. ed, 1998, GTAP Database, Purdue University.

Ignaciuk, A. M. and R. B. Dellink, 2006. Biomass and Multi-product Crops for Agricultural and Energy Production-an AGE Analysis. Energy Economics 28: 308-325.

Jung, I., G., 2001. The strategic importance and economic impacts of Korea-Japan free trading agreement. Presented in trading conference between Korea and Japan held in Hukuoka (SRP).

Jung, J.H., Sung, M.J., Lee, M.H., 2003. Measures to improve import tariff system in Korea: applying a general equilibrium model. Korea Tax Institute.

Kim, S. I., 2008, Implication and impact of oil price increases on trading structure in Korea, Position Paper 08-05, Korea Energy Economics Institute.

Lee, W. O., Lee, D.S., Park, G. S., Lim, J. G., Lee, M. B., Lee, S.I., Park, Y.D., Oh, S.S., 2007, Implication and impact of era of $100 of international oil price, Position Paper 07-07, Korea Energy Economics Institute.

Knothe, G., Sharp, C.A., Ryan, T.W., 2006. Exhaust emissions of biodiesel, petrodiesel, neat methyl esters, and alkanes in a new technology engine. Energy and Fuels 20, 403-408.

Korea Energy Economics Institute, 2008. Year book of Energy Statistics 2007. Ministry of Commerce, Industry, and Energy.

Korean Research Association of Biodiesel, 2006. Evaluation of on-site practices of biodiesel as transport fuels in Korea. Korea Institute of Petroleum Quality.

Lofgren. H., Rebecca Lee Harris, and Sherman Robinson, 2002, A Standard Computable General Equilibrium(CGE) Model in GAMS. International Food Policy Research Institute (IFPRI).

Ma, F., Hanna, M.A., 1999. Biodiesel production: a review. Bioresource Technology 70, 1-15.

Mathews, J.A, 2007. Biofuels: what a biopact between North and South could achieve. Energy Policy 35, 3550-3570.

Ministry of Commerce, Industry, and Energy, 2007. Projection of economic feasibility of biodiesel and policy suggestion. Korea Energy Economics Institute.

Ministry of Commerce, Industry, and Energy, 2008. Petroleum And Alternative Fuel Business Act. <http://www.law.go.kr/LSW/PrecInfoP.do?precSeq=64849>

Morris, R.E., Pollack, A.K., Mansell, G.E., Lindhjem, C., Jia, Y., Wilson, G., 2003. Impact of biodiesel fuels on air quality and human health. Subcontractor Report, NREL/SR-540-33793, National Renewable Energy Laboratory, Golden, CO.

Prakash, C.B., 1998. A critical review of biodiesel as a transportation fuel in Canada. A Technicla report, GCSI-Global Change Strategies International Inc. Canada.

Rejinders, L., 2006. Conditions for the sustainability of biomass based fuel use. Energy Policy 34, 863-876.

Roeger, W., 2005, International oil price changes: impact of oil prices on growth and inflation in the EU/OECD, International Economics and Economic Policy 2, 15-32.

Rutherford, T. and Paltsev, S., 1999. From an Input-Output table to a general equilibrium model: Assessing the excess burden of indirect taxes in Russia. Working Paper, Department of Economics, University of Colorado.

Sen, A., 1963. Neo-classical and neo-Keynesian theories of distribution. Economic Record, 53-64.

Shoven, J. and John Walley, 1992. Applying General Equilibrium. Cambridge University Press.

Speidel, H.K., Lightner, R.L., Ahmed, I., 2000. Biodegradability of new engineered fuels compared to conventional petroleum fuels and alternative fuels in current use. Applied Biochemistry and Biotehcnology 84-86, 879-897.

Swan, T., 1970. Golden ages and production functions. in A. Sen (ed.). Growth Economics. Penguin Books, Harmondsworth, England, 203-218.

Thissen, M., 1998. A classification of empirical CGE modeling. SOM Research Report 99C01, University of Groningen, Groningen, The Netherlands.

Tokgoz, S. and Elobeid, A., 2006. An analysis of the link between ethanol, energy, and crop markets. Working Paper 06-WP 435, Center for Agricultural and Rural Development, Iowa State University <www.card.iastate.edu.>

Townsend, B. and Ravi Ratnayake, 2000. Trade Liberalization and the Environment: A Computable General Equilibrium Analysis. World Scientific, USA.

UN-Energy, 2007. Sustainable bioenergy: a framework for decision makers. United Nations.

Van der Laaka, W.W.M., Raven, R.P.J.M., Verbong, G.P.J., 2007. Strategic niche management for biofuels: analyzing past experiments for developing new biofuel policies. Energy Policy 35, 3213-3225.

Van Gerpen, J., Shanks, B., Pruszko, R., Clements, D., Knothe, G., 2004. Biodiesel production technology. NREL/SR-510-36244, National Renewable Energy Laboratory.

Varian, H.R., 1992. Microeconomic Analysis. W.W.Norton & Company, Inc. U.S.A.

<Appendix> Benchmark data for the CGE model

Sector	AGR	LIVE	WOOD	FEED	PET	ELEC	TRAN
AGR	448,255	525,607	8,262	1,168,976	0	0	0
LIVE	73,358	10,859,488	1,554	58,511	0	0	0
WOOD	475,993	672,273	8,950,173	42,214	6,287	1,836	55,017
FEED	0	4,273,715	0	82,252	0	0	0
PET	269,533	979,746	429,756	23,532	29,023,830	1,772,383	10,491,567
ELEC	107,284	227,319	623,381	33,134	343,619	1,293,081	368,789
TRAN	32,194	813,554	874,342	303,760	499,158	122,841	8,243,353
OTHER	4,717,913	5,755,884	6,981,693	1,605,922	2,562,277	8,625,558	15,275,175
BIO	0	0	0	0	0	0	88,785
subtotal	6,124,530	24,107,586	17,869,161	3,318,301	32,435,171	11,815,699	34,522,686
wage	1,362,749	2,591,043	3,786,304	236,675	1,017,831	2,234,360	16,061,169
net profit	15,006,219	2,724,695	3,003,875	779,982	2,063,484	5,398,538	6,118,912
depreciation	1,246,236	1,023,333	1,143,943	179,794	1,046,298	5,194,544	5,645,295
production tax	452,137	616,569	832,943	7,000	13,803,025	970,634	-30,054
gross value added	18,067,341	6,955,640	8,767,065	1,203,451	17,930,638	13,798,076	27,795,322
total input	24,191,871	31,063,226	26,636,226	4,521,752	50,365,809	25,613,775	62,318,008

Sector	OTHER	BIO	intermediate demand	Household demand	Government demand	fixed capital	change in stocks
AGR	15,994,955	61,135	18,146,055	11,175,972	0	44,029	-376,977
LIVE	9,283,909	0	20,276,820	15,066,170	0	118,466	598,934
WOOD	14,765,343	0	24,969,136	3,315,596	0	1,710,759	-85,631
FEED	152,039	0	4,508,006	122,032	0	0	-5,555
PET	33,338,524	0	76,328,871	12,052,046	0	0	699,198
ELEC	17,159,483	0	20,156,090	5,474,392	0	0	0
TRAN	23,115,904	2,618	34,005,106	16,823,848	0	254,926	43,746
OTHER	730,050,318	13,651	775,574,740	384,929,050	82,456,919	226,970,288	1,807,467
BIO	0	7,358	96,143	0	0	0	0
subtotal	843,860,475	84,762	974,060,967	448,959,106	82,456,919	229,098,468	2,681,182
wage	321,335,499	5,253	348,625,630				
net profit	202,460,696	4,213	237,645,186				
depreciation	87,210,369	1,915	102,689,812				
production tax	61,365,263	0	78,017,517				
gross value added	672,371,827	11,381	766,978,145				
total input	1,516,232,302	96,143	1,741,039,112				

Sector	export	sum of final demand	total demand	import	tariff	excise tax	total supply
AGR	232,447	11,075,471	29,221,526	4,615,958	407,887	5,810	24,191,871
LIVE	1,465,100	17,248,670	37,525,490	5,500,444	935,209	26,611	31,063,226
WOOD	2,525,805	7,466,529	32,435,665	5,547,805	162,037	89,597	26,636,226
FEED	12,816	129,293	4,637,299	103,759	4,687	7,101	4,521,752
PET	10,113,439	22,864,683	99,193,554	45,179,699	825,128	2,822,918	50,365,809
ELEC	44,040	5,518,432	25,674,522	60,747	0	0	25,613,775
TRAN	18,324,936	35,447,456	69,452,562	7,134,554	0	0	62,318,008
OTHER	239,360,424	935,524,148	1,711,098,888	186,990,936	4,539,465	3,336,185	1,516,232,302
BIO	0	0	96,143	0	0	0	96,143
subtotal	272,079,007	1,035,274,682	2,009,335,649	255,133,902	6,874,413	6,288,222	1,741,039,112
wage							
net profit							
depreciation							
production tax							
gross value added							
total input							

요 약

유가 충격이 바이오디젤 생산에 미치는 경제적 영향 : 바이오디젤과 석유의 상호보완성을 중심으로

배 정 환*

2000년대 들어 국제유가의 지속적인 상승은 석유 의존적인 국가들의 대체연료 개발을 촉진시켜왔다. 석유에 대한 대체연료 개발의 초기 단계에서 상업적 성공을 거두기 위해서는 제도적인 장치가 잘 갖추어져야 한다. 우리나라는 디젤에 대한 대체연료인 바이오디젤의 상업화에 성공한 국가라고 할 수 있다. 현재 바이오디젤 생산의 99%는 디젤에 대한 첨가제로 규정되어 있는 BD5이고, 정유사에서 공급 책임을 지고 있다. 반면에 BD20은 바이오디젤 회사가 직접 최종소비자에게 판매할 수 있지만 전체 생산량의 1%에 불과하다.

본 연구는 연산가능일반균형모형을 이용하여 국제 유가의 상승이 국내 에너지 산업과 바이오디젤 산업에 미치는 경제적 효과를 살펴봄으로써 바이오디젤이 석유 제품에 대한 대체 역할을 하고 있는지를 분석하였다. 분석 결과 BD5의 형태로 바이오디젤이 보급되고 있는 상태에서는 국제 유가 상승시 바이오디젤이 석유에 대한 대체재가 아닌 보완재의 역할을 하는 것으로 나타났다. 주로 석유, 수송, 바이오디젤, 전력 부문 등 에너지 부문의 감소 효과가 크게 나타났고, 일반 제조업 및 서비스업과 같은 비에너지 부문의 경우 대체효과로 인해 소폭 생산이 증가하는 것으로 나타났다. 결론적으로 BD5와 같이 석유와 보완적인 관계를 갖는 제품보다는 BD20와 같이 석유와 대체적인 관계를 갖는 제품이 많이 유통되도록 하는 제도 개선이 필요함을 제시하였다.

주요 단어 : 바이오디젤, 유가의 변동성, 보완성, CGE 모델링

경제학문헌목록 주제분류 : Q42, Q48, Q54

* 전남대학교 경영대학 경제학부 조교수. Tel.: +82-62-530-1542;
E-mail address: jhbae@jnu.ac.kr