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Factor Decomposition of Responsiveness of the Domestic Price to Crude Oil Price

Cheng-Yih Hong [1]*, Chung-Huang Huang[2], Jian-Fa Li [3]

[1]Faculty of Finance, Chaoyang University of Technology, Taiwan, [2]Vice President, Taiwan Research Institute, Taiwan, [3]Faculty of Finance, Chaoyang University of Technology, Taiwan. *Email: hcyih@cyut.edu.tw

ABSTRACT

Taiwan is an economy that is highly dependent on energy imports. Changes in oil price affect not only the cost of production but also economic growth. Since 2000, the crude oil price has risen and become an unstable factor for economic development. Due to the rapid rise of emerging economies and the competitive international economic environment, Taiwan is facing a moment of industrial restructuring. Energy-saving technologies and improved efficiency may play an important role. Taiwan must improve its industrial productivity and production technology to contribute to the alleviation of the global warming problem. From the crude oil intensity and the change in spillover effects of the crude oil price, we may detect whether industrial production efficiency and adaptability to energy and production technology improves or not. Based on the input-output table during the period of 1981 to 2016, the present study employs the industry-related price model and factor decomposition model to investigate the change in Taiwan's reliance on crude oil through the oil intensity index. Although efforts have been made to advance technology and improve energy dependence, the results of this study indicate that imported crude oil intensity and price responsiveness have actually increased and that the negative effects of the structural efficiency of production and domestic market demand have substantially increased imported crude oil intensity and price responsiveness, again emphasizing the vulnerability of Taiwan's production. Thus, the speed of improvement in energy technology is insufficient to keep up with economic growth.

Keywords: Factor Decomposition, Crude Oil Price, Industry-related Price Model
JEL Classifications: Q42,Q43,C6

1. INTRODUCTION

Taiwan lacks crude oil production, depending almost entirely on imports to supply various economic activities. The stability of crude oil prices influences production costs and has become a key factor in its economic development, affecting its future economic growth. Since Taiwan experienced both the oil crises and its economic boom in the 1990s, the government and businesses have been investing heavily in new energy technology, endeavoring to adjust the industrial structure. After Taiwan joined the World Trade Organization (WTO) in 2002, trade liberalization has expanded the scale of international trade, increasing domestic production and exports and fueling the demand for international crude oil. Irrespective of these changes, the overall industrial energy intensity has improved gradually, decreasing from 9.45 (liters of oil equivalent (LOE)/NT\$$10^3$) in 2003 to 7.37 (LOE/NT\$$10^3$) in 2015. The energy intensities of the three main sectors, which are the agricultural sector, the industrial sector, and the service sector, decreased from 7.4 (LOE/NT\$$10^3$), 18.9 (LOE/NT\$$10^3$), and 1.6 (LOE/NT\$$10^3$) in 2003 to 5.0 (LOE/NT\$$10^3$), 12.4 (LOE/NT\$$10^3$), and 1.4 (LOE/NT\$$10^3$) in 2012, respectively. However, compared with that of other advanced countries, Taiwan's crude oil intensity remains high.

In 2008, the global financial crisis severely affected the economies of Europe and North America. Because nearly 70% of Taiwan's economic growth depends on trade, Taiwan could not evade the impact of the crisis. The capital transfers that accompanied the financial crisis triggered a rapid rise in international crude oil prices, compounding Taiwan's economic difficulties. In contrast to most of the previous studies conducted in Taiwan that used domestic energy intensity to address dependence on crude oil, in the present study, we employed the import intensity of final demand to investigate the dependence of Taiwanese industries on crude oil imports. A factor decomposition model of import intensity was used to explore the factors affecting dependence, enabling us to indirectly determine Taiwan's long-term industrial restructuring. We used the price responsiveness to crude oil output to analyze the response of domestic production costs and prices to changes in international crude oil prices. In addition, a factor decomposition model was also applied to uncover the factors affecting the responsiveness to crude oil prices. These methods contrast with those of the literature (i.e., primarily using statistical methods to estimate energy price elasticity). The results of the present study could provide an understanding of the properties and production technologies of various industries in Taiwan.

2. LITERATURE REVIEW

The previous oil crises confirmed that economic growth worldwide is overly reliant on oil. Numerous studies have revealed that fluctuations in energy prices result in substantial economic losses (Hamilton, 1996; Davis and Haltiwanger, 2001; Lee and Ni, 2002). Hamilton, 2003; 2011). In addition, to maintain continued economic growth, newly industrialized countries respond to rises in crude oil prices by implementing subsidies. Studies have applied energy price elasticity to investigate the relationship between energy demand and prices. In particular, numerous studies have explored the price elasticity of China's energy demand or changes in income elasticity (Asadoorian et al., 2008; Ma et al., 2008; Lin and Jiang, 2011). Because globalization has developed rapidly, exchange rates have also become a major factor influencing energy prices and increasing the impact on energy prices (Kilian and Park, 2009; Fukunaga et al., 2011).

Studies on the impact of increases in crude oil prices on the macro-economy can be divided into empirical analyses and predictive analyses. Empirical analysis primarily involves using the vector autoregressive (VAR) model for inference, whereas predictive analysis involves using economic theory as a basis for estimating the ripple effects of economic booms. The econometric model was popular in the 1980s for analyzing the effects of crude oil price changes (Hickman et al., 1987). Beenstock (1995) examined developing countries that imported oil by applying a macro-econometric model to analyze the influence of increases in crude oil prices on import prices and production costs. In addition, multiple studies have analyzed the relationship between changes in crude oil prices and changes in economic cycles (Kim and Loungani, 1992; De Miguel et al., 2003).

Burbidge and Harrison (1984) documented the relationship between macroeconomic changes and crude oil prices. Mork (1989) examined the influence of fluctuations in crude oil prices on GDP, observing asymmetries between Burbidge and Harrison (1984) documented the relationship between macroeconomic changes and crude oil prices. Mork (1989) examined the influence the two. The results of a study by Mory (1993) supported this conclusion. Lee et al. (1995) used the generalized autoregressive conditional model to analyze volatility in crude oil prices and confirmed the presence of asymmetries. The relationship between crude oil prices and macroeconomic indicators was investigated by Hooker (1996), who confirmed Granger causality between the two; Hamilton (1996) confirmed this conclusion. Numerous studies have also examined the influence of changes in international crude oil prices on industrial production and prices (Nagano, 2004; Klein et al., 2005; Ono, 2005; Fuzikawa et al., 2007; Fukunaga et al. 2011).

Klein et al. (2005) employed the industry-related price model to estimate the reaction of price indices in the U.S. to crude oil prices over the years. They show that the reactions were 10.5% in 1977, 3.8% in 1987, and 3.3% in 1997. These results indicate that from 1977 to 1997, the influence of changes in crude oil prices on price levels in the U.S. gradually reduced. Nagano (2004) documented that as crude oil prices increase by \$10, the average output of the mining industry in Japan declines by 0.4%, and the consumer price index increases by 0.09%.

Ono (2005) highlighted that if crude oil prices increase by 39%, the total output value of industry in Japan would be reduced by 0.36%. Ono indicates that the fiber industry would be the most affected (reduced by 9.81%), followed by the petroleum products industry (reduced by 1.90%) and the personal services industry (reduced by 1.12%). He also finds that consumption would be reduced by 0.65%; investment, by 0.38%; and exports, by 0.02%.

Fuzikawa et al. (2007) employed an industry-related model to calculate the dependency on crude oil imports in Japan and the U.S. and to estimate the impact of volatilities in crude oil prices on price levels in the two countries. The results show that after the oil crisis, dependency on crude oil imports decreased in the U.S. and Japan. Price indices are also less influenced by fluctuations in crude oil prices. The reason for this may be that Japan is particularly effective at reducing investment in crude oil imports and improving domestic production efficiency. Although the improvements in production efficiency in the U.S. do not match those of Japan, the U.S. also achieves significant results in reducing investment in crude oil.

3. EMPIRICAL MODEL

The data for every 5 years and every 3 years from 1981-2016 in the present study are derived from the publication of the input-output table compiled by Directorate General of Budget, Accounting and Statistics (DGBAS), Executive Yuan, Taiwan.

We attempt to estimate the imported crude oil intensity of final demand and the responsiveness to crude oil prices. The following is the empirical model.

3.1. Measure of the Domestic Price in Response to Change in Imported Crude Oil Prices

Based on the industry-related price model, the responsiveness of the domestic price level ($\bar{P}_d$) to change in the imported price of crude oil ($\bar{P}_m$) could be measured as equation (1)

$$\bar{P}_d = \bar{P}_m (MA)(B_d) \tag{1}$$

Where MA is the coefficient matrix of imported goods, and $B_{d=}$ ($[I-\left(I-\bar{M}\right)A]^{-1}$) denotes the Leontief inverse matrix.

$$M_i = m_i\left(\sum_{j=1}^{n} a_{ij} X_j +\right), i = 1, 2, \cdots n \tag{2}$$

$$A=\begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{bmatrix} \tag{3}$$

Where aij = xij/Xj ; aij is the input from industry i per output for industry j (i = 1, …, n; j=1,2, …n); Xj is the total output of industry j and xij is per output for industry j resulting from the input of industry i.

3.2. Factor decomposition model for the sensitivity of Domestic Price to Imported Crude Oil Price

To uncover the determinants of the responsiveness of domestic price to the imported crude oil price, $\overline{P}_d$ could be decomposed at two periods. We could obtain equation (4).

Assuming a change in domestic price ($d\overline{P}_d$) from period 0 to period 1 as follows:

$$\begin{aligned} d\overline{P}_d &= \overline{P}_d(1) - \overline{P}_d(0) \\ &= \overline{P}_m(1)M(1)A(1)B_d(1) - \overline{P}_m(0)M(0)A(0)B_d(0) \\ &= \overline{P}_m(1)M(1)A(1)B_d(1) - \overline{P}_m(1)M(1)A(1)B_d(0) \\ &+ \overline{P}_m(1)M(1)A(1)B_d(0) - \overline{P}_m(0)M(0)A(0)B_d(0) \\ &= \overline{P}_m(1)M(1)A(1)B_d(1) - \overline{P}_m(1)M(1)A(1)B_d(0) \\ &+ \overline{P}_m(1)M(1)A(1)B_d(0) + \overline{P}_m(1)M(0)A(0)\,B_d(0) \\ &- \overline{P}_m(1)M(0)A(0)B_d(0) - \overline{P}_m(0)M(0)A(0)B_d(0) \\ &= [\overline{P}_m(1) - \overline{P}_m(0)]M(0)A(0)B_d(0) \\ &+ \overline{P}_m(1)[M(1)A(1) - M(0)A(0)]B_d(0) \\ &+_m(1)M(1)A(1)[B_d(1) - B_d(0)] \end{aligned} \tag{4}$$

Because the individual industry accounted for the different weight in the whole economy and the domestic price responsiveness to the imported goods price is not the same, equation (4) could be restated after considering the weight of an individual industry as equation (5).

$$W(1)\overline{P}_d(1) - W(0)\overline{P}_d(0) = (W(1) - W(0))\overline{P}_d(0) + W(1)(\overline{P}_d(1) - \overline{P}_d(0)) = (W(1)\text{-}W(0))\overline{P}_d(0) + W(1)[\overline{P}_m(1) - \overline{P}_m(0)]M(0)A(0)B_d(0) + W(1)\overline{P}_m(1)[M(1)A(1) - M(0)A(0)]B_d(0) + W(1)_m(1)M(1)A(1)\,[B_d(1) - B_d(0)] \tag{5}$$

Where $[\overline{P}_m(1)-\overline{P}_m(0)]M(0)A(0)B_d(0)$ represents the factor of change in the initial price of imported goods (crude oil); $\overline{P}_m(1)[M(1)A(1) - M(0)A(0)]B_d(0)$ is the factor of technology change of imported goods; $_m(1)M(1)A(1)[B_d(1) - B_d(0)]$ is the factor of change in domestic production structure and technology.

4. EMPIRICAL RESULTS

4.1. The Responsiveness of Domestic Price to Imported Crude Oil Price

Table 1 reports the sensitivity of domestic prices to changes in crude oil prices. In this study, we assumed that international crude oil prices doubled in the estimation of the impact on domestic prices. The results were as follows:

Between 1983 and 2004, international crude oil prices remained mostly under US$40 per barrel. During this period, the sensitivity to crude oil price was also relatively low. International crude oil prices began climbing rapidly in 2005, peaking at US$134.78 per barrel in June 2008. The extent to which crude oil prices affected overall industry prices was 1.176% in 1981, before prices declined slightly. However, this increase was not substantial. After 2006, the sensitivity increased, rising to 7.58% and 8.631% in 2011 and 2016, respectively. The increase indicates that domestic prices became more sensitive to crude oil prices. The sensitivity was 7.339 times higher in 2016 than in 1981.

The responsiveness of an individual industry to changes in imported crude oil prices varies. The petrochemical, travel, and transportation industries are the most sensitive. In 2016, air transport had the highest sensitivity (15.66%), followed by the fishery (15.31%), plastic (14.72%), and synthetic fiber (14.71%) sectors. Comparison of the changes in sensitivity to oil prices between 1981 and 2016 shows that the sensitivity of the plastics sector increased the most, increasing by 14.89 fold, followed by the sensitivities of the electricity and electronic products sectors, which increased by 14.35 and 14.10 fold, respectively.

4.2. Factor Decomposition of Domestic Price Sensitivity

As shown in Table 2, with the exception of in 1981-1984, although the effect of the initial imported prices of crude oil was the most critical factor affecting the change in domestic price level, this phenomenon was inevitable for Taiwan, which is virtually entirely reliant on energy imports. Between 1986 and 1989, the effect of the initial imported price of crude oil was 1.3821%. However, the effects of imported goods in technology and industrial restructuring reduced the domestic price sensitivity to imported crude oil price. This reduction reflects the effectiveness of the progress in energy-saving technologies and industrial restructuring during this period.

During the periods from 2001 to 2004 and from 2011 to 2016, the change in the input technology of imported goods continued to be a factor mitigating the rise in domestic price level. Although the effects of the change in production structure and technology remained positive, it improved gradually compared with those of the previous three periods. International crude oil prices remained high between 2011 and 2016. The price sensitivity increased substantially to 1.155%, and Taiwan encountered a new era of industrial restructuring, the effect of which deteriorated. During this period, the improvement in input technology of imported goods was the key factor suppressing increases in the domestic price level.

Table 1: Responsiveness of domestic price to imported crude oil price for individual industries (unit: %)

Sector	1981	1986	1991	1996	2001	2006	2011	2016
Fishery products	1.528	1.39	1.116	1.101	1.694	4.981	12.678	15.331
Other poultry production	0.278	0.246	0.295	0.318	0.387	0.753	2.075	3.672
Feed	0.24	0.22	0.227	0.23	0.292	0.615	1.441	2.116
Petrochemical	3.167	2.509	2.049	2.638	6.247	1.004	2.465	2.591
Chemical fertilizers	1.661	1.035	0.608	0.558	0.894	1.902	5.084	6.332
Synthetic fiber	1.721	1.07	0.73	0.917	0.894	4.77	13.336	14.712
Plastics	0.989	0.658	0.913	0.995	2.62	5.121	13.619	14.723
Petroleum refining	0.595	0.591	0.578	0.432	0.591	2.781	7.798	8.361
Pig iron and crude steel	0.811	0.48	0.405	0.512	0.382	1.056	2.666	3.145
Electronic products	0.376	0.234	0.203	0.265	0.322	0.783	4.199	5.301
Food service	0.569	0.34	0.289	0.304	0.329	1.057	3.342	4.317
Hospitality services	0.795	0.393	0.299	0.265	0.399	1.307	4.508	6.351
Transportation	3.47	2.174	1.806	2.697	2.569	6.916	20.65	15.664
Electricity	0.175	0.471	0.423	0.527	0.587	1.3	3.529	2.512
Communication	0.224	0.112	0.08	0.06	0.105	0.294	1.028	1.452
Financial industry	0.085	0.107	0.07	0.045	0.058	0.17	1.026	1.022
Total industry	1.176	0.789	0.854	0.602	0.756	4.004	7.58	8.631

Data source: This study

Table 2: Factor of change in responsiveness to imported crude oil price (unit: %)

Factor Period	Change in the initial price of import goods (1)	Change in the input technology of import goods (2)	Change in domestic production structure and technology (3)	(4)=(1)+(2)+(3)
1981-1984	0.001	0.0430	0.7894	0.8338
1986-1989	1.382	–0.1690	–0.5210	0.6922
1991-1994	0.7135	0.0731	0.1502	0.9368
1996-1999	0.6975	0.4312	0.4156	1.5442
2001-2004	0.9788	–0.2634	0.0540	0.7694
2004-2006	0.0258	0.0156	0.0030	0.0443
2006-2011	1.1057	–0.8149	0.9069	1.1978
2011-2016	1.2245	–0.8547	0.7852	1.155

Data source: This study

5. CONCLUSION

The responsiveness to changes in imported crude oil prices has increased by a factor of approximately 5-10 since Taiwan joined the WTO, indicating that globalization has intensified the effects of crude oil price fluctuations on production and daily life in Taiwan. Stable international energy supply is a critical factor affecting Taiwan's economic growth. Although efforts have been made to advance technology and improve energy dependence, the empirical results of this study serve as evidence that imported crude oil intensity and price responsiveness have actually increased. Thus, the speed of improvement in energy technology is insufficient to keep up with the extent of economic growth. During the period after the second oil crisis and before Taiwan joined the WTO, improvements in the savings of crude oil import inputs and the structural efficiency of domestic production decreased imported crude oil intensity and price responsiveness. In Taiwan, which lacks natural resources, economic development requires increased efficiency in domestic production and technology, in addition to savings on direct energy input. Although some progress was made in savings on imported crude oil input, the negative effects of the structural efficiency of production and domestic market demand substantially increased imported crude oil intensity and price responsiveness, again emphasizing the vulnerability of Taiwan's production.

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