International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2017, 7(6), 1-10.

The Spanish used Oils Market: A Vector Error Correction Model

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ABSTRACT

The Spanish Used Oils Management Act (Royal Decree 679 of June 2, 2006), which mandated extended producer responsibility in the management of waste oils, set the recovery rate of used oils at 95% in 2006 and the refining rates of used oils at 55% and 65% in 2007 and 2008, respectively. This study examines the dynamic responses of the amount of used oils intended for re-refining and the price of base lubricant oils to the environmental objectives as fixed by the royal decree by estimating a vector error correction model. The results suggest that the quantity variable increases, but the effect is the opposite from the third period and beyond. The price variable increases, but the effect decreases at 2 years and beyond. In addition, the variable quantity causes the variation in the price variable.

Keywords: Industrial Oil, Used Oil, Vector Error Correction, Impulse-response Functions
JEL Classifications: L71, Q47, Q48

1. INTRODUCTION

Used oils include mineral and synthetic lubricants as well as industrial oils that have become unfit for their initially planned use and are essentially hazardous waste[1]. Used oils can be reused through the process of re-refining, a recycling operation in which base oils can be produced by refining waste oils or by burning them to recover energy[2]. According to the Environmental Protection Agency (EPA), two liters of re-refined oil yields three liters of used oil, whereas 100 liters of oil is required to obtain the same amount of base oils (EPA, 1989). Moreover, it is estimated that every ton of re-refined oil prevents three tons of CO_2 emissions from being released into the atmosphere[3]. Furthermore, a liter of used oils manufactured as fuel provides 10.84 kW/hour of power (EPA, 1989). In Spain, the authorization to burn used oils in 1989, the financial incentives for their collection, and stricter regulations regarding the management of waste oils facilitated a sharp increase in the collection rate of used oils. However, these policies implied the prevalence of combustion, to the detriment of re-refining. In the early 2000s, the regulations regarding the burning of used oils were revised and made more stringent. As a result, the collection rate of used oils reached 100% by increasing used oils reused by re-refining.

The Spanish Used Oils Management Act (Royal Decree 679 of June 2, 2006), which mandates extended producer responsibility (EPR) in the management of waste oils, set the recovery and valorization rates of used oils to 95% and 100% for used oils affected by royal decree on July 1, 2006. Moreover, royal decree set the refining rates at 55% and 65% those of regenerable used oils, respectively, beginning in 2007 and 2008. EPR supposes that manufacturers of lubricating oils must ensure the proper management of the waste oils generated by the use of oils and of bearing the full cost of the operations necessary for them. Manufacturers can fulfill the obligations, within the framework of EPR, individually or collectively as an integrated management system (IMS). The IMS must finance all the costs resulting from the correct management of the quantity of used oils equal to that of used oil generated after the use of the oils put on the market by their associates. In turn, manufacturers must develop a business prevention plan (BPP), identifying measures to extend the useful life of lubricants, facilitate the recovery of waste oils and incorporate re-refined base oils into their composition.

1 The inadequate management of waste oils can cause significant negative effects, e.g., one liter of used oil can pollute up to one million liters of water; the uncontrolled burning of five liters of used oil can cause air pollution for as long as three years; and a spill of one liter of engine oil in a body of water can pollute an area as wide as 4,000 m2 (Torras, 1999).

2 The re-refining process involves the removal of pollutants, oxidation products, and additives from such oils (Angulo et al., 1996; Llobet, 1995; Gómez-Miñana, 1993; Ramsden, 1995).

3 SIGAUS (2017a).

In Spain, lubricant producers constitute the IMS for used industrial oils (namely, SIGAUS). Accordingly, lubricant producers contribute to SIGAUS, which was established to finance the management of used oils. This payment was established at 60€/ton of lubricating oil sold. Furthermore, the second BPP 2014-2017 is in force. In 2015, the market share or financial responsibility of SIGAUS, on total industrial oils affected by the legislation, is 87.15%[4]. As the main IMS for these oils, SIGAUS manages waste oils from non-compliant sources, namely, from free riders, which are mainly imported lubricants and lubricants for machinery; the market share associated with these oils decreased from 2.89% in 2012 to 1.41% in 2017. Therefore, the total share of financial responsibility for SIGAUS (with a margin of error of 10%) is 88.56%. In 2016, to protect the recovery and treatment of used oil from the instability of oil prices, SIGAUS established a financing mechanism indexed to the international quotation of lubricants, according to the Independent Commodity Information Services Index (ICIS)[5].

The purpose of this study is to examine the dynamic responses of the amount of used oils intended for re-refining and the price of base lubricants oils to the environmental objectives of recovery and refining of used oils, established by the Spanish Used Oils Management Act. The methodology consists of estimating a vector error correction model (VECM) for the Spanish used oils market during the period 1964-2016. Likewise, the causal relationship between the variables is studied through the Granger causality test. The market for re-refined oils and used oils in Spain has been analyzed previously for the period from 1965 to 1999 by estimating a linear supply and demand function for the re-refined oils market (Arner et al., 2003) and by using a three-stage least squares model (Arner et al., 2006). These studies aimed to obtain the elasticity of the supply and demand function to analyze the effectiveness and efficacy of policies promoting the collection and reuse of waste oil, mainly for burning. However, a VECM has not been previously used to analyze the used oils market or other waste markets. Accordingly, this study constitutes new research in this field.

The remainder of this paper is organized as follows. Section 2 provides background information on the Spanish used oils market. Section 3 reviews the economic literature on the subject of study. Section 4 presents the methodology, and Section 5 discusses the impulse-response functions and variance decomposition. Section 6 summarizes the main conclusions.

2. EVOLUTION OF THE MARKET OF OILS USED IN SPAIN

The management of waste oils has traditionally been characterized by the intrinsic financial imbalances of the collection and re-refining process, due to the atomization of the waste generation and the large investments required in the re-refining activity. As a result, the Spanish used oils market has been regulated since its inception. In 1989, the Spanish lubricating oils market was liberalized, and the regulation of waste oil no longer corresponded to the oil monopoly. From that moment, the interventions in the used oils market have directly addressed externalities arising from the low rate of collection of used oils. The environmental ministry passed an order on February 28, 1989, that obliged licensed collectors to deliver all oils, authorized the combustion of waste oils, and established grants for the collection and reuse of waste oils[6]. The exemption of the tax on hydrocarbons for used oils employed as fuel, which was established in 1995, ensured the economic viability of burning used oils for electric power production, which allowed for an increase in the collection rate of used oils from 49% in 1995 to 86.7% in 2000[7].

Subsequently, Directive 2000/76/EC on waste incineration, which pertained to the burning of used oils, was incorporated into Spanish law by Royal Decree 653/2003 of May 30 and became applicable to new facilities beginning in 2003 and to existing facilities beginning in 2005[8]. This specific regulation, which established stricter regulations regarding the burning of used oils, encouraged the establishment of new re-refining companies after CATOR (42,500 tons of used oils capacity) was installed in 1995 and Aceites Ecológicos (30,000 tons of used oils capacity) began operations between 1996 and 1998. One of these new companies was SANTOIL in Murcia (2000 to 2007), which developed its own process for managing 15,000 tons of waste oil. ECOLUBE/SERTEGO, which was established in 2002 in Madrid, uses the Interline process to manage 33,000 tons of waste oil. In the same year (2002), PMA S.L. was established in A Coruña to refine 30,000 tons of used oils using its own process. SERTEGO, established in 2004, combusted waste oil to produce electric power in Murcia and Huelva and modified its production process to include used oil re-refinement (40,000 and 32,000 tons, respectively, in used oil capacity). In addition, SERTEGO established a used oil re-refining plant in La Rioja in 2005 (20,000 tons of used oil capacity). Consequently, Spain's installed capacity for refining used oils is currently 197,500 tons. As a result, in the early 2000s, the collection rate reached 100% owing to the increased collection of used oils intended for re-refining, which represented 65% of used oils collected in 2005 (Table 1).

In this context, the Spanish Used Oils Management Act, which mandated extended producer responsibility in the management of waste oils, set the recovery rate of used oils at 95% and the refining rates of used oils at 55% and 65%, respectively, in 2007 and 2008. As shown in Table 1, since 2006, SIGAUS has consistently fulfilled the environmental objectives established in the Spanish Used Oils Management Act (Table 1). Likewise, the ratio between used oil

4 New market share according to the independent market study conducted by the consulting firm PwC in 2015. In turn, other used oils subject to Royal Decree 679/2006 include the SIPGY (the IMS for independent producers of used oils), which has a market share of 6.92%, and used oils in imported vehicles (ANIACAM, ANFAC), with a market share of 4.08% (SIGAUS, 2016).

5 SIGAUS (2017b).

6 B.O.E. of March 8, 1989, no. 57.

7 Royal Decree 413/2014 of June 6 (B.O.E. of 10 June 2014, no. 140) regulates the production of electricity at hydroelectric facilities from cogeneration, other resources and renewable energy sources by setting a compensation for investment after Royal Decree 1/2012 of January 27 (B.O.E. of 28 January 2012, no. 24) suspended economic incentives for the new production.

8 B.O.E. of June 14, 2003, no. 142.

Table 1: Lubricating oil consumption (LOC), used oils recovered (UOR) and used oils reused by burning (WOB) and re-refining (WOR) (units=tons)

Year	LOC (1)	Used oils produced %	UOR	UOR rate	WOB %	WOR %	Re-refined oils (2)	(2)/(1) %
2000	525,900	40.00	210,360	86.70	81.24	16.70	18.294	3.40
2001	508,300	40.00	203,320	92.32	73.46	25.12	28.297	5.30
2002	511,000	40.00	204,400	100.00	66.84	32.08	41.516	8.12
2003	514,400	40.00	205,760	100.00	60.36	38.74	49.932	9.70
2004	519,300	40.00	207,720	100.00	42.60	56.33	74.531	14.35
2005	515,600	40.00	206,240	100.00	33.72	65.53	84.050	16.30
2006	507,000	40.00	202,800	100.00	34.61	64.66	86.241	17.00
2007	415,421	41.68	173,151	100.00	26.40	73.60	82.434	20.00
2008	373,461	48.22	180,070	100.00	30.40	69.60	80.065	21.00
2009	312,662	49.50	154,775	100.00	33.20	66.80	65.193	20.00
2010	321,304	44.27	142,237	100.00	33.70	66.30	60.741	19.00
2011	302,265	44.48	134,452	100.00	30.97	69.02	60.695	20.08
2012	276,025	46.98	129,663	100.00	34.50	65.50	54.090	20.00
2013	268,589	47.21	126,796	100.00	35.00	65.02	53.388	19.80
2014	278,341	45.3	126,089	100.00	30.08	69.92	56.900	20.44
2015	291,670	41.39	120,715	100.00	21.23	78.77	61.537	21.00
2016	298,847	40.81	121,961	100.00	26.31	73.68	58.784	20.00

Desde 2006, aceite lubricante sujeto al Real Decreto 679/2006 de 2 de junio y el aceite usado recogido por SIGAUS. Since 2006, lubricating oil subject to Royal Decree 679/2006 of June 2 and the used oil recovered by SIGAUS. El consumo de lubricantes incluye el consumo de aceites de primer refino y regenerados.The consumption of lubricants includes the consumption of refined and re-refined oils. Source: Ministry of Environment (2006) and SIGAUS (2016)

produced and the consumption of lubricants has ranged between 40% and 49.5%, higher than the Ministry of the Environment's forecast ratio of 40%. EPR meant that the financing of the management of waste oils through subsidies was replaced by the contribution of the lubricant manufacturer to SIGAUS. In 2016, in the context of low oil prices, SIGAUS established an additional and transitional financing mechanism, indexed to the international quotation of lubricants, to ensure the management of used oils, according to ICIS, which affects the stretch of collecting used oil[9].

Law 22 of July 28, 2011, on waste and contaminated soils transposes. Directive 2008/98/EC, by which EPR is regulated[9]. In turn, the State Waste Framework Plan, 2016-2022, in compliance with Directive 2008/98/EC, includes among its objectives the establishment of a common legal framework for the implementation of EPR. The application of EPR to other wastes such as waste electrical and electronic equipment (WEEE), has meant a new distribution of responsibilities regarding waste oils. At the end of 2015, with the application of the new regulations on WEEE, where responsibility for oils contained in them is transferred from lubricant manufacturers to equipment manufacturers, the market share of SIGAUS was modified from 87.13% to 87.15%[10]. Additionally, stock fraud voluntarily assumes SIGAUS is modified from 2.89% to 1.41%. Therefore, SIGAUS's financial responsibility is 88.56%. Finally, in 2017, according to the new legislation on end-of-life vehicles (VFU), SIGAUS's market share has been set to 85.34%, and the fraud market that has voluntarily assumed is 1.23% of total used oil subject to royal decree[11]. Therefore, SIGAUS's financial liability is 86.57%.

3. REVIEW OF ECONOMIC LITERATURE

Dynamic analyses of waste markets were previously formulated by introducing the hypothesis of adaptive expectations (Deadman and Turner, 1981; Edwards, 1977; Edwards and Pearce, 1978), wherein the producer of recycled paper plans production at the beginning of a period based on expected prices, costs, and expectations about the availability of waste paper. These studies were performed based primarily on data from the waste paper market. Based on the market experiences of producers, Edwards (1977) based expected prices on past values of prices and variations in expected prices. Kinkley and Lahiri (1984) introduced the rational expectations hypothesis, which is characterized by the expected value of a variable based on all available information, not solely on its past value. Other works incorporating a dynamic model of waste paper generation include those of Anderson and Spiegelman (1977), Edgren and Moreland (1989), Gill and Lahiri (1980), and Nestor (1991). In addition, dynamic models of scrap generation have been developed for steel (Anderson and Spiegelman, 1977); lead (Sigman, 1995); copper (Fisher et al., 1972; Slade, 1980); aluminum (Blomberg and Hellmer, 2000; Suslow, 1986); and nickel, zinc, iron ore, and tin (Evans and Lewis, 2005).

Vectors autoregressive (VARs) have not been previously used in the analysis of waste markets. VAR estimation and, subsequently, the analysis of impulse-response functions and variance decomposition have been the methods commonly used to analyze the effect of a shock on macroeconomic behavior (Maslyuk and Dharmaratna, 2013). Otherwise, the international price of oil directly affects the economic value of used industrial oil and therefore the profitability of recovery and final treatment[12]. A VECM is a vector autoregressive that incorporates, as a constraint,

9 B.O.E. of July 29, 2011, no. 181.

10 Royal Decree 110/2015, of February 20, on waste electrical and electronic equipment (WEEE) (B.O.E. of February 21, 2015, no. 45). New market share according to independent market study conducted by the consulting firm PwC (SIGAUS, 2016).

11 Royal Decree 20/2017, of January 20, on vehicles at end of life (BOE of January 21, 2017, no. 18). New market share according to independent market study conducted by the consulting firm PwC (SIGAUS, 2017a).

12 SIGAUS (2016).

the long-term relationship between variables. If a cointegration relationship exists, the VECM may be more appropriate; however, VECM only allows for the establishment of long-term restrictions (Narayan et al., 2008). In addition, in the presence of cointegration, a model for the differenced data supposes a loss of information (Effiong, 2014). Consequently, there is no unanimous position in the literature regarding the use of a restricted or unrestricted vector autoregressive.

The increase in oil prices between 2002 and 2008 and the sharp decline since the second half of 2008 have renewed interest in the study of the effects of energy price shocks in macroeconomics (Depratto et al., 2009). Hamilton (1983) notes that between the price of energy and production there is a temporal and cyclical correlation. However, since the beginning of the 1980s, economic analysis has aimed to explain why the effect of oil shocks on GDP is weaker than in previous stages and why the effects are both positive and negative, which is attributed to the endogeneity of the price oil in the macroeconomic framework. The nonlinear relationship between oil shocks and the behavior of macroeconomics aggregates are usually studied by VAR structural models or SVARs.

In this paper, the review of the economic literature on oil shocks refers to production and consumption[13]. Jimenez-Rodriguez and Sánchez (2005) empirically studied the effects of oil shocks on the real economy of the main industrialized countries, using linear and nonlinear multivariate VAR models. The results show a nonlinear relationship between oil shocks and GDP. In turn, the effect of increases in the price of oil is higher than the effect of decreases, which is insignificant in most cases. Finally, with respect to oil-importing countries, positive oil shocks have a negative effect on production, except in Japan. Depratto et al. (2009), with respect to Canada, the United Kingdom and the United States for the period 1971-2008, observed that increases in oil prices have temporarily negative effects on the growth *gap* and the trend of growth. This effect persists over time and therefore implies a reduction in current and future production. Al Rasasi and Yilmaz (2016), regarding the aggregate product in Turkey, observed that oil shocks negatively affect the aggregate product, with a period of difference. These authors analyzed asymmetric shocks in particular and suggested that positive and negative shocks negatively affect the product, with a period of difference. On the other hand, Farzanegan and Markwardt (2009), using a VAR model, found a strong and positive relationship between positive oil price shocks and industrial growth in Iran.

Regarding the consequences of oil shocks for consumption, Mehra and Petersen (2005) concluded that net increases in oil prices have a negative effect on consumer spending, while reductions do not have such an effect. Zaman (2015), for five OECD countries (Germany, Canada, United States, United Kingdom and Sweden), noted that the effect of oil shocks on consumption persists over time. Thus, it is observed that the price of oil has a certain predictive effect on consumption for both oil-exporting countries (Canada) and oil-importing countries. Algaeed (2017) analyzed, theoretically and empirically, the relationship between an asymmetric oil shock and consumption in Saudi Arabia in the period 1985-2015. The results show that an increase in the price of oil positively affects income and, consequently, consumption. The relationship also occurs in the opposite direction; however, the average reduction in income is 21%, while consumption decreases by approximately 24%. Finally, Zhang and Broadstock (2014) observed that the effect of oil shocks on consumption is asymmetric in several countries belonging to ASEAN and in East Asia. As a result, the integration of energy markets in the region is desirable to share risks and optimize the allocation of resources to international shocks.

13 The literature on the effects of oil shocks on stock markets, inflation, short-term interest rates and the exchange rate is extensive and includes, for example, the studies of Eryigit (2012), Effiong (2014), Gao et al. (2014) and Yildirim et al. (2015).

4. METHODOLOGY

This work, which involves the estimation of a VECM, as well as the calculation of the impulse-response functions and variance decomposition, aims to examine the dynamic responses in the market of used oils to the environmental objectives of recovery and refining of used oils established by the Spanish Used Oils Management. The market for waste oils has been previously characterized as subordinate to the wider market for petroleum products, lubricants and fuel oil (Arner et al., 2006). In turn, according to Royal Decree 679 of June 2, re-refining is the priority destination of used oils, with 65% of used oils intended for re-refining. Consequently, the variables used in this work are the amount of waste oils intended for re-refining, *WOR,* and the price of the lubricating oil base first refining, *FRP,* in current monetary units. In addition, the causal relations between the *WOR* and *FRP* variables are analyzed. In the following sections, the order of integration of the variables is first analyzed by the unit root M tests of Ng-Perron. Then, according to the method of Engle and Granger (1987), a cointegration contrast is performed by estimating a restricted vector autoregressive (RVAR) or VECM. The sample period is 1964-2016, and data refer to annual periods (see annex of statistical sources).

4.1. Analysis of the order of integration of the variables

The order of integration of variables *WOR* and *FRP* is analyzed by M unit root tests MZA, MZt, and MSB, proposed by Ng-Perron in 1996, and the MPT test (Ng and Perron, 2001). The MPT uses the GLS estimator to establish the deterministic components in the regression for the determination of the integration order, corresponding to the Dickey Fuller test (ADF), which allows for more efficient results (Elliot et al., 1996). The GLS detrending also allows for a more precise autoregressive spectral density estimate and ensures that it is invariant to the parameters of the trend function (Ng and Perron, 2001). Also, they suggest a modification of AIC unit root test, the MAIC, which takes account of the fact that the bias in the estimate of the sum of the autoregressive coefficients is highly dependent on the lag order *k*.

Table 2 shows the value of the test statistics Ng-Perron MZA, MZt, MSB and MPT for the variables *WOR* and *FRP* using the MAIC criterion for determining the number of delays and a maximum delay equal to nine. In all M tests, the null hypothesis of the existence of a unit root is contrasted with the alternative hypothesis of stationarity. According to Table 2, for both variables, *WOR* and *FRP,* the null hypothesis of the existence of a unit root is rejected at any level of significance. Consequently, *WOR* and *FRP* are stationary variables, or I (0). In first differences, however, the null hypothesis of the existence of a unit root is not always rejected at any level of significance. Therefore, a VECM is estimated to analyze first the cointegration relation of the variables and then the dynamic responses of *WOR* and *PPR* to the environmental objectives of recovery and refining of used oils established by Royal Decree 679/2006.

4.2. The VECM

If a set of variables are cointegrated, restrictions can be detected by differing the restricted and unrestricted VAR (Greene, 2008). The VECM, or vector autoregressive in first differences, constitutes a self-regression with constraints that determine a cointegration relationship between non-stationary series. According to the Granger representation theorem, if a set of variables is cointegrated, it can be represented by an error correction model (Novales, 2010). The introduction of the cointegration relationship into the VAR equations implies the formulation of the model in first differences and levels, and all are stationary terms I(0). Usually, a vector of variables *zt* allows for an error correction representation if it can be expressed as follows:

$$A(L)\Delta z_t = -\gamma_t ' w_{t-1} + \mu_t, \quad \gamma_t \neq 0 \tag{1}$$

Where μ_t is a stationary perturbation vector, $A(0) = I_k$, with all roots of the characteristic equation $|A(L)| = 0$ lying outside the unity circle. Therefore, w_{t-1} represents the margin by which the conditions of stable equilibrium between the variables that make up the vector z_t are no longer satisfied at time t-1, and γ is the vector of coefficients with which w_{t-1} is incorporated into the VAR equations. Consequently, at equilibrium, w_{t-1} is equal to cero.

In this representation, w_t is a vector of cointegration relationships between variables of z_t,

$$w_t = \alpha ' z_t \tag{2}$$

In addition, following Mehdi and Seyyed (2013), VECM is a kind of VAR model used with cointegration restrictions which form is:

$$\Delta Y_t = B_1 \Delta Y_{t-1} + \ldots + B_{p-1} \Delta Y_{t-p} + \Pi Y_{t-1} + U_t \tag{3}$$

$$\Pi = \alpha\beta ' \tag{4}$$

Where B_i is the matrix of parameters; $\prod$ contains the long-run information. The matrix α is the matrix of error correction coefficients which measure the speed of adjustment to long-term equilibrium. Matrix β is long-term equilibrium. The error correction terms, $\beta' Y_{t-1}$ are the mean reverting weighted sums of cointegrating vectors and data dated t-1.

Table 3 presents, if, L is the logarithmic notation of the variables, the estimation output of the VECM for the variables *WOR* and

Table 2: Ng-Perron modified unit root test

Model	Intercept				Intercept and trend			
Levels	MZa	MZt	MSB	MPT	MZa	MZt	MSB	MPT
WOR	−5.19174*,**,***	−1.55364*,**,***	0.29925*,**,***	4.86976*,**,***	−9.43183*,**,***	−2.13402*,**,***	0.22626*,**,***	9.81813*,**,***
FRP	−3.83940*,**,***	−1.36293*,**,***	0.35499*,**,***	6.39695*,**,***	−10.6143*,**,***	−2.17956*,**,***	0.20534*,**,***	9.17681*,**,***
First d	MZa	MZt	MSB	MPT	MZa	MZt	MSB	MPT
dWOR	−181260**,***	−2.84556**,***	0.15699**,***	6.00706**,***	−18.1260***	−2.84556***	0.15699***	6.00706***
dFRP	−24.8901	−3.30688	0.13286	1.69770	−25.0980**,***	−3.38214**,***	0.13476**,***	4.56764**,***

Critical values are from Ng-Perron test (2001): Model with intercept asymptotic critical values for 1, 5 and 10% are as follows: (1) MZa: −13.8, −8.1, and −5.7; (2) MZt: −2.58, −1.98, −1.62; (3) MSB: 0.174, 0.233, 0.275; (3) MPT: 1.78, 3.17, 4.45. Model with intercept and trend asymptotic critical values for 1, 5 and 10% are as follows: (1) MZa: −23.8, -17.3, −14.2; (2) MZt: −3.42, −2.91, −2.62; (3) MSB: 0.143, 0.168, 0.18.5; (3) MPT: 4.03, 5.48, 6.67. *,** and *** denote rejection of the null hypothesis at 1%, 5% and 10% significance levels

FRP, without considering intercept and trend. The order of the VECM is determined by the test of exclusion order of the VECM or by the Wald test for the null hypothesis that the order of VCE, p_0, is lower than p_1 versus the alternative hypothesis that p_0, is higher than p_1. The results of the test of exclusion order of the VEC in Table 4, with p equal to 10, show that at a significance level of 10%, the order of the VCE is equal to 2.

The estimation output confirms, at a significance level of 10%, the individual significance of the coefficient β, which is negative at −1.780651 (Table 3). Regarding the coefficient α_1, which is negative at −0.016490, and the coefficient α_2, which is positive at 0.074277, the results confirm their individual significance at a significance level of 5%. Moreover, the coefficients of d($LWOR_{t-1}$) and d($LWOR_{t-2}$) in the price equation are significant at a significance level of 10%. According to Jalil, et al. (2009), there is a causal relationship of *LWOR* in *LFRP*. Therefore, no individual significance is justified for the coefficients of $d(LWOR_{t-1})$ and $d(LWOR_{t-2})$ in the amounts equation or for the coefficients of $d(LFRP_{t-1})$ and $d(LFRP_{t-2})$ in both equations. Thus, the estimated VECM can be considered satisfactory. As a result, the estimated output suggests that there is a cointegration relationship.

In addition, there is a stark contrast among the characteristics of the error term, which highlights the absence of autocorrelation based on the VEC residual serial correlation Lagrange multiplier test. Consequently, the error term is uncorrelated with the lagged values of the variable and with the other variables considered in the specification of the VECM, although there may be contemporaneous correlation in the error term. Table 3 shows that the null hypothesis of no serial correlation is accepted for i equal to 1 at significance level of 5%. Figure 1 presents correlograms to extend the absence of autocorrelation. According to the Jarque-Bera test, the null hypothesis that the residuals are normally multivariate is rejected at a significance level of 5%. Finally, the null hypothesis suggesting the absence of heteroskedasticity (including cross terms) is rejected at a significance level of 5%.

5. RESULTS

5.1. Granger Causality Test

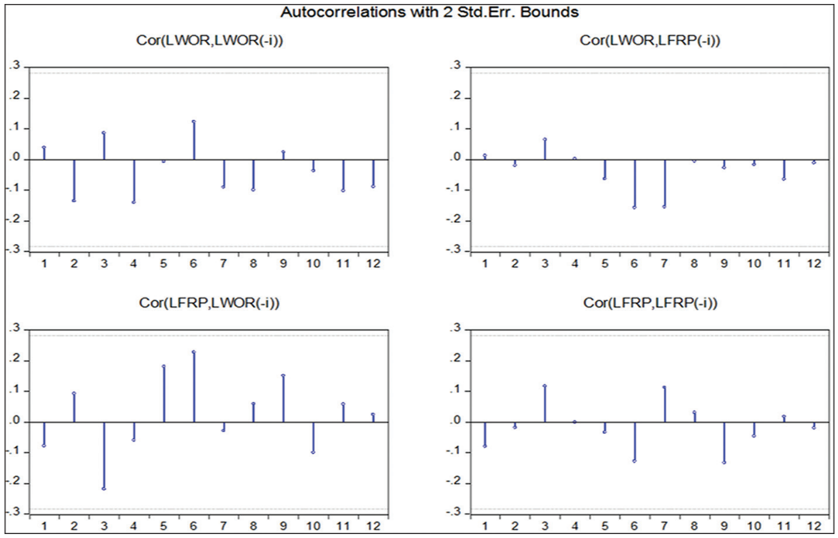
The analysis of the causal relationships between the variables *LWOR* and *LFRP* is performed first by the pairwise causality Granger test. Because the null hypothesis of variable x does not Granger cause variable y, this test shows causation in the short term between the variables. The results in Table 5 corroborate, at a significance level of 5%, that there is no single causal relationship between *LWOR* and *LFRP*.

Subsequently, a test of block exogeneity is performed, which involves two bivariate Granger causality tests (Table 6). In the first

Table 3: Vector error correction estimates

Cointegration equation			
LWOR (*t*−1)	1.000000-1.780651		
LFRP (*t*−1)	(0.07201)		
	[−24.7268]		
VCE	**d (*LWOR*)**		**d (*LFRP*)**
CointEq1	−0.016490		0.074277
	(0.04906)		(0.02411)
	[−0.33610]		[2.65609]
d ($LWOR_{t-1}$)	0.512855		−0.005156
	(0.14257)		(0.08126)
	[3.59733]		[−0.06345]
d ($LWOR_{t-2}$)	−0.250201		−0.114572
	(0.12982)		(0.07400)
	[−1.92724]		[-1.54836]
d ($LFRP_{t-1}$)	0.051902		−0.010034
	(0.26174)		(0.14919)
	[0.19829]		[−0.06726]
d ($LFRP_{t-2}$)	0.134390		0.129938
	(0.26470)		(0.15087)
	[0.50770]		[0.86124]
R^2	0.236870		0.143690
Adjusted R^2	0.169036		0.067574
Serial correlation LM test	Retardos (l)	LM-statistics	P-value
(Null Hypothesis: no serial correlation at lag order h)	1	6.619094	0.1574
	2	3.408455	0.4919
VEC residual normality test	Jarque-Bera	Df	P-value
Orthogonalization: Cholesky (Lutkepohl)	10.31436	4	0.0355
(Null Hypothesis: residuals are multivariate normal)			
VEC residual heteroskedasticity test: Includes cross terms	Chi-square	Df	P-value
	83.42750	60	0.0244

Figure 1: Correlograms



test, the null hypothesis that the variable d(*LWOR*) Granger causes the other variables in the model is examined, and the second test examines the null hypothesis that the variable d(*LFRP*) Granger causes the other variables in the model. Accordingly, the results in Table 6 show, at a significance level of 5%, that there is no single causation of *LWOR* in *LFRP* or of *LFRP* in *LWOR*.

However, the existence of a cointegration relationship between variables implies a causal long-term relationship. In turn, according to Jalil et al. (2009), *LWOR* is the Granger cause of the variable *LFRP*. Additionally, Jalil et al. (2009) noted that if there is a Granger causal relationship between variables, the forecast analysis of variance decomposition measures the relative importance of the variables. If a variable explains a reduced percentage of the other variable prediction error, it can be concluded that a weak Granger causal relationship exists.

5.2. Impulse-response Functions and Variance Decomposition

A shock to the *i*-th variable not only directly affects variable *i* but is also transmitted to all other endogenous variables through the dynamic lag structure of the VARs. Thus, impulse-response functions (IRFs) of an innovation produce a chain effect over time that affects all variables in the VARs. The IRFs quantify the effect of one standard deviation or a variable shock in the present and future behavior of other variables. Accordingly, IRFs demonstrate whether the response of a variable to a shock occurs only in the short term or persists over time (Algaeed, 2017). To identify the *i*-th innovation, similarly to the case in which there is a shock to the *i*-th endogenous variable y_{it}, the Cholesky transformation is used to orthogonalize original innovations (Johnston and Dinardo, 2001). Consequently, the Cholesky transformation implies that the order of variables in a VAR should be defined.

Figure 2 shows the IRFs of *LWOR* and *LFRP* variables for a one-standard-deviation positive shock in the *LWOR* variable produced by the objectives of 95% waste oil recovery and the re-refining of 55% and 65% of regenerable used oils, as fixed

Table 4: VEC lag exclusion wald tests

Lags	*dLWOR*	*dLFRP*	Joint
dlag1	3.288409	1.487352	6.800422
	[0.193166]	[0.475363]	[0.146818]
dlag2	2.151409	0.904074	2.790643
	[0.341057]	[0.636331]	[0.593449]
dlag3	1.628751	7.566082	10.32012
	[0.442916]	[0.022753]	[0.035367]
df	2	2	4

Table 5: Pairwise Granger causality tests

Null hypothesis	F-statistic	P-value
LFRP does not Granger cause *LWOR*	0.65516	0.7521
LWOR does not Granger cause *LFRP*	1.27834	0.3008

by Royal Decree 679/2006, in 2007 and 2008, respectively. As is typically done in other works, a maximum number of horizons equal to 10 is considered. In this case, the *LWOR* variable is ordered first, followed by the variable *LFRP*. According to Figure 2, *LWOR* increases, although it decreases at 3 years and beyond. Similarly, *LFRP* increases, but the effect decreases at 2 years and beyond. In addition, the IRFs are, as expected, positive. Finally, if the combined graphs of the IRFs are considered, namely, if the effect is considered from the supply and demand point of view, the response of the variable *LFRP* ends in the 6th-year period because the decreasing of lubricating oil consumption. As a result, as shown in Figure 2, the response of the variable *LWOR* ceases 3 years later, in the 9th-year period.

The results of the variance decomposition are similar to those of the IRFs for the VECM. Variance decomposition provides information about the relative importance of each random innovation in affecting the variables in the VARs. The source of the forecast error is the variation in the current and future values of the endogenous variables resulting from innovations to these variables. Table 7 presents the forecast error of each variable at a given horizon in the VECM (SE value) following the percentage of these forecast errors due to each of the endogenous variables. According to Table 7, the forecast errors of 0.36 and 0.21 for *LWOR* and *LFRP*, respectively, in year one suggest that the prediction error is justified by the environmental objectives of recovery and refining of used oils established in 2006. The analysis of causal relationships, moreover, demonstrates that the variable *LWOR* is the Granger cause of the variable *LFRP*. In turn, the variable *LFRP* explains less than 10% of the prediction error of *LWOR*, thus indicating a weak causal Granger relation, whereas *LWOR* explains 36% of the prediction error of *LFRP* in horizon 9. Consequently, the analysis of variance decomposition also suggests the existence of a causal relationship of *LWOR* in *LFRP*.

6. CONCLUSIONS

The Spanish Used Oils Management Act (Royal Decree 679 of June 2, 2006), which mandates EPR in the management of waste oils, set the recovery and valorization rates of used oils to 95% and 100% for used oils affected by royal decree on July 1, 2006. Moreover, royal decree set the re-refining rates of regenerable used oil in 2007 and 2008 to 55% and 65%, respectively. Consequently, systems other than that established in 1989 under the state budget with respect to the financing of the recovery and refining of waste oils culminated in the implementation of an IMS for waste oils (namely, SIGAUS). As the main IMS for these oils, SIGAUS manages waste oils from non-compliant sources, the proportion of which decreased from 2.89% in 2012 to 1.41% in 2015. Hence, the purpose of this study was to examine the dynamic responses of the amount of used oils intended for re-refining and the price of base lubricant oils to the environmental objectives of recovery and refining of used oils established by the Spanish Used Oils Management Act. The method consisted in first analyzing the order of integration of the variables according to the Ng-Perron unit root test. Subsequently, a VECM was estimated for the period 1964-2016 to calculate IRFs and determine variance decomposition. Likewise, the causal relationship between the variables was studied through the Granger causality test. The estimation output suggests a cointegrating relationship between the variables *LWOR* and *LFRP*. In turn, *LWOR* is the Granger cause of the variable *LFRP*.

A one-standard-deviation shock to positive waste oils intended for re-refining that results from the objectives fixed by Royal Decree 679/2006 causes the variable *LWOR* to increase. However, the variable decreases at 3 years and beyond. In addition, the variable *LFRP* increases, but the effect is smaller at 2 years and beyond. Therefore, the objectives of recovery and re-refining fixed in 2007

Figure 2: Vector error correction impulse-response functions

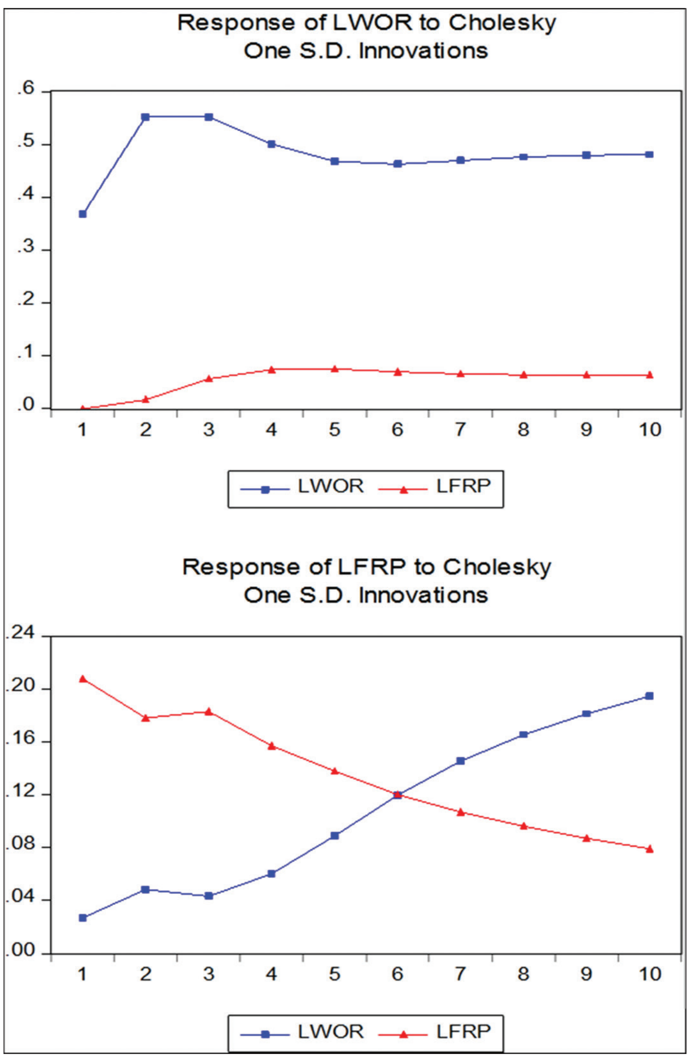


Table 6: VEC Granger causality/block exogeneity wald test

Dependent variable: dLWOR			
Excluded	**χ^2**	**g.l.**	**P-value**
d*LFRP*	0.285074	2	0.8672
All	0.285074	2	0.8672
Dependent variable: dLFRP			
Excluded	**χ^2**	**g.l.**	**P-value**
d*LWOR*	2.715242	2	0.2573
All	2.715242	2	0.2573

Table 7: Variance decomposition

Horizon	Standard error	*LWOR*	*LFRP*
LWOR			
1	0.367851	100.0000	0.000000
2	0.664079	99.93526	0.064741
3	0.865682	99.52945	0.470546
4	1.002870	99.10565	0.894347
5	1.109336	98.80753	1.192475
6	1.204120	98.64840	1.351596
7	1.294225	98.56986	1.430144
8	1.380716	98.52735	1.472648
9	1.463155	98.49899	1.501005
10	1.541460	98.47781	1.522187
LFRP			
1	0.209666	1.654748	98.34525
2	0.279503	3.949498	96.05050
3	0.337012	4.373003	95.62700
4	0.376735	6.066191	93.93381
5	0.411011	9.787956	90.21204
6	0.444753	15.64112	84.35888
7	0.480128	22.63238	77.36762
8	0.516962	29.79265	70.20735
9	0.554796	36.56892	63.43108
10	0.593318	42.75055	57.24945

and 2008 by royal decree are in accordance with the IRFs of the *LWOR* and *LFRP* variables. In addition, the analysis of variance decomposition further corroborates the causation of *LWOR* in *LFRP*. Finally, the IRFs for the variable *LWOR* suggest that the effect ended in 2015. Consequently, in 2015 and 2016, new waste oils intended for re-refining shock took place as a result of the new share of responsibilities regarding oils used for the application of EPR to other residues. In turn, in 2016, a new funding mechanism for the financing section of the recovery linked to the international price of lubricants was established.

Statistical Annex

Data for *WOR*, the amount of used oils intended for re-refining, prior to 1993 are sourced from the Government Delegation to CAMPSA (various years); the Spain's state-owned petroleum products company, CAMPSA (various years); and the Ministerial Resolution of Grants. For 1994 and thereafter, data for *WOR* are sourced from information provided by the Ministry of Environment (personal communications) and its annual publication, Medio Ambiente en España. A conversion factor of 0.6 is used to calculate the quantity of waste oils in terms of an equivalent quantity of re-refined oil.

The variable *FRP* is the nominal price of first-refined base oil, including taxes. Data pertaining to the oil monopoly period are sourced from the Government Delegation in the CAMPSA year books, while prices prevailing from 1987 to 1991 are market prices provided by REPSOL, an integrated global energy company based in Spain. For 1992 and thereafter, import prices are derived from the databases of DATACOMEX (Spanish Ministry of Industry and Technology), which is available at http://datacomex.comercio.es/ [October 10, 2016], and STACOM (ICEX, an agency for foreign trade of the Spanish Ministry of Industry, Tourism and Trade), available at http://estacom.icex.es/ [October 10, 2016].

7. ACKNOWLEDGMENTS

I would like to thank Jesús Mur Lacambra, working in the Department of Economic Analysis of Zaragoza University, for his comments on this work. In addition to J.Mª. Moreno, main research of Grupo Decisión Multicriterio Zaragoza (GDMZ), which provided support.

REFERENCES

Al Rasasi, M., Yilmaz, M. (2016), The effects of oil shocks on Turkish macroeconomic aggregates. International Journal of Energy Economics and Policy, 6(3), 471-476.

Algaeed, A.H. (2017), The effects of asymmetric oil price shocks on the Saudi consumption: An empirical investigation. International Journal of Energy Economics and Policy, 7(1), 99-107.

Anderson, R.C.Y., Spiegelman, R.D. (1977), Tax policy and secondary material use. Journal of Environmental Economics and Management, 4, 68-82.

Angulo, J., de las Heras, J.F., Pantoja, J.L.M. (1996), La regeneración de aceites usados: Un proceso viable. Ingeniería Química, 320, 173-176.

Arner, A., Barberán, R., Mur, J. (2003), Las políticas públicas de fomento de la regeneración de aceites usados. Hacienda pública esp. Revista de Economía Pública, 167, 33-55.

Arner, A., Barberán, R., Mur, J. (2006), La política de gestión de residuos: Los aceites usados. Revista Economia Aplicada, 42, 81-100.

Blomberg, J., Hellmer, S. (2000), Short-run demand and supply elasticities in the West European market for secondary aluminium. Resource Policy, 26, 39-50.

CAMPSA (Varios Años), Memoria. Madrid: Compañía Arrendataria del Monopolio de Petróleos. Available from: http://www.cnmv.com. [Last accessed on 2017 Mar].

De Pratto, B., De Resende, C., Maier, P. (2009), How Changes in Oil Price Affect the Macroeconomy, Bank of Canada Working Paper. Available from: http://www.bankofcanada.ca/wp-content/uploads/2010/02/wp09-33.pdf. [Last accessed on 2017 Mar].

Deadman, D., Turner, R.K. (1981), Modelling the supply of wastepaper. Journal of Environmental Economics and Management, 8, 100-103.

Edgren, J.A., Moreland, K.W. (1989), An econometric analysis of paper and wastepaper markets. Resource Energy, 11, 299-319.

Edwards, R. (1977), Price Expectations and the Supply of Waste Paper in the UK and the USA, Occasional Paper 77-13, Department of Political Economy, University of Aberdeen.

Edwards, R., Pearce, D. (1978), The effect of prices on the recycling of waste materials. Resource Policy, 4, 242-248.

Effiong, E.K. (2014), Oil price shocks and Nigerian's stock market: What have we learned from crude oil market shocks? OPEC Energy Review,38, 36-58.

Elliot, G., Rothenberg, T.J., Stock, J.H. (1996), Efficient test for an autoregressive unit root. Econometrica, 64(4), 813-836.

Engle, R.F., Granger, W.J. (1987), Co-integration and error correction: Representation, estimation, and testing. Econometrica, 55(2), 251-276.

EPA. (1989), How to Set Up a Local Program to Recycle Used Oil, Environmental Protection Agency Document. Available from: https://www.nepis.epa.gov/exe. [Last accessed on 2016 Oct].

Eryigit, M. (2012), The dynamical relationship between oil price shocks and selected macroecomic variables in Turkey. Economic Research, 25(2), 263-276.

Evans, M., Lewis, A.C. (2005), Dynamic metals demand model. Resources Policy, 30, 55-69.

Farzanegan, M.R., Markwardt, G. (2009), The effects of oil price shocks on the Iranian economy. Energy Economics, 31, 134-151.

Fisher, F.M., Cootner, P.H., Baily, M.N. (1972), An econometric model of the world copper industry. Bell Journal of Economics and Management Science, 3, 568-609.

Gao, L., Kim, H., Saba, R. (2014), How does the oil price shock affect consumers? Energy Economics, 45, 313-323.

Gill, G., Lahiri, K. (1980), An econometric model of wastepaper recycling in the USA. Resources Policy, 6, 320-325.

Gómez-Miñana, J.A. (1993), Los aceites usados. Quién tiene la culpa de que se quemen. Revista Técnica Medio Ambiente, 34, 17-22.

Greene, W.H. (2008), Análisis Econométrico. Madrid: Prentice-Hall.

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

Jalil, N.A., Ghani, G.M., Duasa, J. (2009), Oil prices and the Malaysia economy. International Review of Business Research Papers, 5(4), 232-256.

Jimenez-Rodriguez, R., Sanchez, M. (2005), Oil price shocks and real GDP growth: Empirical evidence for some OCDE countries. Applied Economics, 37, 201-228.

Johnston, J., Dinardo, J. (2001), Métodos de Econometría. Madrid: Vicens Vives.

Kinkley, C.C., Lahiri, K. (1984), Testing the rational expectations hypothesis in a secondary materials market. Journal of Environmental Economics and Management, 11, 282-291.

Llobet, D.L. (1995), Hacia un sistema global de gestión. In: CIMAT, editor. I Conferencia Internacional de Gestión de Residuos RESIDUA 95, Sevilla.

Maslyuk, S., Dharmaratna, D. (2013), Renewable electricity generation, CO2 emissions and economic growth: Evidence from middle-income countries in Asia. Revista de Estudios de Economía Aplicada, 31-1, 217-244.

Mehdi, S., Seyyed, Y.A. (2013), Modeling the impact of money on GDP and inflation in Iran: Vector-error-correction-model (VECM) approach. African Journal of Business Management, 7(35), 3423-3434.

Mehra, Y.P., Petersen, J.D. (2005), Oil prices and consumer spending. Federal Reserve Bank of Richmond Economic Quartely, 91(3), 53-72.

Ministerio de Medio Ambiente. (2006), Medio Ambiente en España 2005, Secretaría General Técnica. Available from: http://www.magrama.gob.es/es/estadistica/temas/estadisticas-ambientales/memoria-2005.aspx. [Last accessed on 2016 Oct].

Narayan, P.K., Narayan, S., Prasad, A. (2008), A structural VAR analysis of electricity consumption and real GDP: Evidence from the G7 countries. Energy Policy, 36, 2765-2769.

Nestor, D.V. (1991), Increasing the Rate of Recycling when Demand is Price-Inelastic: A Case Study of the Market for Old Newspapers, Dissertation. Knoxville: The University of Tennessee.

Ng, S., Perron, P. (2001), Lag length selection and the construction of unit root tests with good size and power. Econometrica, 69, 1519-1554.

Novales, A. (2010), Econometría. Madrid: McGraw-Hill.

Ramsden, D.P. (1995), Used Oil Recycling-Quality again in R’95 Recovery Recycling Re-Integration International Congress, UK.

SIGAUS. (2016), Nuevo Sistema de Financiación 2016, Noticias, nº 22. Available from: http://www.sigaus.es. [Last accessed on 2017 Mar].

SIGAUS. (2017a), Noticias. Available from: http://www.sigaus.es/comunicacion/sala-de-prensa/noticias/nueva-cuota-de-mercado2017.aspx. [Last accessed on 2017 Jul].

SIGAUS. (2017b), Memoria de Sostenibilidad 2016. Available from: http://www.sigaus.es/media/2472914/memoria2016_completa_flipbook.pdf. [Last accessed on 2017 Jul].

Sigman, H.A. (1995), A comparison of public policies for lead recycling. RAND Journal of Economics, 26, 452-478.

Slade, M.E. (1980), An econometric model of the US secondary copper industry: Recycling versus disposal. Journal of Environmental Economics and Management, 7, 123-141.

Suslow, V.Y. (1986), Estimating monopoly behaviour with competitive recycling: An application to Alcoa. RAND Journal of Economics, 17, 389-403.

Torras, J.M. (1999), El re-refinamiento como solución sostenible para el aceite usado. Proyecto Ecoroil Residuos, 49, 88-92.

Yildirim, N., Ozcalebi, O., Ozkan, S.O. (2015), Revisiting the impacts of oil price increases on monetary policy implementation in the largest oil importers. Original Scientific Paper Faculty of Economics. Istanbul University UDC. Available from: http://www.file:///C:/Users/asun/Downloads/SSRN-id2632948.pdf. [Last accessed on 2017 Mar].

Zaman, N. (2015), Do Oil Price Shocks Affect Household’s Consumption Evidence from Five OECD Countries, Lund University.

Zhang, D., Broadstock, D. (2014), Impact of international oil price shocks on consumption expenditures in ASEAN and East Asian. In: Han, P.Y., Kimura, F., editors. Energy Market Integration in East Asia: Energy Trade, Cross Border Electricity, and Price Mechanism, ERIA Research Project Report FY2013, No. 29. Jakarta: ERIA. p345-367.