Application of Price-Elastistic Supply Input-Output Model on the Economic Impacts of Hurricanes Katrina and Rita: Disruption in U.S. Oil-Industry

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Abstract

Recent Hurricane Katrina and Rita caused severe economic cessations without expectations in Louisiana State. The natural disasters temporarily produced quantity losses in oil-industry and lead to further economic losses via interindustrial relations. In a sense that oil industry plays a key role to support national economy, estimation of the economic impacts of the disasters should be based on the supply-driven input-output (IO) model. However, common limitation in IO models is over-estimate total impacts in a relatively long-term duration due to the linear characteristics of IO coefficients. Empirically, we observe consumers change their behaviors as price changes. The price change would follow price elasticity as well as quantity changes in the market. Therefore, by constructing a new supply-driven model using price elasticity of demand for oil refinery, that is, price-elastistic supply-driven model, this study will analyze the national economic impacts of disrupted oil-industry due to Hurricane Katrina and Rita. This price-elastistic supply-driven model is a temporal expansion of supply-driven IO study. This study, also, has an important implication in the aspect that it is the first empirical application of price-type supply-driven model for the U.S.

I. Introduction

Economic impact analyses on various natural disasters have been studied actively. Especially, we experienced a severe tragedy from Hurricanes on New Orleans in August 2003, which reminds us the importance of preparation once again; what should have been prepared to reduce the damages from similar previous experiences? As a part of answers on the question, certainly we can reduce the chained damages with our efforts, although it is not easy to block the nature's attacks on our community perfectly. The endeavors include tied-communications between all participants in our community, physical repairs of frail places through checking regularly, express-operation activity from federal and local government, and so on. However, with what can we prepare those necessary activities?

The estimation of economic impacts on the disasters has been played a key role in implementing federal tax and distributing necessary resources to the public. Because the economic models estimating the economic losses from historical disasters of certain regions serve to distribute appropriate resources of federal and local governments to the targeted region, many social and regional scientists have interested in and contributed to developing an appropriate economic model. Certainly, the economic models provide base information on preventing and mitigating a disaster occurred from the disruption of communities and residents of the targeted region. To estimate appropriate impacts, hence, the economic model should be well designed to estimate the actual damages from a disaster onto the region.

In the sense, this study involves two issues. One is to introduce a new national input-output model combined with price elasticity of demand. Another investigates the U.S. economic impacts from the recent huge natural disasters of hurricanes Katrina and Rita, based on the price elasticitic supply-driven IO model.

The rest of this paper includes the introduction of the issues and results in the previous study of economic impacts analyses from the Hurricanes Katrina and Rita. In the third section, the price-elastistic supply-driven IO model for the U.S. and the data for the elastistic model are explained. Based on the model, results of this study are addressed. Also, the conclusions and remarks are followed.

II. Issues

Recent hurricanes Katrina and Rita caused severe economic cessations without expectations in Louisiana state. Holtz-Eakin (2005) stated the direct capital losses from the hurricanes Katrina and Rita ranged from $70 billion to $130 billion. According to Louisiana federal reimbursement report, the losses are estimated up to $115 billion (Kent, 2006). Another estimate is conducted by National Hurricane Center (2007) and reporting $92.3 billion damages from the two hurricanes.

However, those economic impacts do not count for the economic interrelations, although many direct economic losses lead to further economic losses via interindustrial and interstate relations. Using spatially disaggregate Input-Output model, Park et al. (2006) reported total economic losses, including direct and indirect losses, resulted from the shut-down of New Orleans port during seven months as $62.1 billion. Further, Kim et al. (2007) addressed the economic impacts from the hurricane disasters in oil-refinery industry as $4.8 billion for 13 months disruptions, based on temporarily and spatially extended Input-Output (IO) model.

Certainly, to estimate the economic impact more accurately, it is important to construct better model able to examine the interindustry connections.

Before introducing a new IO model addressing the interindustry connections reflecting behaviors of consumers, it would be necessary to address following issues that help to understand the limited conditions of the IO analysis.

- Can regional specific direct losses resulted from a disaster extend to the national direct losses?
- Can the suggested economic model address regional and/or temporal (industrial) substitution effects?
- Do the disturbances from a disaster have forward or backward industrial linkage effects? That is, which model is more appropriate between supply- or demand- driven model?

To observe the first issue, it is necessary to overview the economic effects of two hurricanes on the U.S. economy. Based on the GDP data, the economic situations of the U.S. are overviewed historically. As seen in Table 1, the real GDPs (constrained to 2000 dollars) of the U.S. are consistently increasing from 2002 to 2005. Similarly, all regions during the identical periods show the same patterns as the U.S. However, while the real GDPs of Louisiana increased until 2004, the GDP of Louisiana between 2004 and 2005 decreased by 1.49 percent. Also, we can observe that the GDP proportions which Louisiana takes out of the U.S. are small and decreasing from 1.3 percent (on 2002) to 1.23 percent (on 2005).

However, the small GDP proportion of Louisiana is not applicable to the Mining sector. Second and third column in Table 2 show ‘Top 10’ states which take high real GDP in the U.S.

for the Mining sector, where 'Mining' industry including 'Oil' industries. Three states, e.g. Texas, Louisiana, and New Mexico among the states in Gulf of Mexico (that is, Petroleum Administration for Defense District III) are ranked at the first, second, and seventh respectively, taking over 50 percent of the U.S. Mining industry. Although Texas is the largest state of GDP for 'Mining' industry, the GDP of 'Mining' industry of Louisiana is decreased most severely in the U.S., showing 13.7 percent decrease.

Table 1. Changes of Real GDP (millions of chained 2000 dollars) and the changes of proportions to the U.S. of each region, Louisiana state, and the U.S.: 2002-2005

	2002		**2003**		**2004**		**2005**	
Region and State	GDP ($M)	Percent	GDP ($M)	Percent	GDP ($M)	Percent	GDP ($M)	Percent
NEW ENGLAND	568,750	5.70%	581,648	5.68%	605,270	5.68%	619,138	5.61%
MIDEAST	1,851,979	18.55%	1,887,783	18.44%	1,961,319	18.40%	2,017,731	18.27%
GREAT LAKES	1,553,618	15.56%	1,592,373	15.55%	1,624,738	15.24%	1,645,095	14.90%
PLAINS	650,187	6.51%	669,180	6.54%	691,650	6.49%	707,446	6.41%
SOUTHEAST	2,183,214	21.87%	2,249,395	21.97%	2,355,601	22.09%	2,464,520	22.32%
SOUTHWEST	1,072,012	10.74%	1,094,165	10.69%	1,147,570	10.76%	1,207,473	10.94%
ROCKY MOUNTAIN	320,931	3.22%	327,997	3.20%	344,138	3.23%	362,199	3.28%
FAR WEST	1,781,052	17.84%	1,834,540	17.92%	1,931,577	18.12%	2,016,757	18.27%
Louisiana	129,740	1.30%	131,625	1.29%	137,524	1.29%	135,474	1.23%
U.S.	9,981,850	100.00%	10,237,201	100.00%	10,662,196	100.00%	11,041,471	100.00%

Notes 1. Source: U.S. Bureau of Economic Analysis

2. Definition of Regions:

a. NEW ENGLAND: Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont

b. MIDEAST: Delaware, District of Columbia, Maryland, New Jersey, New York, and Pennsylvania

c. GREAT LAKES: Illinois, Indiana, Michigan, Ohio, and Wisconsin

d. PLAINS: Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, and South Dakota

e. SOUTHEAS: Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Virginia, and West Virginia

f. SOUTHWEST: Arizona, New Mexico, Oklahoma, and Texas

g. ROCKY MOUNTAIN: Colorado, Idaho, Montana, Utah, and Wyoming

h. FAR WEST: Alaska, California, Hawaii, Nevada, Oregon, Washington

Total decreased value of GDP of the U.S. for the Mining sector is $2.8 billion. The Gulf of Mexico region takes over 74 percent of the U.S. decrease of Mining sector. The decreases of the U.S., therefore, can be explained by the natural disasters of the Hurricanes Katrina and Rita occurred sequentially in 2004. In the sense, the effect of the two Hurricanes on Oil industries are not constrained to the Gulf of Mexico, but extended to the national event (BEA, 2005). That is, the temporary losses of oil production and refinery capacity resulted from the Hurricanes Katrina and Rita made affection to the losses of U.S. oil capacity. Because Oil industries are critically connected to other industries, the production losses of the U.S. requests to examine the economic impacts extended to other relative industries via inter-industry relationships (Park et al., 2006; Kim et al., 2007).

Table 2. Top 10 states taking high proportions out of the U.S. for the Mining sector: 2004-2005[3)]

States	Real GDP constrained to 2001 ($M.)[1)]		Proportions of Real GDP to the U.S.[2)]			Change in Real GDP by State: 2004-2005[2)]	
	2004)	2005	2004	2005	Difference	Value ($M.)	Percentage
Texas	40657	40259	37.50%	38.11%	0.61%	-398	-0.98%
Louisiana	11090	9569	10.23%	9.06%	-1.17%	-1521	-13.72%
Oklahoma	6372	6870	5.88%	6.50%	0.63%	498	7.82%
Alaska	5468	4911	5.04%	4.65%	-0.39%	-557	-10.19%
California	5220	4759	4.81%	4.50%	-0.31%	-461	-8.83%
Wyoming	4207	4169	3.88%	3.95%	0.07%	-38	-0.90%
New Mexico	4300	4158	3.97%	3.94%	-0.03%	-142	-3.30%
Colorado	4122	4143	3.80%	3.92%	0.12%	21	0.51%
West Virginia	2862	2874	2.64%	2.72%	0.08%	12	0.42%
Kentucky	2243	2298	2.07%	2.18%	0.11%	55	2.45%
U.S.	108415	105641	100.00%	100.00%	0.00%	-2774	-2.56%

Notes 1) U.S. Bureau of Economic Analysis.
2) The author calculated. Although the 'Oil sector', which is a sub-sector of the 'Mining sector', reflects the changes better, the data for 2005 are not available until Jun., 2007.

Also, as seen in Table 2, the real GDP of other states outside Gulf coasts are changed differently; Alaska and California are negatively changed, while Oklahoma is positively changed in real GDP between 2004 and 2005. To include all regional substitutions after the disasters to the analysis of economic impact, I used the national input-output (IO) model, which called USIO consisting of 47 USC industry sectors shown in Table A1 of Appendix (29 commodity sectors and 18 service sectors; see Park et al. (2007) for more detail on the sector description).

Further, in a sense that oil industry plays a key role to support national economy by providing energy, the interindustrial economic impacts from the oil-refinery disruptions due to the disasters should be estimated with forward linked industrial connections, instead of backward connections. Most previous efforts have focused on constructing various demand-driven IO models because of their widely accepted usefulness in regional science. After Ghosh's suggestion of the supply-driven IO model, a debate over its plausibility ensued (Oosterhaven, 1988; 1989). Much of this was resolved with Dietzenbacher's (1997) suggestion of the interpretation of a price model, equivalent to Leontief's price model.

Although there has been a debate on the inoperability of supply-driven model, however Park (2007) shows that it is still appropriate to use the supply-driven IO model when analyzing indirect impacts from the direct losses of monetary value. In static market equilibrium, producers will not change the current technical relationships that are based on historical sales during the immediate period after an exogenous event. This reflects the fact that Ghosh's supply-driven model is in terms of monetarily expressed quantities and hence applicable when using the supply-side IO in the circumstance of static market equilibrium with abnormal economic cessations. Based on the static market equilibrium condition, Park (2006) and Park et al. (2006) tested the economic impacts on closures of major ports due to hypothetical dirty-bomb attacks or Hurricane Katrina.

Although the applications are still useful, even in the case that normal market equilibrium is not maintained, instead of the direct use of supply-side quantity model, Ghosh's (1958) case can be switched to a price-type supply-driven model, and play a role in estimating economic impacts. To address this switching process, exogenous price elasticities of demand are combined with the supply-driven model, adjusting quantity responses to price impacts. This study adopted the Park's (2007) logic underlying the theoretical background necessary to utilize the supply-side model.

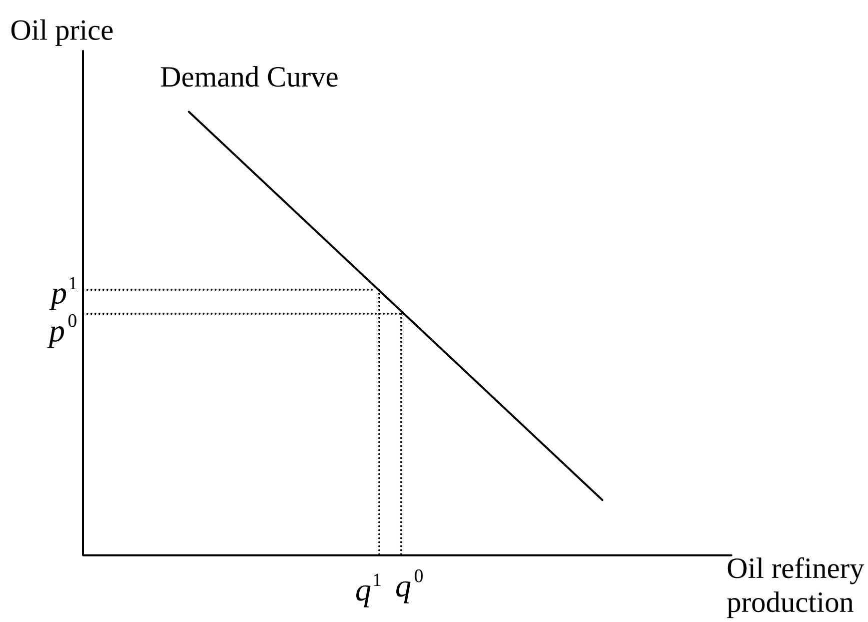
Common limitation in traditional IO models is over-estimate total impacts in a relatively long-term duration due to the linear characteristics of IO coefficients. Recently, Park (2007) addressed a new approach to expanding the supply-driven IO model by combining price elasticity of demand. The suggestion is useful to overcome the IO limitation, because the expanded model can reflect resilient effects conducted by consumers resulted from a disaster. Hence, this study adopt a new supply-driven model using price elasticity of demand only for oil refinery, that is, price-elastistic supply-driven model, in order to analyze the national economic impacts of disrupted oil-industry due to Hurricane Katrina and Rita. This price-elastistic supply-driven model is not only a temporal expansion of supply-driven IO study, but also the first empirical application of price-type supply-driven model for the U.S. Based on these conditions and limitations, a new model is suggested in the next section.

III. Model and Data

III-1. Model

The most rigorous limitation in IO models is a fixed coefficients characteristic which provides over-estimate total impacts in a long-term. The fixed coefficients assumption ignores the reaction of market system via flexible behaviors of suppliers and consumers. Of course, market power can be maintained during some short-term if behaviors in market expect a disaster would exist shortly, and hence, the fixed coefficients assumption is still useful. However, if a disaster were expected to exist in long-run period, market equilibrium would adjust following the market signal, that is, price. In the case, the direct use of Input-Output model might overestimate the interindustrial effects (Park, 2007).

Figure 1. Oil price changes due to Oil-refinery production losses, following fixed (average) price elasticity.



As shown in Figure 1, the losses of oil refinery production $\Delta q (= q^1 - q^0)$ due to Hurricane Katrina and Rita would increase oil price, following the demand curve. Then, new market equilibrium is temporarily decided at the new price p^1, where consumers' demands are reflected. Introducing exogenous price elasticity of demand ($\bar{\varepsilon}_p$) will make demand curve linear, and hence, the changes of monetary quantity and price on demand curve will convert the traditional quantity-type demand-driven models in equation (1.) and (2.) to a price-type supply-driven model as shown in equations (3.) and (4.).

$$\mathbf{X^s}^{\mathbf{T}} = \mathbf{A}\mathbf{X^s}^{\mathbf{T}} + \mathbf{Y} \tag{1.1}$$

$$= (\mathbf{I} - \mathbf{A})^{-1}\mathbf{Y} \tag{1.2}$$

where, $\mathbf{X^s}$ denotes the monetary value row vector of total inputs (outlays) for each sector and its elements are expressed as x_j^s, which is the row sum of intermediate flows and value added factors of sector j. In the market equilibrium, the transpose of $\mathbf{X^s}$ ($\mathbf{X^s}^{\mathbf{T}}$) equals to total outputs vector, $\mathbf{X^d}$.

$\mathbf{Y}$ includes various kinds of final demands for industry sector i. The element y_{ik} denotes the deliveries in dollar values from industry sector i to final users k. Generally, k contains private consumers, governments, investments, and exports.

$\mathbf{A}$ is the technical coefficient matrix of intermediate interindustry flows. The element a_{ij} denotes the proportional deliveries in dollar's worth from industry sector i to j.

Superscript $\mathbf{T}$ denotes the transpose of the matrix.

Hence, the total impacts according to the direct losses of final demands for the oil industry would be obtained via,

$$\Delta\mathbf{X}^{s^{\mathbf{T}}} = (\mathbf{I} - \mathbf{A})^{-1}\Delta\mathbf{Y}_{\mathbf{oil}} \tag{2.}$$

From the equation (2.), price-type input-output model are obtained as,

$$\Delta\mathbf{X}^{s^{\mathbf{T}}} = [\mathbf{I} - \hat{\mathbf{X}}^{s^{\mathbf{T}}}\mathbf{B}(\hat{\mathbf{X}}^{s^{\mathbf{T}}})^{-1}]^{-1}\Delta\mathbf{Y}_{\mathbf{oil}} \tag{3.1}$$

$$= \hat{\mathbf{X}}^{s^{\mathbf{T}}}(\mathbf{I} - \mathbf{B})^{-1}(\hat{\mathbf{X}}^{s^{\mathbf{T}}})^{-1}\Delta\mathbf{Y}_{\mathbf{oil}} \tag{3.2}$$

where, $\mathbf{A} = \hat{\mathbf{X}}^{s^{\mathbf{T}}}\mathbf{B}(\hat{\mathbf{X}}^{s^{\mathbf{T}}})^{-1}$, because $\mathbf{X}^{s^{\mathbf{T}}} = \mathbf{X}^{\mathbf{d}}$.

Hence,

$$(\hat{\mathbf{X}}^{s^{\mathbf{T}}})^{-1}\Delta\mathbf{X}^{s^{\mathbf{T}}} = (\mathbf{I} - \mathbf{B})^{-1}(\hat{\mathbf{X}}^{s^{\mathbf{T}}})^{-1}\Delta\mathbf{Y}_{\mathbf{oil}}\,, \tag{4.1}$$

and

$$\Delta\mathbf{P}^{s^{\mathbf{T}}} = (\mathbf{I} - \mathbf{B})^{-1}\Delta\mathbf{P}^{\mathbf{Y_{oil}}} \tag{4.2}$$

Because the price elasticity of demand for oil industry sector, ε_p^{oil}, is defined as $\dfrac{\delta q^{oil} / q^{oil}}{\delta p^{oil} / p^{oil}}$,

where $q^{oil} = x_{oil}^s$, the price change δp^{oil} is obtained based on the exogenous price elasticity of demand $\bar{\varepsilon}_p^{oil}$ as,

$$\delta p^{oil} = \frac{\delta q^{oil} / q^{oil}}{\bar{\varepsilon}_p^{oil} / p^{oil}} \tag{5.1}$$

$$= \frac{\delta q^{oil} p^{oil}}{\bar{\varepsilon}_p^{oil} q^{oil}} \tag{5.2}$$

$$= \delta q^{oil} \pi^{oil} \tag{5.3}$$

where $\pi^{oil} = \dfrac{p^{oil}}{\bar{\varepsilon}_p^{oil} q^{oil}}$ is exogenous for oil industry sector. It is relatively easier to find the fixed p^{oil} and q^{oil} right before the event than to find the exogenous price elasticity of demand.

As Dietzenbacher (1997) noticed, in the case of price increases, there is no reason to split where the price increases of oil refinery product, e.g. from final demand sectors or intermediate products, because final users should pay for all increased prices in any cases. Therefore, the price increases of oil refinery products would be assumed as price increases of final users.

Therefore, based on the equations (4.) and (5.), the vector of derived total (relative) price changes $\Delta\tilde{\mathbf{P}}^{s\,\mathbf{T}}$ are obtained as,

$$\Delta\tilde{\mathbf{P}}^{s\,\mathbf{T}} = (\mathbf{I}-\mathbf{B})^{-1}\Delta\mathbf{Q}^{\mathbf{oil}}\mathbf{\Pi}^{\mathbf{oil}} \tag{6.}$$

where, $\Delta\mathbf{Q}^{\mathbf{oil}}$ is a vector only including oil industry quantity losses, δq^{oil}, for the USC sectors, and $\mathbf{\Pi}^{\mathbf{oil}}$ is a exogenous vector involving valid π^{oil}.

III-2. Data

Figure 2 shows total oil-refinery products pattern for the U.S. by month for 29 months between April 2004 and September 2006. The simple comparison for the identical months between the Window 04 and Window 05 shows that the former window doesn't include the serious disruptions due to a hurricane while the latter window involves serious quantity losses due to Hurricanes Katrina and Rita. Since 2006, the U.S. oil refinery production certainly seems to be recovered to the status right before the disasters occurred. Based on the figures, I assume that the U.S. oil-refinery products had disruptions only for last four months of 2005.

Table 3 shows the summary of input data necessary to estimate the total output vector $\Delta\tilde{\mathbf{P}}^{s\,\mathbf{T}}$. First, I used separate the oil-refinery products into five types: Finished Motor Gasoline, Kerosene-Type Jet Fuel, Distillate Fuel Oil, Residual Fuel Oil, and Propane (Commercial use), in order to calculate the amount of q^{oil}. To estimate price decreases of oil industry (USC sector 10) later for consumption types, I classified those oil-refinery types combining with consumption sector, based on the petroleum consumption note available at the http://www.eia.doe.gov/emeu/states/sep_use/notes/use_petrol.pdf. From the classification, I distribute ‘Distillate’ and ‘Residual’ Fuel Oil to four-consumption types; residential, commercial, industrial and transportation, based on 2003 proportions from ‘Adjusted Sales of Fuel Oil by End Use’ available at the http://tonto.eia.doe.gov/dnav/pet/pet_cons_top.asp. Therefore, the vector q^{oil} by consumption sector and oil-refinery type is suggested in the third column of Table 3.

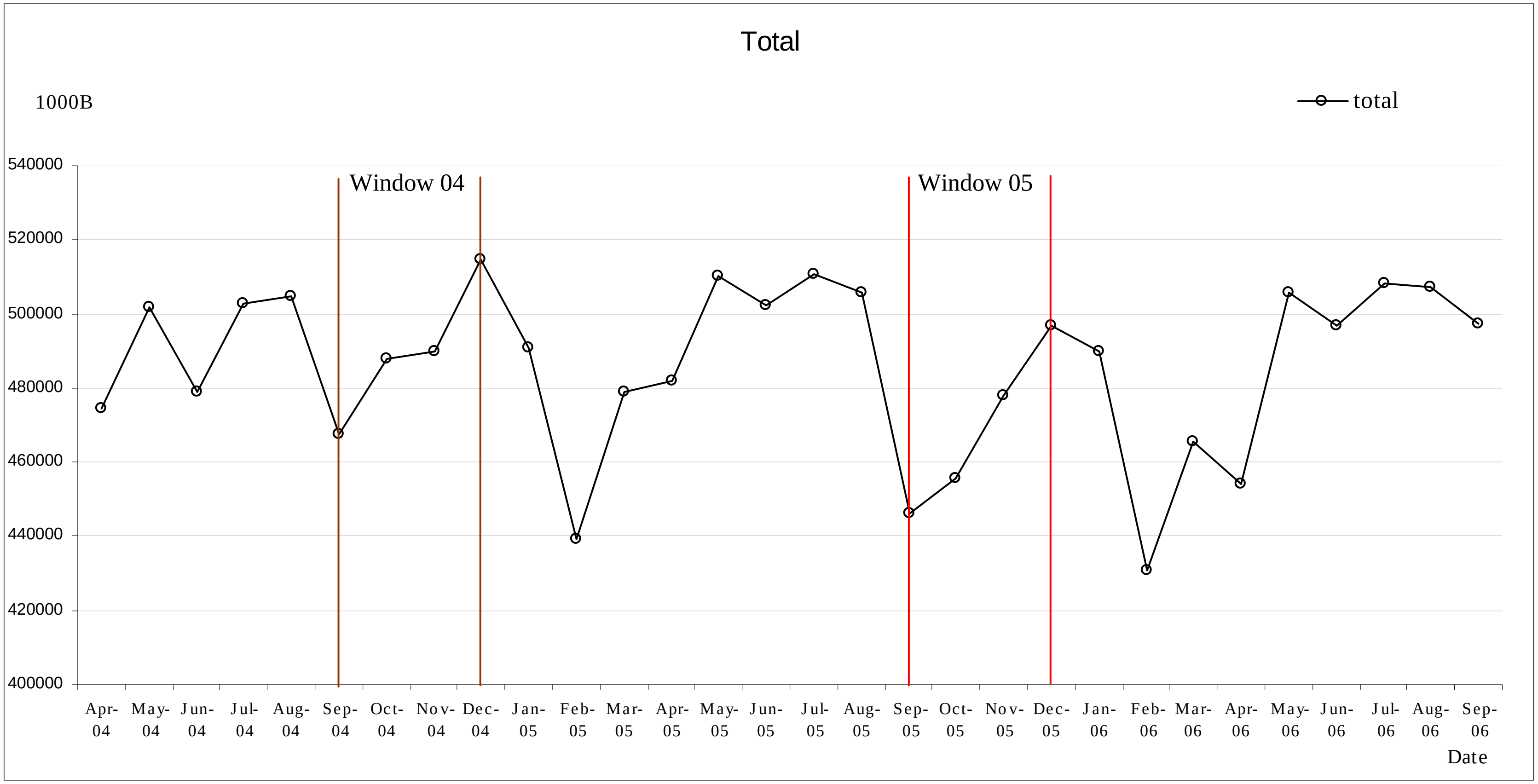
Second, the fourth column vector p^{oil} is calculated as average prices using the monthly prices between January through July of 2005, which exclude the Hurricanes effects. Those prices only depend on oil-refinery type.

Third, I obtained price elasticities of demand, $\bar{\varepsilon}_p^{oil}$, by consumption type from the http://www.eia.doe.gov/smg/asa_meeting_2004/fall/files/exe/Elasticity%20Estimates.htm. Then, using the definition of π^{oil} suggested in equations (5.), I calculated the column vector of π^{oil}.

Fourth, I forecasted the δq^{oil} with Holter-Winters method for last four months of 2005 for each oil-refinery production type. The statistical results are shown in Table A2 of Appendix. The results are statistically acceptable, because Theil’s U is close to 0 (Maddala, 1977). After then, I distribute the direct quantity losses with the same proportions as used in calculating the q^{oil}.

Finally, based on the equation (5.3), the vector δp^{oil} is estimated. Also, the weighted δp^{oil} s , which are multiplied by the weight obtained from the proportions of the δq^{oil} to the sum of δq^{oil}, are suggested in the last column. The sum of the element in column vector of δp^{oil} would be total price increase due to oil-refinery disruptions, reflecting economic behaviors in the U.S. market. Therefore, the total price-type direct losses on the U.S. oil market due to the two Hurricanes would be \$5.1534 per barrel, that is, \$1.23 per gallon.

Figure 2. Total Oil Refinery Production for the U.S. by Month: April 2004 through September 2006



Source: Author' calculations of raw data from EIA official website (http://tonto.eia.doe.gov/dnav/pet/pet_pnp_wiup_dcu_r30_w.htm)

Table 3. Data Summary Necessary to Estimate Total Output Vector

Consumption Sector	Oil-Refinery Product Type	q^{oil}	p^{oil}	$\bar{\varepsilon}_p^{oil}$	π^{oil}	δq^{oil}	W[2]	δp^{oil}	W* δp^{oil}
Transportation	Finished Motor Gasoline	263272550	69.528	-0.0334	-0.000008	-37750	0.2696	0.298	0.0804
	Kerosene-Type Jet Fuel	48463714	65.382	-0.0017	-0.000792	-23989	0.1713	18.993	3.2543
	Distillate Fuel Oil	89976381	67.920	-0.0058	-0.000129	-42582	0.3041	5.504	1.6740
	Residual Fuel Oil	6732933	39.336	-0.0058	-0.001000	-4008	0.0286	4.009	0.1148
Residential	Distillate Fuel Oil	12403498	67.920	-0.0997	-0.000055	-5870	0.0419	0.322	0.0135
Commercial	Distillate Fuel Oil	7037068	67.920	-0.4135	-0.000023	-3330	0.0238	0.078	0.0018
	Propane	33689621	41.412	-0.4135	-0.000003	-8493	0.0607	0.025	0.0015
	Residual Fuel Oil	1331172	39.336	-0.4135	-0.000071	-792	0.0057	0.057	0.0003
Industrial	Distillate Fuel Oil	13083732	67.920	-0.2018	-0.000026	-6192	0.0442	0.159	0.0070
	Residual Fuel Oil	11764067	39.336	-0.2018	-0.000017	-7002	0.0500	0.116	0.0058
TOTAL		487754736				-140008	1.0000		**5.1534**
Unit		Barrel(B)[1]	\$/B			1000B		\$/B	\$/B

Notes 1) The classifications between consumption sector and oil-refinery product type are available at http://www.eia.doe.gov/emeu/states/sep_use/notes/use_petrol.pdf and 2003 percentages of ‘Adjusted Sales of Fuel Oil by End Use’ from http://tonto.eia.doe.gov/dnav/pet/pet_cons_top.asp were used to distribute ‘Distillate’ and ‘Residual’ Fuel Oil to the consumption sectors.

2) $W_c = \delta q_c^{oil} / \sum_c \delta q_c^{oil}$, where subscript c denotes Consumption Sector.

IV. Results

Based on 2001 U.S. IMPLAN data set, I created supply-side version of the U.S. national Input Output model, which consists of 47 industry sectors. Table 4 shows the total price increases of each industry sector. The disruption in oil refinery affects to other relative non-service industries, e.g. Nonmetallic minerals (USC sector 8), Fertilizers (USC sector 13), and Basic chemicals (USC sector 11), increasing additional prices for those sectors. Also, the disruption increases the prices of service industries, such as Utility (USC sector 30), Transportation (USC sector 33), Real estate and rental and Leasing (USC sector 38), and Management of companies and enterprises industries (USC sector 40) more than other service industries.

Table 4. Total Impacts via Price-type Supply-driven USIO Model

USC Sector	Total Price Increase	Proportion	Total Impact ($M.)
USC1	0.0092	0.084%	-1.29
USC2	0.0105	0.096%	-1.47
USC3	0.0087	0.080%	-1.22
USC4	0.0089	0.081%	-1.24
USC5	0.0077	0.070%	-1.07
USC6	0.0780	0.710%	-10.92
USC7	0.0000	0.000%	-0.01
USC8	0.6115	5.570%	-85.61
USC9	0.1724	1.570%	-24.13
USC10	7.1545	65.171%	-1001.69
USC11	0.2088	1.902%	-29.23
USC12	0.0021	0.019%	-0.29
USC13	0.2882	2.625%	-40.34
USC14	0.0766	0.697%	-10.72
USC15	0.0735	0.670%	-10.29
USC16	0.0421	0.384%	-5.90
USC17	0.0605	0.551%	-8.47
USC18	0.0600	0.546%	-8.40
USC19	0.0129	0.118%	-1.81
USC20	0.0576	0.524%	-8.06
USC21	0.0905	0.825%	-12.67
USC22	0.0895	0.815%	-12.53
USC23	0.0717	0.653%	-10.04
USC24	0.0221	0.201%	-3.09
USC25	0.0481	0.438%	-6.73
USC26	0.0085	0.077%	-1.19
USC27	0.0108	0.099%	-1.51
USC28	0.0115	0.105%	-1.61
USC29	0.0119	0.109%	-1.67
USC30	0.1662	1.514%	-23.26
USC31	0.0088	0.080%	-1.23
USC32	0.1339	1.220%	-18.75
USC33	0.1719	1.566%	-24.06
USC34	0.1064	0.969%	-14.89
USC35	0.0142	0.129%	-1.98
USC36	0.0464	0.422%	-6.49
USC37	0.0535	0.487%	-7.48
USC38	0.1555	1.416%	-21.77
USC39	0.0921	0.839%	-12.89
USC40	0.1819	1.657%	-25.46
USC41	0.0914	0.832%	-12.79
USC42	0.0171	0.156%	-2.39
USC43	0.0032	0.029%	-0.45
USC44	0.0711	0.648%	-9.95
USC45	0.0239	0.218%	-3.34
USC46	0.0082	0.075%	-1.15
USC47	0.3244	2.955%	-45.42
TOTAL	10.9780	100.000%	-1537.01

Although the price-type model shows the price increases for each sector, our concern might be more related to understanding how much the economic impacts would be from the increased prices. Because total quantity losses during the last four months of 2005 are 140 Million Barrels, total value losses including the increased price are easily obtained, only by multiplying the losses of quantity and the increased price. The amounts are $721.5 million for four months. Based on the direct losses, total economic losses via the USIO are $1.537 billion. For the Oil industry (USC sector 10) lose $1 billion totally and other industries in the U.S. occurred $537 million losses due to the two Hurricanes.

To check the reasonability of this result, I compared the total losses simply with previous research. It is very interesting; this study shows that the simple total economic losses per month would be $384 million, while Kim et al. (2007) shows that the total losses per month would be $373 million. Although the two studies used the similar data source, this study is conducted based on the national level, while they used only PADD III data. Further, the price-type supply driven USIO is completely different from their temporally and spatially extended IO model. Therefore, the result in this study can be acceptable, although this study is conducted at the different basis from the previous study.

V. Conclusions

Input-Output models are attractive because they can be made operational and accessible at low cost. However, the widely used input-output approaches routinely include the caveat about the fixed technologies assumption and it has been important issues to overcome the overstated results (Park et al, 2007). I applied a new model reflecting the economic behaviors in the market, which is recently suggested by Park (2007), to the oil refinery disruptions due to the Hurricanes Katrina and Rita.

Recent Hurricane Katrina and Rita caused severe economic cessations, and led to further economic losses via interindustrial relations. This study is conducted based that oil industry plays a key role to support national economy, and hence the estimation of the economic impacts of the disasters should be based on the supply-driven input-output (IO) model. The new price-type supply-driven model using price elasticity of demand for oil refinery showed that total price increased up to 11 dollars nationally based on 5.15 dollars' direct losses. The total economic losses would be $1.54 billion during four months. This price-elastistic supply-driven model is a temporal expansion of supply-driven IO study, and showed a reasonable result compared to the previous research. However, this approach didn't touch the fixed coefficient assumptions; only reflected the economic behaviors to adjust the direct losses for the IO inputs. Therefore, further researches include the spatial and temporal extensions of the price-type supply-driven IO model.

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Appendix

Table A1. Definitions of USC sectors

Classification	USC	Description
Commodity Sectors	USC01	Live animals and live fish & Meat, fish, seafood, and their preparations
	USC02	Cereal grains & Other agricultural products except for Animal Feed
	USC03	Animal feed and products of animal origin, n.e.c.
	USC04	Milled grain products and preparations, and bakery products
	USC05	Other prepared foodstuffs and fats and oils
	USC06	Alcoholic beverages
	USC07	Tobacco products
	USC08	Nonmetallic minerals (Monumental or building stone, Natural sands, Gravel and crushed stone, n.e.c.)
	USC09	Metallic ores and concentrates
	USC10	Coal and petroleum products (Coal and Fuel oils, n.e.c.)
	USC11	Basic chemicals
	USC12	Pharmaceutical products
	USC13	Fertilizers
	USC14	Chemical products and preparations, n.e.c.
	USC15	Plastics and rubber
	USC16	Logs and other wood in the rough & Wood products
	USC17	Pulp, newsprint, paper, and paperboard & Paper or paperboard articles
	USC18	Printed products
	USC19	Textiles, leather, and articles of textiles or leather
	USC20	Nonmetallic mineral products
	USC21	Base metal in primary or semi-finished forms and in finished basic shapes
	USC22	Articles of base metal
	USC23	Machinery
	USC24	Electronic and other electrical equipment and components, and office equipment
	USC25	Motorized and other vehicles (including parts)
	USC26	Transportation equipment, n.e.c.
	USC27	Precision instruments and apparatus
	USC28	Furniture, mattresses and mattress supports, lamps, lighting fittings, and illuminated signs
	USC29	Miscellaneous manufactured products, Scrap, Mixed freight, and Commodity unknown
Non-Commodity (Service) Sectors	USC30	Utility
	USC31	Construction
	USC32	Wholesale Trade
	USC33	Transportation
	USC34	Postal and Warehousing
	USC35	Retail Trade
	USC36	Broadcasting and information services
	USC37	Finance and Insurance
	USC38	Real estate and rental and leasing
	USC39	Professional, Scientific, and Technical services
	USC40	Management of companies and enterprises
	USC41	Administrative support and waste management
	USC42	Education Services
	USC43	Health Care and Social Assistances
	USC44	Arts, Entertainment, and Recreation
	USC45	Accommodation and Food services
	USC46	Public administration
	USC47	Other services except public administration

Table A2. Statistical Results for Holt-Winters Approach to Forecasting Normal Status of Petroleum Products.

	Variables	Finished Motor Gasoline	Kerosene-Type Jet Fuel	Distillate Fuel Oil	Residual Fuel Oil	Propane
Weights	WEIGHT1			0.10557		
	WEIGHT2			0.10557		
	WEIGHT3			0.25000		
Seasonal Parameters	Jan.	0.981936	1.00504	1.000949	1.067233	1.007469
	Feb.	0.912215	0.912229	0.863495	0.940192	0.913564
	Mar	0.981089	0.965312	0.964908	0.996497	0.974637
	Apr	0.984929	0.982261	0.980456	0.943777	1.002169
	May	1.047497	1.013063	1.026438	0.988171	1.076859
	Jun	0.999575	1.019491	1.018364	0.997407	1.015592
	Jul	1.026859	1.050165	1.071777	0.986143	1.021838
	Aug	1.024822	1.054973	1.063236	0.991798	1.001733
	Sep	0.967058	0.982992	0.943255	0.92337	0.979689
	Oct	1.019783	0.987138	0.972791	0.985073	1.004934
	Nov	1.00413	0.986175	1.016575	1.070262	0.97629
	Dec	1.050107	1.041161	1.077756	1.110076	1.025225
	Total sum of squares (SST)	2170293909	122683005	1497905488	22834285	52349973
	Sum of the squared residuals (SSE)	263987462	315618891	147487608	6188059	7055825
	R-Squares (= 1-SSE/SST)	0.8784	0.7427	0.9015	0.7290	0.8652
	THEILU	0.0137	0.0264	0.0227	0.0283	0.0185