Evaluación de las políticas de gestión de aceites usados: la responsabilidad ampliada del productor

Evaluation of waste oil management policies: the extended producer responsibility

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RESUMEN
El Real Decreto 679, de 2 de junio de 2006, de gestión de los aceites industriales usados, establece la responsabilidad ampliada del productor (RAP). Para su aplicación se constituye el Sistema Integrado de Gestión de Aceites Usados en España (SIGAUS), sustituyéndose la financiación de la gestión de los aceites usados mediante subvenciones por los importes recaudados de la aportación del productor de aceites lubricantes. A su vez, el real decreto establece los objetivos medioambientales de recogida del 95% de aceites usados generados, valorización del 100% de aceites usados recogidos y regeneración del 55%, en 2007, y el 65%, desde 2008. La extensión de la RAP en 2015 a otros residuos, que contienen aceites usados, modifica la responsabilidad financiera de SIGAUS. Asimismo, en 2016, es necesario disponer de mecanismos de financiación adicionales, indexados a la cotización internacional de los lubricantes. Este trabajo tiene por objeto analizar la eficiencia de la RAP en la gestión de los aceites usados. La metodología consiste en la estimación de las elasticidades de oferta y demanda, así como el desarrollo de un modelo de equilibrio parcial, del mercado de aceites usados. De acuerdo con los resultados, la RAP constituye un estándar de material reciclado, basado en un sistema de permisos negociables, y es más eficiente que una subvención. El precio del permiso justifica la aportación del productor a SIGAUS de 60 € por tonelada. Finalmente, los resultados sugieren que la RAP garantiza la financiación de la gestión del aceite usado hasta 2015.

Palabras clave: Aceites usados, Regulación medioambiental, Eficiencia, Responsabilidad ampliada del productor, Subvenciones.

ABSTRACT
Royal Decree 679/2006 of June 2 on the management of used industrial oils mandates the producer extended responsibility (EPR). For its implementation, the Integrated Waste Oil Management System (SIGAUS) is established, replacing the financing of the management of waste oils through subsidies for the amounts collected from the contribution of the producer of lubricating oils. In turn, the royal decree sets environmental targets for collecting 95% of waste oils generated, the recovery of 100% of waste oils collected, and regeneration of 55%, in 2007, and 65%, since 2008. The extension of EPR in 2015 to other waste, containing waste oils, modifies SIGAUS' financial responsibility. Additional financing mechanisms, indexed to the international quote of lubricants, are also needed in 2016. This work aims to analyze the efficiency of EPR in the management of

waste oils. The methodology consists of estimating supply and demand elasticities and developing a partial equilibrium model of the waste oils market. According to the results, EPR is a recycled material standard (RMS), based on a negotiable permit system (NPS), and is more efficient than a subsidy. The price of the permit justifies the producer's contribution to SIGAUS of 60€ per ton. Finally, the results suggest that the EPR guarantees the financing of waste oil management until 2015.

Keywords: Used oils, Environmental policy, Efficiency, Extended producer responsibility, Subsidies.

1 INTRODUCTION

Royal Decree 679/2006 of June 2 on used industrial oils establishes EPR for the management of industrial oils used in Spain. Waste oils are hazardous waste and include all mineral or synthetic oils, industrial or lubrication, which are no longer suitable for the intended initially use[1]. Waste oils affected by Royal Decree 679/2006 are used mineral oils from combustion engines and transmission systems, lubricants, turbines, and hydraulic systems, and mixtures and emulsions containing them and excluding marine and aviation, process, and grease oils. The EPR, in the management of waste oils, means that manufacturers of lubricating oils must ensure the correct management of the waste oils delivered to them, companies, or workshops, to comply with the obligation of delivery of waste oils to authorized managers, as well as to cover the total cost of the management operations[2].

Royal Decree sets the ecological targets for collecting 95% of waste oils produced and the recovery of 100% of the waste oils collected in 2006. Besides, the regeneration of 55% in 2007 and 65% in 2008 of the oils recovered[3]. Additionally, Royal Decree 679/2006 imposed on manufacturers the obligation to develop a BPP to establish measures to prevent the environmental impact of industrial oil waste, to reduce its generation and to facilitate its valorization, preferably through regeneration or other forms of recycling, and to incorporate regenerated base oils into its composition[4]. Manufacturers of industrial oils can ensure the collection and management of oils if, together with other economic operators, they organize integrated management systems (IMS)

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[1] B.O.E. of June 3, 2006, No. 132.

[2] Law 22/2011 of July 28 on contaminated waste and soils transposes Directive 2008/98/EC, the Waste Framework Directive, establishes a common legal framework for the implementation of the EPR (B.O.E. of 29, July 2011, No. 181).

[3] Regeneration consists of removing contaminants, oxidation products, and additives containing waste oils for obtaining base lubricating oil (Angulo *et al.*,1996; Gómez-Miñana, 1993; LLobet Díaz, 1995 and Ramsden, 1995). The base lubricating oils, first refined or regenerated, are mixed with additives to achieve the quality and performance levels required to manufacture lubricants according to their destination (automotive and industrial uses). In Spain, the performance of installed technologies, or obtaining regenerated oil from used oil, ranges from 60 to 75%. Combustion, or waste oils as fuel, constitutes another form of recovery of the used oil, following a decontamination process.

[4] Currently, BPP for the period 2018-2021 is in force (SIGAUS, 2020).

authorized and controlled by the Autonomous Communities[5]. In 2006, the leading manufacturers of lubricants in Spain constituted the Integrated Waste Oil Management System (SIGAUS), by which financing the management of waste oils is carried out by the lubricant oil manufacturing sector. The funding for managing waste oils through public subsidies is replaced by the amounts collected from the producer's contribution to SIGAUS of 0.06 € per kilogram of industrial oil placed on the market.

Currently, EPR applies to other waste. Royal Decree 110/2015 of February 20 on waste electrical and electronic equipment (WEEE) has meant that the responsibility for the oils contained in the residues of those products is transferred from the lubricant manufacturer to the manufacturer of those products. Consequently, it supposed a further allocation of responsibilities for waste oils subject to Royal Decree 679/2006. According to the 2015 market study, with the entry into force of Royal Decree 110/2015, SIGAUS' market share increases from 87.13% to 87.15%, and the fraud bag it voluntarily assumes, as majority IMS, namely free riders, decreased from 2.89% to 1.41%, of waste oil affected by Royal Decree 679/2006[6].

Consequently, new regulations on waste oils in WEEE modified the financing responsibility of waste oils for the first ten years. Besides, in 2016 the context of low oil prices has highlighted the need for an additional financing mechanism to cover the intrinsic shortfall in waste oil collection and management activities, according to the Independent Commodity Information Services Index (ICIS)[7]. In 2017, by Royal Decree 20/2017, of January 20, on end-of-life vehicles (ELV) wherein responsibility for oils contained in such vehicles is transferred to the manufacturer of such vehicles[8]. Economic incentive policies' efficiency in promoting the collection and correct management of waste oils in Spain has previously been studied in Arner *et al.* (2005, 2006b). The main finding was that an RMS, applied through a SPN, is more efficient than a subsidy because the marginal private cost (MPC) of an RMS is lower than the MPC of a subsidy. Besides, the IMS for waste oil is an RMS (Arner, 2010). After ten years of EPR in the management of waste oils, the objective of this work is to analyze the efficiency of this policy to determine the price of the permit and the contribution of the lubricant producer to SIGAUS, and its MPC, to update the data series.

[5] Integrated waste oil management systems are the set of relationships, procedures, mechanisms, and actions which, subject to authorization and supervision by the autonomous communities in whose territorial area they are implemented, are performed by the economic operators concerned through voluntary agreements approved or authorized by or through collaboration agreements with the competent public administrations.
[6] Independent market study conducted by the consultant independent PwC (SIGAUS, 2016,a).
[7] SIGAUS (2016b).
[8] In 2018, the market affected by different EPR regulations accounts for 83% of the total lubricant market of 462,573 tons. The remaining 17% correspond to greases, process oil, or marine oils subject to the Marpol Convention. The market share subject to EPR, excluding oil exported (in electrical and electronic equipment, components, and vehicles), corresponds to SIGAUS at 86.48% (including unidentified oils, 2.19%, and a margin of error of 0.1%); WEEE at 0.60%; ELV at 5.38%; IMS independent producers (SIGPI) at 6.56%, and Automotive imports at 0.99% (SIGAUS, 2020).

The methodology for assessing the efficiency of the EPR consists of developing a partial equilibrium model of the waste oils market and calculating the incidence and MPC of this policy. The empirical application to IMS of waste oils in Spain consists of estimating a cointegration equation between the variable amount of waste oils intended for regeneration, *WOR*, and the first refining base lubricating oils price, in nominal terms *FRP*, using Dynamic Ordinary Minimum Squares (DOLS). According to the results, the EPR is more efficient than a subsidy being, respectively, the MPC of these policies -1.25 and -1.55. In turn, the price of the permit, equal to 0.86 euros per ton, allows obtaining the value of the lubricant manufacturer's contribution to SIGAUS, of 60 euros per kilogram.

The work has the following sections. Subsequently, the economic literature review on the efficiency of economic incentive policies in waste management. The next section presents the analysis of the efficiency of EPR in waste oil IMS. Section four and five are referring to the empirical application to the Spanish waste oil market and results. The last section summarizes the main conclusions.

2 REVIEW OF ECONOMIC LITERATURE

From an economic perspective, waste generation is conceptualized as a negative externality derived from production and consumption activities. The payment systems for waste generated allow internalizing these costs and generating the optimal amount of waste. However, this policy creates a clear incentive for illegal dumping and incineration (Jenkins, 1993). Alternatively, to reduce the amount of waste to be disposed of, economic analysis considers policies that promote recycling. The main incentives are deposit-refund systems (DRS), taxes on natural raw materials, recycling subsidies, and RMS.

The DRS is defined as the combination of a product tax and a recycling subsidy. Various authors (Dinan, 1993; Fullerton and Kinnaman, 1995; Sigman, 1995; Palmer and Walls, 1997 and 1999) point out that the SDR is an efficient policy to reduce the amount of waste to be disposed of because they combine the two effects that characterize a Pigouvian tax: reducing the product and replacing natural inputs with recycled ones[9]. If applied individually, product taxes influence only the reduction in origin and recycling subsidies, and consequently, they miss the possibility of reducing the amount of waste to be disposed of by combining the two policies (Palmer and Others, 1997). However, the high costs of implementing the DRS harm the relative efficiency of this policy.

[9] Fullerton and Wolverton (2000) generalize the SDR and assimilate it to a product tax and a subsidy to clean activity (emission control, recycling, or disposal in a controlled landfill).

If a DRS is applied to producers rather than consumers, the cost decreases because the number of agents and products concerned is lower[10].

In turn, the DRS is consistent with the principle of producer responsibility and EPR[11]. The tax holds producers accountable for disposal costs and encourages the reduction of waste and the weight of products - if established on intermediate products - and the recycling subsidy promotes the use of recycled materials (Palmer and Walls, 1999). Reducing the weight of products is part of a company's strategy for the design and characteristics of its product, particularly, its recyclability[12]. Calcott and Walls (2005) point out that, in the absence of efficient market operation, an DRS, join with a final elimination tax, encourages a design that promotes a sufficient level of recycling[13].

Taxes on natural raw materials reduce the amount of final product and the use of natural resources and recycling if the marginal productivity of natural and recycled inputs differs and, therefore, the optimal solution involves subsidizing the final product (Palmer and Walls, 1994). Only if the marginal productivity of natural and recycled inputs is constant and equal to unity is this policy efficient (Miedema, 1983; Sigman, 1995). Recycling subsidies encourage recycling, but also consumption and the amount of waste generated (Miedema, 1983; Palmer and Walls, 1994; Sigman, 1995; Palmer and others, 1997). In this case, the optimal solution requires a product tax to be applied.

The RMS in production, or obligation to contain a percentage of recycled inputs in their composition, encourages recycled materials. However, if the marginal productivity of these materials is relatively high, they increase the amount of product and waste and the product must be taxed; otherwise, the product must be subsidized (Palmer and Walls, 1997). RMS can be established individually for each company or industry, through an NPS, which provides greater flexibility and reduces its cost (Dinan, 1992; Palmer *et al.*, 1995). This system involves the exchange of permits between those companies that use over-recycled inputs relative to the standard and those that do not comply. The latter must acquire permits to comply with the obligation imposed by the standard. The cost of RMS depends on the characteristics with which the permissions system is defined. If the number of permissions is set relative to the standard, RMS will be efficient. Otherwise, the result

[10] The current integrated management systems for which the producer is responsible for the waste generated by its products - such as packaging management systems - charge a fee for collecting and separating waste. This rate is a product tax and therefore does not encourage recycling (Palmer and Walls, 1999).
[11] The principle of producer responsibility implies some form of financial responsibility of the manufacturer managing the waste that will generate his product.
[12] The design of the products currently acquires great relevance in waste management. The facility of managing a product to be recycled is alternatively defined as a product's characteristic (Fullerton and Wu, 1998). Besides, it is defined as the company's cost (Calcott and Walls, 2000) or the content of specific material in the product (Eichner and Pethig, 2001).
[13] The tax, lower than the Pigou tax that would correct externality in the spill, would incentivize the reduction of waste by families without generating serious illegal disposal problems. The optimal design that maximizes recycling could only obtained through the efficient functioning of the market.

will be undefined, and the cost will be greater than the cost of a product tax (Sigman, 1995). In general, even establishing the negotiable permit system, RMS influences recycling, but not prevention in waste generation, and the product should be taxed (Walls and Palmer, 2001; Walls, 2003).

3 EFFICIENCY OF THE EPR IN WASTE OILS IMS

Since 2007, SIGAUS has met the collection and regeneration objectives set by the Royal Decree 679/2006 (Table1). Also, the percentage of waste oil generation of lubricant consumption has been higher than the initial estimate of the Ministry of the Environment, of 40%. In IMS, the ratio of used oil produced, and lubricant consumption is changed in each fiscal year, with a variation in 2006-2015, between 41.68% and 49.5%. As a result, the share of waste oil generation in IMS is 45%, for the entire period, while the share of waste oils intended for regeneration is 69%. In turn, the average consumption of lubricants and the amount of waste oils generated for that period are equal, respectively, to 280,000 tons and 126,000 tons.

Table 1. Consumption of lubricating oils (*LC*), waste oils collected and intended for burning (*WOB*), regeneration (*WOR*), and consumption of regenerated base oil (*RBO*)

Year	LC t (1)	Waste oil generated %	Waste oil collected t	Collection rate	WOB %	WOR %	RBO t (2)	(2)/(1) %
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

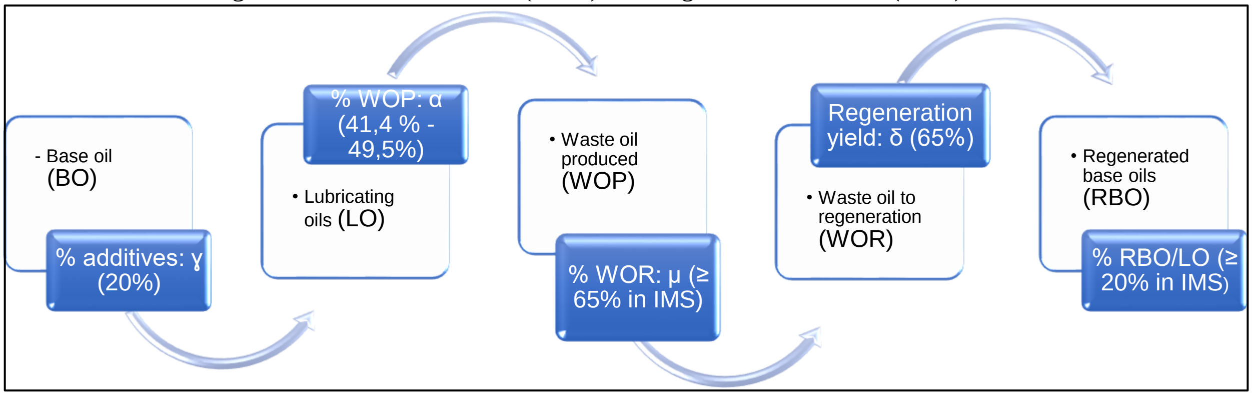
Note: since 2006, lubricating oil affected by Royal Decree 679/2006 of June 2 and the used oil collected by SIGAUS
Own source

This section presents a partial equilibrium model of the waste oils market to assess the efficiency of different economic incentive policies proposed in the management of waste oils[14]. In the market for lubricating oils, the production and consumption of the refined and regenerated base oils (BO) is added with the percentage, ɣ, of additives incorporated for the manufacture of lubricants, to determine the production of lubricating oils (LO). The share of additives in lubricants' composition has evolved with the differentiation of lubricants and their practical application

[14] A more detailed analytical development of the partial equilibrium model of the waste oil market was in Arner *et al.* (2005, 2006b).

currently around 20%. If EPR is applied in the management of waste oils, the percentage of waste oil generation from the consumption of lubricating oils, α, is modified each year according to the waste oils collected by the IMS (Figure 1). In 2006-2015, the α coefficient is between 41.4% and 49.5% (Table 1). In turn, waste oils are intended for regeneration in a variable percentage, μ, which in IMS is at least 65%.

Figure 1. Produced Used Oil (WOP) and Regenerated Base Oil (RBO) in IMS



Source: own source

Consequently, as base oils are the fundamental component of lubricating oils, the equilibrium price of base oils determines the equilibrium price in the lubricant oil market. If P is the price of base oils, the supply function of waste oils intended for regeneration is,

$$S_{aur} = f(P) \qquad (1)$$

In turn, if δ is the performance of the regeneration process or percentage of the generation of regenerated oils from waste oils, the supply function of regenerated base oils is[15],

$$S_{abr} = \partial S_{aur}(P) \qquad (2)$$

Therefore, the equilibrium condition in the market for regenerated base oils, *if* $D_{abr}(P)$ is the demand function of regenerated base oils is,

$$\partial S_{aur}(P) = D_{abr}(P) \qquad (3)$$

From equation (3), the ratio of the elasticities of the supply function of regenerated base oils, E_s, and the demand function of regenerated base oils, E_d, is obtained (4)

$$E_s dP_s = E_d dP_d$$

Where P_s is the supply price and P_d the demand price.

[15] In the IMS, the performance of the regeneration process is 65%.

Equation (4) allows analyzing the efficiency of the economic incentive policies proposed for managing waste oils -a subsidy *s* and an RMS based on an NPS- to promote the collection and regeneration of waste oils, by calculating the marginal incidence and MPC of these policies.

If *s* is a subsidy per unit of regenerated base oil, P_s and P_d differ by the equation,

$$P_d = P_s(1-s) \quad (5)$$

Therefore, the ratio of supply and demand elasticities in equation (5) is,

$$E_s dP_s = E_d(dP_d - d_s) \quad (6)$$

Consequently, the marginal incidence of a subsidy, *s*, on P_s is,

$$\frac{dP_s}{d_s} = \frac{E_d}{E_d - E_s} \quad (7)$$

Finally, being the marginal incidence of a subsidy, *s*, on P_d,

$$\frac{dP_d}{d_s} = \frac{E_s}{E_d - E_s} \quad (8)$$

The MPC of this policy, defined as market price reduction, P_d, because of a subsidy, is obtained by replacing the level of intervention corresponding to dP_s in equation (8),

$$CPM_s = \frac{E_s}{E_d} dP_s \quad (9)$$

Therefore, if supply elasticity, E_s, is positive and demand elasticity, E_d, negative, the subsidy implies the supply price, P_s, increasing, and the reduction of the demand price, P_d.

The RMS in the manufacture of lubricating oils (LO) is the obligation for the producers of lubricating oils to incorporate a certain percentage of regenerated base oils r^* (RMS = r^* LO). If set for the industry, RMS is based on an NPS. In the application of EPR, the manufacturer of lubricating oils finances the management of waste oils generated by lubricants placed on the market, refined, and regenerated oils. Consequently, the lubricant producer replaces refined base oils with regenerated ones. Therefore, each unit of regenerated base oil results in 1/r* negotiable permits. If the permit price is π, the regenerator obtains a subsidy equal to π/r^*. Subsequently, the marginal incidence of the permit price, π, on P_s is,

$$\frac{dP_s}{d_\pi} = \frac{\frac{1}{r^*}E_d}{E_d - E_s} \quad (10)$$

In turn, equilibrium requires a second condition regarding the market for negotiable permits (NPS). In that market, the supply function $S_{NP}(\pi)$ is given by the ratio between the quantity of regenerated oils produced, if the regenerator receives a subsidy, π/r^*, and r^*. The demand function,

$D_{NP}(\pi)$, is determined by the amount of lubricating oils put on the market (LO). Therefore, the equilibrium condition in the market is,

$$\frac{1}{r^*}\delta S_{aur}[P_s(1+\frac{\pi}{r^*})] = \frac{RMS}{r^*} \qquad (11)$$

If $S_{aur} = f(P)$ is a linear function of the price, from equation (11) it can be obtained that $dr^* = d\pi$. Equation (11) indeterminacy resolves if the regulator sets *r**. The marginal incidence of r* on P_s and P_d is presented, respectively, in equations (12) and (13).

$$\frac{dP_s}{dr} = \frac{\frac{1}{r_i}E_d}{E_d - E_s} \qquad (12)$$

$$\frac{dP_d}{dr} = \frac{\frac{1}{r_i}E_s}{E_d - E_s} \qquad (13)$$

Where r_i constitutes the initial share of regenerated oils in the consumption of first refining lubricants.

Finally, the MPC of this policy is that of a subsidy, π/r^*,

$$CPM_{RMS} = \frac{r_i}{r^*}\frac{E_s}{E_d}dP_s \qquad (14)$$

Therefore, the comparison between the MPC of a subsidy and an RMS, applied through an NPS, is equivalent to comparing a subsidy equal to the permit price, π , and a subsidy equal to π/r^* . Being r_i/r^* less than 1, the MPC of an RMS, applied using an SPN, is lower than that of a subsidy. As a result, EPR is a more efficient policy than a subsidy to promote the collection and regeneration of waste oils.

4 ESTIMATING A SUPPLY AND DEMAND FUNCTION FOR WASTE OILS INTENDED FOR REGENERATION

An empirical analysis of the regenerated oil market has previously been carried out (Arner *et al.*, 2003) by estimating a supply and demand function, using Ordinary Least Squares (OLS). That work got the supply elasticity for regenerated oils of 1.33 and the demand elasticity for regenerated oils of 0.39. In turn, the market for waste oils has been characterized (Arner *et al.*, 2006a) through a supply function of waste oils, defined as collected waste oils, and a demand function regarding the main valorization operations of waste oils (regeneration and combustion). Until 2000, waste oils were mainly intended for fuel, with a direct relationship between the price of fuel and the price of waste oils. Consequently, the market estimate for waste oils was made using three-stage OLS

(OLS3S). In this market, it is obtained the supply price elasticity since 1991 of 2.97, and the demand price elasticity to fuel price is, since 1991 of 1.32.

Since 2005, the reuse of waste oils by regeneration increased up to 65% of waste oils. Consequently, the price of waste oils now is related to the price of lubricating oils, being exogenous to the market. As regenerated waste oil is also accounted for, the amount of waste oils intended for regeneration depends on their value in previous years. Subsequently, estimates are using DOLS. The variables considered are *WOR*, endogenous variable to be explained, and *FRP*. The sample period is 1964-2015 and the data refer to annual periods. The *WOR* variable is defined in metric tons, and the *FRP* variable is defined in € per ton[16].

The study of the order of integration of the variables is carried out using the M tests of Ng-Perron (2001). Table 2 presents the Ng-Perron unit root M test results, being the null hypothesis, H_0, that the variable is not stationary. The Akaike Information Criterion (AIC) is used for the determination of the number of delays. The results show that, in second differences, H_0 is accepted for the *WOR* variable and *FRP* variable in the model with constant and trend. In levels and first differences, the results have been omitted because they also mean accepting the existence of a unit root in both variables.

Therefore, the estimates of the supply and demand waste oils intended for regeneration functions are to analyze the cointegration relationship between the variables. Besides, the elasticities of the supply and demand function are obtained. Estimates are by DOLS, using Akaike Information AIC to determine the number of delays and advances.

Table 2. NG-Perron Unit Root Test

Model/ Variable	**Model with constant**				**Model with constant and trend**			
2as dif.	**MZa**	**MZt**	**MSB**	**MPT**	**MZa**	**MZt**	**MSB**	**MPT**
dWOR	-13909,6	-83,395	0,006	0,001	-48,194	-4,908	0,101	1,891
dFRP	-0,061	-0,156	2,551	320,475	0,240	0,395	1,645	526,432

Note: The asymptotic critical value of the Ng-Perron test statistic (2001), in models with constant, at the significance level, respectively, of 1, 5 and 10% are: (1) MZa: -13.8, -8.10 and -5.70; (2) MZt: -2.58, -1.98 and -1.62; (3) MSB: 0.174, 0.233 and 0.275; (3) MPT: 1,780, 3,170 and 4,450. In models with constant and linear trend are: (1) MZa: -23.8, -17.3 and -14.2; (2) MZt: -3.42, -2.91 and -2.62; (3) MSB: 0.143, 0.168 and 0.185; (3) MPT: 4.03, 5.48 and 6.67.

[16] The variable *WOR*, amount of waste oils intended for regeneration, is obtained, before 1993, from the Yearbook of the Delegation of the Government to CAMPSA (several years), from the Yearbook of CAMPSA (several years), and the Ministerial Grant Resolution in each financial year. In 1993, the report was provided by the Ministry of the Environment of the Valencian Community (personal communication). Since 1994, the information has come from the Ministry of the Environment (personal communication), and the publication Environment in Spain (2006). The conversion factor of waste oils into regenerated oils used is 0.6. The variable *FRP* is the price of first refining base lubricating oils, including taxes, in nominal terms. The Oil Monopoly stage, from the Delegation of the Government to CAMPSA (several years), although for the period 1987-1991 they are market prices provided by REPSOL (personal communication). Since 1992, import prices have been obtained from the DATACOMEX (Ministry of Industry and Technology) foreign trade databases, which can be found at http://datacomex.comercio.es/ [April 24, 2017], STACOM (ICEX), available at http://estacom.icex.es/ [April 24, 2017].

Being L the logarithmic notation of the variables, the supply function of waste oils intended for regeneration to be estimated is,

$$LWOR = \beta_1 LFRP \qquad (15)$$

where β_1 *is* the coefficient of the *LFRP* regressor.

Results are satisfactory from the point of view of the overall significance of the estimates, and the individual significance of the coefficient of the *LFRP* variable (Table 3). The coefficient β_1 positive, up to 1.82, at the significance level of 5%, constitutes the value of the price elasticity of the supply function of waste oils intended for regeneration. According to the AIC, the number of advantages and delays automatically specified considering a maximum of delays equal to 10, is equal to 10. The Engle-Granger cointegration test contrasts if the residues of the cointegration equation are stationary, being the null hypothesis, H_0, the residues of the cointegration equation are not stationary. According to the Engle-Granger t-statistic and the Engle-Granger z-statistic statistic, H_0 is rejected at the significance level of 5%. Consequently, the variables *LWOR* and *LFRP* were cointegrated.

Regarding the error term, under the Jarque-Bera statistic null hypothesis, H_0, the residues are distributed according to a normal distribution, is accepted at the significance level of 5%. In turn, the value of the Q autocorrelation statistic implies accepting the null hypothesis, H_0, of no autocorrelation in the error term, at the significance level of 5%, from the third delay.

Table 3. Estimates for *WOR* supply function

Dependent variable: *LWOR*			
Automatic specification of the number of advances and delays according to AIC, max. delays 10			
Variable	Coefficient	Statistic *t*	*p-value*
LFRP	1,829	25,891	0,000
*R-square:*0.866 *R-square* corrected: 0.617			
Statistic Jarque-Bera	Value		p-value
	0,329		0,848
Box-Pierce/Ljung-Box Q statistic	Delay	Value	Probability
	1	5,119	0,034
	2	6,791	0,034
	3	7,143	0,067
Engle-Granger cointegration test (MacKinnon (1996) p-value)			
Automatic specification of the number of delays according to AIC, max. delays 10			
Statistic	Value		p-value
Engle-Granger tau-statistic	-2,049		0,221
Engle-Granger z-statistic	-7,144		0,288
Engle-Granger Equation Dependent variable: D(RESID)			
Variable	Coefficient	Statistic *t*	*p-value*
RESID(-1)	-0,118	-2,049	0,045
D(RESID(-1))	0,173	1,425	0,160
R-squared: 0.100 *R-square corrected:* 0.081			

In waste oil IMS, there are not demand function estimates (price equation) for waste oils intended for regeneration. As the lubricant manufacturer replaces first refining base oils with regenerated oils, the demand for regenerated base oils is given by the RMS. Besides, the demand for waste oils intended for regeneration is given by RMS. In this work, the calculation of supply and demand price elasticities is simplified to obtain the supply price elasticity from the estimates of a supply function for waste oils intended for regeneration; meanwhile, the demand elasticity to RMS is got for equilibrium, as supply elasticity inverse value, considering the regulator sets the RMS.

5 RESULTS

Under EPR by SIGAUS, the manufacturer of lubricating oils contributes to funding the management of waste oils generated by the lubricant oils placed on the market, first refined and regenerated oils. Consequently, the lubricant manufacturer replaces first refining base oils with regenerated base oils to manufacture lubricants. Under Royal Decree 679 of June 2, waste oils are intended for regeneration by a percentage of at least 65% of waste oil. Therefore, considering a regeneration process performance of 65%, the regulator establishes an RMS or obligation for lubricating oils to incorporate a percentage of regenerated oils equal to at least 20%.

The EPR efficiency assessment consists of determining the permit price and the producer's contribution to the IMS, as well as the MPC. Under this policy, the share of oils regenerated in lubricant consumption increased from 16.30%, before IMS, to a percentage of at least 20% (Table 1). Consequently, the determination of the price of the permit is carried out on the basis that regulations set a dr^* up to 21.95%, by calculating the marginal incidence of the permit price and the MPC, using an elasticity of the supply and demand function of waste oils intended for regeneration, respectively, of 1.82 and 0.55. Consequently, according to equation (10), if r^* equal to 0.20 is considered, the marginal incidence of the permit price on P_s is negative, of - 2.14. In turn, being negative dP_s, of - 0.47, according to equation (14), it is obtained that the MPC of this policy is equal to -1.25. Therefore, P_s decreases because of the permit price and the MPC highlights the significant reduction in lubricant consumption in Spain (Table 1). In turn, it is verified that the MPC of a subsidy is negative of -1.55 and, therefore, EPR is more efficient than a subsidy.

The price of the permit, π, is obtained from, dr^*, equal to 21.95% and a previous intervention level equal to zero. If the conversion is made to monetary units per ton of lubricant oil placed on the market, it is obtained that the price of the permit, π, is equal to 0.86 € per ton. Consequently, with the marginal incidence of the permit price on P_s, equal to -2.14, the lubricant producer's contribution to the IMS is 60 € per ton. In turn, the subsidy received by waste oil regenerators, π/r^*, is equal to 180 € per ton of waste oils intended for regeneration. These values are those of the producer's contribution to SIGAUS and the amount of the subsidy granted by SIGAUS to collectors and regenerators[17].

6 CONCLUSIONS

In 2017 counts ten years of implementation of Royal Decree 679/2006 of June 2 incorporating EPR in the management of waste oils in Spain. The ecological objectives set by Royal Decree 679/2006 are the collection of 95% and recovery of 100% of the waste oils collected, on July 1, 2006, as well as the regeneration of 55% and 65% of the waste oils collected, respectively, on January 1, 2007, and 2008. Lubricant manufacturers to ensure the collection and correct management of waste oils, which workshops and companies deliver to them, constitute SIGAUS. In 2015, most lubricant manufacturers are joined SIGAUS, with the market share being 87.15% and the fraud bag it voluntarily assumes, as majority IMS, of 1.41%, of used oil subject to the royal decree. Consequently, since 2006 the financing of the management of waste oils in Spain, in place of public subsidies, has been made from the amounts collected from the lubricant producer's contribution to IMS, fixed at 0.06 € per kilogram. In the context of low oil prices, in 2016 an additional financing mechanism indexed to the international price of lubricants was established.

The objective of this work was to evaluate the efficiency of the EPR in the first ten years of SIGAUS, determining the equilibrium price of the permit and the manufacturer's contribution to the IMS, as well as the MPC, updating the data series. The methodology consisted of the definition of a partial equilibrium model of the waste oil market to assess the efficiency of EPR concerning a subsidy and RMS. The main results are that the application of EPR in the management of waste oils in Spain constitutes an RMS, applied through an NPS, and is more efficient than a subsidy.

Therefore, according to the results, RMS applied using an NPS, is consistent with the EPR because the producer finances the waste that will be generated by its product and, in turn, uses recycled materials, by replacing first refined base oils with regenerated oils and developing other prevention actions. This feature has previously been attributed in the economic literature to DRS (Palmer and Walls,1999). Besides, EPR in waste oil management is an RMS, applied using an NPS, in which the number of permits matches the RMS. If the producer's contribution is considered to constitute a product tax, this policy is eligible to constitute an optimal policy (Sigman, 1995; Walls and Palmer, 2001; Walls, 2003).

The empirical analysis consists of calculating the elasticities of the supply and demand of waste oils intended for regeneration. In the lubricating oils market, because the lubricant producer

[17] SIGAUS (2010).

applying EPR replaces first refined base oils with regenerated ones, the demand for regenerated base oils is equal to RMS. Besides, the demand for waste oil intended for regeneration is equal to RMS. Consequently, the calculation of elasticities has been carried out based on the estimation of a function of the supply of waste oils intended for regeneration, using DOLS. In turn, the data series have been updated for the period 1964-2015. According to the results, the elasticity of the supply of waste oils intended for regeneration is 1.82. Subsequently, the supply of waste oils intended for regeneration remains elastic to the price variable. It justifies that since 2016, in the context of low oil prices, additional financing mechanisms have been in place to cover the intrinsic shortfall in waste oil collection and management activities.

Secondly, the EPR efficiency analysis results, applied to the IMS of waste oils in Spain, are that the price of the permit is 0.86 € per ton and, consequently, the producer's contribution to the IMS of 60 € per ton. Together with the amount of the subsidy received by the regenerators, of 180 €, these values are those established by SIGAUS. Finally, the MPC of EPR policy, negative at -1.25, is lower than that of a subsidy, at -1.55. It could justify the significant adjustment of the lubricant market in Spain when EPR is applied. In 2015, the application of EPR in managing other wastes, such as WEEE, has led to a further sharing of responsibilities for waste oils subject to Royal Decree 679/2006. Consequently, the regulation of waste oil management established in 2006 is amended to apply to other wastes which, containing waste oils, determine a new allocation of responsibilities. Finally, a new financing mechanism indexed to the international quote of lubricants was established in 2016.

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