Crude Oil Intensity, Production Efficiency and Adaptability to Energy- Evidence from an Economy with a High Dependence on Energy Imports

Chung-Huang Huang, Taiwan Research Institute, Taiwan
Han-Pang Su, Taiwan Research Institute, Taiwan
Chin-Wen Yang, Taiwan Research Institute, Taiwan
Jian-Fa Li, Chaoyang University of Technology, Taiwan
Cheng-Yih Hong, Chaoyang University of Technology, Taiwan

The Asian Conference on Sustainability, Energy & the Environment 2015
Official Conference Proceedings

Abstract
Taiwan is an economy with highly dependent on energy imports. Change in oil price not only affects the cost of production, but also on the economic growth. Due to the international crude oil prices being relatively stable with low price except the first two oil crises, it has brought up Taiwan's economic growth. However, after 2000 the crude oil price has risen and become an unstable factor for economic development. Taiwan is facing an industrial restructuring. Energy-saving technologies and improved efficiency might play an important role. Additionally, Kyoto Protocol to the United Nations Framework Convention on Climate Change in 1997 was to set CO_2, CH_4, N_2O, HFC_s, PFC_s and SF_6 reduction targets as the improvement of global warming climate. As a member of international society, it is necessary to improve the industrial productivity to contribute to the global warming problem. From crude oil intensity and spillover effects of change in crude oil price, we might detect whether industrial production efficiency and adaptability to energy improves or not. Based on the input-output table during the periods of 1981 to 2011, the present study employs the factor decomposition model to investigate change in Taiwan's reliance on crude oil through the index of imported crude oil intensity. The empirical results show that although some progress was made in savings on imported crude oil inputs, the negative effects of the structural efficiency of production and domestic market demand substantially increased imported crude oil intensity and price responsiveness, again revealing the vulnerability of Taiwan’s production.

Keywords: Factor Decomposition, Economic Spillover Effects, Crude Oil Price, Crude Oil Intensity

1. Introduction

After two crude oil crises in the 1970s, which upset the economy in Taiwan, the international prices of crude oil remained relatively stable, driving Taiwan's economic development. Following 2000, international crude oil prices rose gradually, peaking in July 2008 before beginning to fluctuate wildly. Nevertheless, crude oil prices remain high. However, these price increases differ from those during the oil crises in the 1970s. Newly industrialized countries and an expanding global supply chain are driving the rapid growth in oil demand. In addition, the development of international financial markets is also increasing speculative demand in the oil market.

Taiwan lacks oil production, depending almost entirely on imports to supply oil for 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. Therefore, 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 trade, increasing domestic production and exports and fueling the demand for international crude oil. Despite this, overall industrial energy intensity has improved gradually, falling from 9.45 (liters of oil equivalent(LOE)/NT$10^3) in 2003 to 7.52 (LOE/NT$10^3) in 2014. The energy intensities of the three main industries, the agricultural sector, the industrial sector, and the service sector, fell 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 energy intensity remains high.

Whether Taiwan's energy efficiency would improve with economic development remains unknown. The efforts of the government and businesses are evident in the annual decline in domestic energy intensity. However, the sustainable development of a country's economy relies on improvements in energy-saving technologies and the efficient response to changes in the international economic environment and to industrial restructuring. Considering the aforementioned concerns, in this study, we examined the influences of changes in international crude oil prices on industry costs and prices over a period during which international crude oil prices doubled. Improvements in industrial crude oil utilization technology were investigated from the perspectives of quantity and price. To achieve these objectives, we employed the industry-related model, estimating the imported crude oil intensity of final demand for a quantity analysis and the price responsiveness toward the crude oil price for a price analysis. These analyses facilitated observing the changes in crude oil dependence by Taiwanese industries and the responsiveness to crude oil prices over 30 years.

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 this crisis. The capital transfers that accompanied the financial crisis accelerated a rapid rise in international crude oil prices, compounding Taiwan's economic difficulties. Unlike most previous studies conducted in Taiwan that used domestic energy intensity to address dependence on oil, in this study, the import intensity of final demand is employed to examine the dependence of Taiwanese industries on oil imports. We used the price responsiveness

to investigate the response of domestic production costs and prices to changes in crude oil prices. In addition, a factor decomposition model was also applied to investigate the factors affecting the responsiveness to crude oil prices. These methods contrast with those reported in the literature (i.e., primarily using statistical methods to forecast energy price elasticity). These results of the present study afford an understanding of the properties and production technologies of various industries in Taiwan.

2. Literature Review

Numerous studies have revealed that fluctuations in energy prices result in substantial economic losses (Bruno & Sachs, 1985; Hamilton, 1983, 1996; Davis & Haltiwanger, 2001; Lee & Ni, 2002). This phenomenon has not changed in the twenty-first century because the economic growth of newly industrialized countries has substantially increased energy demand, prompting speculation in energy futures markets and also increasing the instability of international energy prices (Barsky & Kilian, 2004; Blanchard & Gali, 2007; 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 (International Energy Agency, Organization of the Petroleum Exporting Countries, Organization for Economic Co-operation and Development [OECD], and World Bank, 2010). In particular, numerous studies have explored the price elasticity of China's energy demand or changes in income elasticity (Fan et al., 2007; Hang & Tu, 2007; Asadoorian et al., 2008; Ma et al., 2008; Lin & Zhujun, 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, 2008; Kilian & Park, 2009; Fukunaga, Hirakata, & Sudo, 2011).

Economic development and globalization have destabilized international energy prices. Numerous studies have analyzed the effects of changes in crude oil prices on economic development and societies from various perspectives, focusing on the extent to which asymmetries in energy price elasticity have affected economic growth rates and domestic prices. Price asymmetries can be used to estimate the direction of changes in economic variables (Dargay, 1992; Gately et al., 1993; Haas et al., 1998; Madsen et al., 1998; Gately et al., 2002; Adeyami et al., 2007; Fan et al., 2007; Ma et al., 2008; Neto, 2012; Inglesi-Lotz, 2011; Sentenac-Chemin, 2012). Alternatives between factors of production have also been used to analyze asymmetries (Fan et al., 2007; Ma et al., 2008; Roy et al., 2006). Dowlatabadi et al. (2006) and Boone et al. (1996) have used technological advances to investigate asymmetries in energy prices, endogenizing rates of technological progress to construct energy demand functions. By contrast, Kumar et al. (2009) used the relationship between technological advances and energy prices to divide the productivity of the energy sector into efficiency change effects and rates of change in technology.

Various researchers have used menu costs caused by increases in oil prices to analyze asymmetries. Madsen et al. (1998) analyzed manufacturing and retail businesses and found that businesses can benefit from price adjustments even when asymmetries exist in energy prices. However, Blinder (1994) maintained that product prices tend to be rigid. Studies have also investigated the causes of energy price asymmetries and

various factors have been observed during different periods (Wirl, 1988; Grubb, 1995; Sentenac-Chemin, 2012). Nordhaus (1977) compared income changes with the energy demand response generated by energy price changes and assessed the time adjustments of oil crises. Boone et al. (1996) created an OECD energy demand function, noting that when technological advancement was included in the function, the long-term price elasticity decreased. Hunt et al. (2003) reported the same results (as did Popp, 2001; Griffin et al., 2005; Huntington, 2006; Kumar et al., 2009; and Dowlatabadi et al., 2006).

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, applying a macroeconometric 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 business cycles (Finn, 2000; Rotemberg & Woodford, 1996; Kim & Loungani, 1992; Miguel et al., 2003). Finn (2000) maintained that energy input affects the level of capital accumulation and estimated the influence of increases in crude oil prices on gross domestic product (GDP).

Burbidge and Harrison (1984) analyzed 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 the two. The results of a study by Mory (1993) also supported this conclusion. Lee et al. (1995) used the generalized autoregressive conditional heteroskedasticity 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 (1996a), who confirmed Granger causality between the two; Hamilton (1996) confirmed this conclusion. According to the premise that the relationship between crude oil prices and GDP is nonlinear, Hamilton (2003) performed econometric analysis. Bernanke et al. (1997) indicated that appropriate financial policies can be implemented to reduce the impact of crude oil prices. Balke et al. (2002) used the VAR model to analyze asymmetries in crude oil prices and indicated that adjustment costs and financial policies cause asymmetries. However, Hamilton and Herrera (2004) reported contrasting results. Dalsgaard et al. (2001) and Hunt et al. (2001) analyzed the influence of changes in international crude oil prices on the global economy, estimating that the elasticity values of each country's GDP in response to oil prices were between −0.01 and −0.02. Bohi (1991) maintained that rises in energy prices reduce enterprise production and GDP; this reduction is attributable to the direct impact and the indirect influence of capital and labor substitution effects.

In addition, changes in international crude oil prices produce various economic effects on each country. Mork et al. (1994) extended the work of Hamilton (1983), Burbidge and Harrison (1984), and Mork (1989) by analyzing and comparing the relationship between crude oil prices and GDP of the United States, Canada, Japan, Germany, France, the United Kingdom, and Norway. Bjørnland (2000) analyzed the influence of crude oil price shocks in the 1970s on Germany, the United Kingdom, the United States, and Norway. The results indicated that the price shocks exerted short-term negative effects on all of the countries except Norway. Abeysinghe (2001) analyzed newly industrialized countries. Numerous studies have also examined the influence of changes in international crude oil prices on industrial production and prices (Federer,

1996; Nagano, 2004; Klein, 2005; Ono, 2005; Fuzikawa et al., 2007; Fukuda & Kondo, 2009; Fukunaga et al., 2009).

3. Empirical Model

The data for every 5 year and every 3 year from 1981-2011 in the present study is drawn from the publication of input-output table compiled by Directorate General of Budget, Accounting and Statistics (DGBAS), Executive Yuan, Taiwan. We aim to estimate the imported crude oil intensity of final demand and the responsiveness of domestic price level toward crude oil price. The following are the empirical model.

3.1 Measurement of Import Intensity of Final Demand

The measurement of import intensity of final demand ($\overline{\mathrm{m}}$) for individual industry is

$$\overline{\mathrm{m}} = \mathrm{MA}\,\bar{x} = \mathrm{MAB}\,\overline{f_d} \tag{1}$$

Equation (1) stands for imports per unit final demand production for individual industry in which it is focused on the imported crude oil intensity in the present paper. Where $\bar{x}$ represents final demand production of individual industry; B is a Leontief inverse matrix. M and A stand for import coefficient and input coefficient for individual industry, respectively. $\overline{f_d}$ represents the ratio for individual sector as change in one-unit domestic final demand. It could be stated as

$$(1,\ldots,1)\,\overline{f_d} = 1 \tag{2}$$

3.2 Responsiveness of the Domestic Price toward Crude Oil Price

Based on the industry-related price model, the responsiveness of the domestic price ($\overline{\mathrm{P}}_{\mathrm{d}}$) toward imported price of crude oil ($\overline{\mathrm{P}}_{\mathrm{m}}$) could be measured as equation (3)

$$\overline{\mathrm{P}}_{\mathrm{d}} = \overline{\mathrm{P}}_{\mathrm{m}}(\mathrm{MA})(\mathrm{B}_{\mathrm{d}}) \tag{3}$$

where MA is the coefficient matrix of imported input and B_{d} denotes the Leontief inverse matrix.

3.3 Factor Decomposition Model for Sensitivity of Domestic Price toward Imported Crude Oil Price

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

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

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

Since the individual industries accounted for the different weight in the whole economy and the price responsiveness toward imported input price is not the same, equation (4) could be restated after considering the weight of individual industry as equation (5).

$$
\begin{aligned}
&W(1)\overline{P}_d(1) - W(0)\overline{P}_d(0) = (W(1) - W(0))\overline{P}_d(0) + W(1)(\overline{P}_d(1) - \overline{P}_d(0)) \\
&= (W(1) - W(0))\overline{P}_d(0) + W(1)[\overline{P}_m(1) - \overline{P}_m(0)]M(0)A(0)B_d(0) + W(1)\overline{P}_m(1)[M(1)A(1) \\
&\quad - M(0)A(0)]B_d(0) + W(1)\overline{P}_m(1)M(1)A(1)[B_d(1) - B_d(0)] \qquad (5)
\end{aligned}
$$

where $[\overline{P}_m(1) - \overline{P}_m(0)]M(0)A(0)B_d(0)$ stands for the effects of adjustment in the initial price of imported inputs (crude oil); $\overline{P}_m(1)[M(1)A(1) - M(0)A(0)]B_d(0)$ is the effects of adjustment in technology for imported inputs; $\overline{P}_m(1)M(1)A(1)[B_d(1) - B_d(0)]$ is the effects of adjustment in domestic production structure and technology.

4. Empirical Results

4.1 Changes in Import Intensity of Final Demand

In Table 1 overall, the ratio of imports required for every incremental increase in final demand production in Taiwan increased from 25.55% in 1981 to 26. 62 % in 2011. However, according to the long-term trends, the year 1981 was just one year after the second oil crisis, during which Taiwan was forced to improve production efficiency and reduce energy dependence. Therefore, industrial restructuring became the economic policy. Between 1986 and 2001, import intensity decreased annually, indicating that Taiwan's industrial restructuring improved production efficiency.

Table 1 Import Intensity of Final Demand

Sector	1981	1986	1991	1996	2001	2006	2011
Fishery products	0.02	0.02	0.01	0.01	0.01	0.01	0.01
Other poultry production	0.08	0.08	0.05	0.04	0.02	0.01	0.01
Feed	0.21	0.19	0.14	0.11	0.07	0.06	0.07
Crude Oil and Natural Gas	6.64	2.03	1.54	1.6	2.65	4.92	5.25
Petrochemical	1	1.29	1.31	1.24	0.89	1.59	1.63
Chemical fertilizers	0.08	0.03	0.02	0.02	0.01	0.03	0.04
Synthetic fiber	0.12	0.13	0.05	0.04	0.03	0.03	0.03
Plastics	0.37	0.37	0.43	0.38	0.32	0.24	0.3
Petroleum refining	0.96	0.69	0.72	0.51	0.62	0.93	1.63
Transportation	0.12	0.2	0.24	0.25	0.21	0.08	0.09
Pig iron and crude steel	0.81	0.83	0.74	0.48	0.56	1.09	1.03
Electronic products	0.86	1.41	1.23	2.2	3.3	0.47	3.2
Food service	0.07	0.03	0.03	0.03	0.03	0.08	0.07
Hospitality services	0	0.12	0.2	0.14	0.11	0.39	0.35
Electricity	0	0	0	0.01	0	0.01	0.01
Communication	0.08	0.09	0.11	0.1	0.06	0.05	0.25
Financial industry	0.02	0.03	0.02	0.03	0.03	0.03	0.12
Total industry	25.55	19.1	19.41	19.29	18.8	24.68	26.62

Data Source: this study.

Import intensity increased substantially between 2006 and 2011, reflecting an increase in Taiwan's imported dependence that was caused by a rapid increase in international crude oil prices after 2004 and Taiwan's imports increased substantially after it joined the WTO in 2002. As for the crude oil and gas sector, import intensity in 1981 was 6.64%; dependence on crude oil was high compared with that in other industries, but declined substantially between 1986 and 2001, demonstrating that the industry's energy efficiency improved slightly. Nonetheless, the import intensity of the crude oil and gas sector again increased substantially between 2006 and 2011, reaching 5.25% by 2011. We conducted this study based on the input-output table for 2011, so there was a gap of more than 3 years, and the current crude oil import intensity might be even higher.

4.2 Sensitivity of Domestic Price toward Crude Oil Price

Table 2 reports the sensitivity of domestic price for individual industries toward volatility in crude oil prices. In the present study, we assumed that international crude oil prices doubled in the estimation of the impact on domestic price. Between 1983 and 2004, crude oil prices remained mostly under US$40 per barrel. During this period, the sensitivity of domestic price toward 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 the prices declined slightly. However, this increase

was not substantial. After 2006, sensitivity increased, rising to 4.004% and 7.58% in 2006 and 2011, respectively. This increase indicates that domestic prices became more sensitive toward international crude oil prices. Sensitivity was 6.448 times higher in 2011 than it was in 1981.

Table 2 Responsiveness of Domestic Price toward Crude Oil Price for Individual Industries

Sector	1981	1986	1991	1996	2001	2006	2011	2011/1981
Fishery products	1.528	1.390	1.116	1.101	1.694	4.981	12.678	8.296
Other poultry production	0.278	0.246	0.295	0.318	0.387	0.753	2.075	7.471
Feed (food for farm animals)	0.240	0.220	0.227	0.230	0.292	0.615	1.441	5.995
Petrochemical	3.167	2.509	2.049	2.638	6.247	1.004	2.465	0.778
Chemical fertilizers	1.661	1.035	0.608	0.558	0.894	1.902	5.084	3.062
Synthetic fiber	1.721	1.070	0.730	0.917	0.894	4.770	13.336	7.749
Plastics	0.989	0.658	0.913	0.995	2.620	5.121	13.619	13.765
Petroleum refining	0.595	0.591	0.578	0.432	0.591	2.781	7.798	13.097
Pig iron and crude steel	0.811	0.480	0.405	0.512	0.382	1.056	2.666	3.286
Electronic Products	0.376	0.234	0.203	0.265	0.322	0.783	4.199	11.181
Food Service	0.569	0.340	0.289	0.304	0.329	1.057	3.342	5.878
Hospitality services	0.795	0.393	0.299	0.265	0.399	1.307	4.508	5.671
Air transportation	3.470	2.174	1.806	2.697	2.569	6.916	20.650	5.951
Transportation	0.175	0.471	0.423	0.527	0.587	1.300	3.529	20.164
Communication	0.224	0.112	0.080	0.060	0.105	0.294	1.028	4.592
Financial sector	0.085	0.107	0.070	0.045	0.058	0.170	1.026	12.038
Total industry	1.176	0.789	0.854	0.602	0.756	4.004	7.580	6.448

Data Source: this study.

The price sensitivity in each sector toward changes in imported crude oil prices varies. The price in the petrochemical and air transportation sectors are the most sensitive before 2011. However, after 2011 the price sensitivity in the air transportation sector had the highest one(20.65%), followed by those in the plastic sector(13.619%), synthetic fiber sector(13.336%), and fishery products sector(12.678%). Comparison the sensitivity toward changes in crude oil price between 1981 and 2011 illustrating that the sensitivity of the price in the air transportation service sector increased the most, growing by 20.164 times, followed by the sensitivities of the plastic and petroleum refining sectors, which grew by 13.765 and 13.097 times, respectively.

4.3 Factor Decomposition of Domestic Price Sensitivity

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 increase 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 inputs in technology and industrial restructuring reduced the sensitivity toward imported crude oil price. This reduction reflects the effectiveness of progress in energy-saving technologies and industrial restructuring during this period.

Table 3 Factor of Adjustments in Responsiveness toward Imported Crude Oil Price

Factor / Period	adjustment in the initial price of imported crude oil(1)	adjustment in technology for imported inputs (2)	adjustment in domestic production structure and technology (3)	(4)=(1)+(2)+(3)
1981-1984	0.0014	0.0430	0.7894	0.8338
1986-1989	1.3821	-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

Data Source: this study.

During the periods from 2001 to 2004 and from 2006 to 2011, the effect of adjustment in technology for imported inputs continued to be a factor mitigating the rise in domestic price level. Although the factor of adjustment 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 2006 and 2011. The price sensitivity increased substantially to 1.1978%, and Taiwan encountered a new stage of industrial restructuring, the effect of which deteriorated. During this stage, technical level of imported inputs was the key factor suppressing increases in domestic prices.

5 Conclusion

Domestic energy intensity has declined annually. On the contrary, import intensity has increased. In particular, after Taiwan joined the WTO, a rise in international trade has increased energy dependence to approximately 30%-40%. In addition, energy dependence is also reflected in responsiveness to international crude oil prices. Price responsiveness toward crude oil price has increased by a factor of approximately 5 to 10 since Taiwan joined the WTO, illustrating 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 indicate 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. The present study derives a preliminary solution through a factor

decomposition model. During the period after the second oil crisis and before Taiwan joined the WTO, improvements in the savings of imported crude oil 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 investments. Although some progress was made in savings on imported crude oil inputs, the negative effects of the structural efficiency of production and domestic market demand substantially increased imported crude oil intensity and price responsiveness, again revealing the vulnerability of Taiwan's production.

References

Abeysinghe, T. (2001). Estimation of direct and indirect impact of oil price on growth. *Economic Letters*, 73, 147-153.

Adeyemi, O. I., & Hunt, L. C. (2007). Modeling OECD industrial energy demand: Asymmetric price responses and energy-saving technical change. *Energy Economics*, 29, 693-709.

Asadoorian, M. O., Eckaus, R. S., & Schlosser, C. A. (2008). Modeling climate feedbacks to electricity demand: the case of China. *Energy Economics*, 30, 1577-1602.

Balke. N. S., Brown, S. P. A., & Yücel, M. K. (2002). Oil price shocks and the U.S. economy: Where does the asymmetry originate? *Energy Journal*, 23(3), 27-52.

Barsky, R. B., & Kilian, L. (2004). Oil and the macroeconomy since the 1970s. *Journal of Economic Perspectives*, 18, 115-134.

Beenstock, M. (1995). An econometric model of the oil importing developing Countries. *Economic Modelling*, 12(1), 3-14.

Bernanke, B. S., Gertler, M., & Watson, M. (1997). Systematic monetary policy and the effects of oil price shocks. *Brookings Papers on Economic Activity*, 1, 91-142.

Bjørnland, H. C. (2000). The dynamic effects of aggregate demand, supply and oil price shocks-A comparative study. *Manchester School*, 68(5), 578-607.

Blanchard, O. J., & Gali, J. (2007). The macroeconomic effects of oil shocks: Why are the 2000s so different from the 1970s? *NBER Working Papers* No. 13368.

Blinder, A. S. (1994). On sticky prices: Academic theories meet the real world. In N. G. Mankiw (Ed.), *Monetary Policy*, Illinois, Chicago: University of Chicago Press.

Bohi, D. R. (1991). On the macroeconomic effects of energy price shocks. *Resources and Energy*, 13, 145-162.

Boone, L., Hall, S., & Kemball-Cook, D. (1996). Endogenous technical progress in fossil fuel demand: The case of France. *Journal of Policy Modeling*, 18(2), 141-155.

Bruno, M., & Sachs, J. D. (1985). *Economics of worldwide stagflation*. Massachusetts, Cambridge: Harvard University Press.

Burbidge, J., & Harrison, A. (1984). Testing for the effects of oil-price rises using vector autoregressions. *International Economic Review*, 25(2), 459-484.

Dalsgaard, T., Andre, C., & Richardson,P. (2001). Standard shocks in the OECDINTERLINK Model. *OECD Economics Department Working Papers* No. 306, ECO/WKP, 32.

Dargay, J. M. (1992). Are price and income elasticities of demand constant? *Oxford Institute for Energy Studies EE16*.

Davis, S. J., & Haltiwanger, J. (2001). Sectoral job creation and destruction responses to oil price changes. *Journal of Monetary Economics*, 48(3), 465-512.

De Miguel, C., Manzano, B., & Marín-Moreno, J. M. (2003). Oil price shocks and aggregate fluctuations. *Energy Journal*, 24(2), 47-62.

Dowlatabadi, Hadi and M. A. Oravetz (2006). "US long-term energy intensity: backcast and projection. *Energy Policy*, 34, 3245-3256.

Fan, Y., Liao, H., & Wei, Y-M (2007). Can market oriented economic reforms contribute to energy efficiency improvement? Evidence from China. *Energy Policy*, 35(4), 2287-2295.

Ferderer, P. J. (1996). Oil prices volatility and the macroeconomy. *Journal of Macroeconomics*, 18, 1-26.

Finn, M. G. (2000). Perfect competition and the effects of energy price increases on Economic Activity. *Journal of Money, Credit and Banking*, 32, 400-416.

Fuzikawa, K., Simota M., & Watanabe, T. (2007) "The spillover Effect of imported crude oil price: Evidences from U.S. and Japan. *The Processing of the Japan Society of International Economics*. (In Japanese)

Fukunaga, Ichiro, Naohisa Hirakata and Nao Sudo (2011). The effects of oil price changes on the industry-level production and prices in the United States and Japan. In *Commodity Prices and Markets, NBER East Asia Seminar on Economics*, 20,195-231, Illinois, Chicago: University Chicago Press.

Gately, D. (1993). Oil Demand in the US and Japan: Why the demand reductions cause by the price increases of the 1970's won't be reversed by the price declines of the 1980s. *Japan and the World Economy*, 5, 295-319.

Gately, D., & Huntington, H. G. (2002). The asymmetric effects of changes in price and income on energy and oil demand. *Energy Journal*, 23(1), 19-55.

Griffin, J. M., & Schulman, C. (2005). Price asymmetry: A proxy for energy saving technical change? *Energy Journal*, 26(2), 1-21.

Grubb, M. (1995). Asymmetrical price elasticities of energy demand. In Barker, T., Ekins, P., Johnstone, N. (Eds). *Global Warming and Energy Demand*, London: Routledge. pp. 305-310.

Grubb, M., Carraro, C., & Schellnhuber, J. (2006). Endogenous technological change and the economics of atmospheric stabilization. *Energy Journal*, Special Issue.

Haas, R., & Schipper, L. (1998). Residential energy demand in OECD-countries and the roles of irreversible efficiency improvements. *Energy Economics*, 20(4), 421-442.

Hamilton, J. D. (1983). Oil and the macroeconomy since World War II. *Journal of Political Economy*, 91, 228-248.

Hamilton, J. D. (1996). This is what happened to the oil price/macroeconomy Relation. *Journal of Monetary Economics*, 38(2), 215-220.

Hamilton, J. D. (2003). What is an oil shock? *Journal of Econometrics*, 113(2), 363-398.

Hamilton, J. D. (2011). Nonlinearities and the macroeconomic effects of oil prices. *Macroeconomic Dynamics*, 15(3), 364-378.

Hamilton, J. D., & Herrera, A. M. (2004). Oil shocks and aggregate macroeconomic behavior: The role of monetary policy. *Journal of Money, Credit and Banking*, 36(2): 265-291.

Hang, L., & Tu, M. (2007). The impacts of energy prices on energy intensity: Evidence from China. *Energy Policy*, 35(5), 2978-2988.

Hickman, B. G., Huntington, H. G., & Sweeney, J. L. (Eds.) (1987). *Macroeconomic Impacts of Energy Shocks*. Amsterdam: North-Holland.

Hooker, M. A. (1996). What happened to the oil price-macroeconomy relationship? *Journal of Monetary Economics*, 38, 195-213.

Hunt, B., Isard, P., & Laxton, D. (2001). The macroeconomic effects of higher oil prices. *International Monetary Fund. IMF Working Paper*, WP/01/14.

Hunt, L. C., Judge, G., & Ninomiya, Y. (2003). Underlying trends and seasonality in UK energy demand: a sectoral analysis. *Energy Economics*, 25(1), 93-118.

Huntington, H. G. (2006). A note on price asymmetry as induced technical change. *Energy Journal*, 27(3), 1-8.

IEA, OPEC, OECD, World Bank. Analysis of the scope of energy subsidies and suggestions for the G-20 Initiative. IEA, OPEC, OECD, World Bank joint report, 16 June 2010, http://www.iea.org/weo/docs/G20_Subsidy_Joint_Report.pdf.

Inglesi-Lotz, R. (2011). The evolution of price elasticity of electricity demand in South Africa: A Kalman filter application. *Energy Policy*, 39, 3690-3696.

Klein, L. R., Duggal, V. G., & Saltzman, C. (2005). The sensitivity of the general price level to change in the price of crude oil. *Business Economics*, 40(4), 74-77.

Kilian, L. (2009). Not all oil price shocks are alike: Disentangling demand and supply shocks in the crude oil market. *American Economic Review*, 99(3), 1053-1069.

Kilian, L., & Park, C. (2009). The impact of oil price shocks on the U.S. stock market. *International Economic Review*, 50(4), 1267-1287.
Kim, I.-M., & Loungani, P. (1992). The role of energy in real business cycles. *Journal of Monetary Economics*, 29, 173-189.

Kumar, S., & Managi, S. (2009). Energy price-induced and exogenous technological change: Assessing the economic and environmental outcomes. *Resource and Energy Economics*, 31, 334-353.

Lee, K., Ni, S., & Ratti, R. A. (1995). Oil shocks and the macroeconomy: The role of price variability. *Energy Journal*, 16(4), 39-56.

Lee, K., & Ni, S. (2002). On the dynamic effects of oil price shocks: A study using industry level data. *Journal of Monetary Economics*, 49(4), 823-852.

Lin, B., & Jiang, Z. (2011). Estimates of energy subsidies in China and impact of energy subsidy reform. *Energy Economics*, 33, 273-283.

Ma, H., Oxley, L., Gibson, J., & Kim, B. (2008). China's energy economy: Technical change, factor demand and interfactor / interfuel substitution. *Energy Economics*, 30, 2167-2183.

Madsen, J. B., & Yang, B. Z. (1998). Asymmetric price adjustment in a menu-cost model. *Journal of Economics*, 68(3), 295-309.

Mork, K. A. (1989). "Oil and the Macroeconomy when Prices Go Up and Down: An Extension of Hamilton's Results. *Journal of Political Economy*, 97, 740-744.

Mork, K. A., Olsen, Ø., & Mysen, H. T. (1994). Macroeconomic responses to oil price increases and decreases in seven OECD countries. *Energy Journal*, 15(4), 19-35.

Mory. J. F. (1993). Oil prices and economic activity: Is the relationship symmetric? *Energy Journal*, 14(4), 151-161.

Nagano, M. (2004). Increases in crude oil v.s. Japan/ eastern economies: The impact of price volatility on real sector. *MRI Monthly Review*, 1-13. (in Japanese)

Neto, D. (2012). Testing and estimating time-varying elasticities of Swiss gasoline demand. *Energy Economics*, 34(6), 1755-1762.

Nordhaus, W. D. (1977). *International studies in the demand for energy. editor, with contributions*. Netherlands, Amsterdam: North-Holland Publishing Company.

Ono, M. (2005). The impact of rising oil prices on the Japanese economy. *Institute for International Trade and Investment*, NO.60.

Popp, D. C. (2001). The effect of new technology on energy consumption. *Resource and Energy Economics*, 23, 215-239.

Rotemberg, J. J., & Woodford, M. (1996). Imperfect competition and the effects of energy price increases on economic activity. *Journal of Money, Credit and Banking*, 28, 549-577.

Joyashree, R., Sanstad, A. H., Sathaye, J. A., & Khaddaria, R. (2006). Substitution and price elasticity estimates using inter-country pooled data in a translog cost model. *Energy Economics*, 28, 706-719.

Sentenac-Chemin, E. (2012). Is the price effect on fuel consumption symmetric? Some evidence from an empirical study. *Energy Policy*, 41, 59-65.

Wirl, F. (2008). The asymmetrical energy demand pattern: Some theoretical explanations. *OPEC Review*, 12(4), 353-367.

Contact email: chhuang@tri.org.tw
Contact email: hpsu@tri.org.tw
Contact email: jp62001@tri.org.tw
Contact email: jfli@cyut.edu.tw
Contact email: hcyih@cyut.edu.tw