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The Determinant Factors for the Rate of Recycling: The Example of Used Lube Oils in Tunisia

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Abstract

This study analyses the effects of several waste management policies on recycling rate of hazardous industrial waste such as used lube oils by using country-level temporal data for Tunisian Company of Lubricants (TCL) from 1980-2015. The examined policy variables include pricing waste collection, curbside recycling services and drop-off centres. In this paper, we aim to demonstrate that different recycling programs such as curbside and drop-off recycling act as complements in increasing recycling rate. The empirical results indicate that these policy variables are also found to be effective measures to increase the rate of regenerating of used lube oils.

Keywords: Waste management; Recycling; Energy conservation; Temporal model

Introduction

Polluting less, producing better, saving the raw materials, saving energy, and recycling are necessary actions to face the growing world population. In fact, the world population is expected to reach more than ten billion, in 2020, and will produce billion tons of waste.

Nowadays, our environment should take advantage of the increasing attention accorded to the balance between the environment preservation, the criteria of profitability and the development of Small Medium businesses (SME), Small Averages Industries (SAI) and great industry groups.

Confronted with the increasing consumption and the technological change, many countries become aware of pollution and the risks of disturbing the quality of life. Indeed, decision-makers and manufacturers should take into consideration the "zero waste", which means that all new manufactured products can be recycled. Moreover, in order to save the limited resources and to preserve the environment, many industrialists have decided to support and to market recycling ideas.

The environment protection, the waste processing, the recycling of materials and the distribution of new products which are usually treated at the international scale are being recently treated at regional and national levels. An interesting case study along these lines is the Tunisian Company of Lubricants (TCL), which is the principal and pioneer society specialized in used lube oil re-refining in this country.

Thus, the main objective of this study is to analyse the issues surrounding the factors that affect recycling rate of used lube oils for Tunisian Company of Lubricants by using a set of temporal observations of recycling and waste management policies, along with institutional variables.

Literature Review

Several studies have been conducted to understand the effects of various waste management policies on reducing waste and increasing the amount of recycling. They have analysed the impact of policies on per capita waste generation and recycling demand.

In this context, Gamba and Oskamp [1] demonstrated that curb side recycling program means the collection and reassembly of recyclable waste in special containers, which may be subsequently transported to waste transfer station for further treatment and recycling.

Saltzman et al. [2] developed a theoretical framework to analyse the collection of recyclable waste such as plastic, paper and glass by recovering part and recycling them.

According to Jenkins [3], the recycling process is based on sociological factors such as the trend of attitudes and the degree of environmental awareness to this practical ecological through the distance and the time required for collecting and sorting waste recyclable to valuate it.

Calcott and Walls [4] were interested in the ecological behaviour and its significant effects on recycling. They argued that the household desire to collect waste can have important role on recycling sector.

In the same line of research, Gonzalez-Torre et al. [5] determined that waste selective collection systems are commonly used in Europe. They also considered that collection system requires less time and effort over system for sorting recyclable waste. Although, these two operations have implicitly contributed to increase the rate of recycling, other recycling programs are very important such as curb side recycling which was the most available in developed countries. For example, in Florida, more than 75% of the population has access to system collection for waste recyclable [6].

The collection system is not the only essential factor for the recycling sector, but also the drop off recycling centre is an important determinant of the success of recovering waste. In this context, Saphores et al. [7] showed that recycling centres are in specially selected places where recyclable material is available and the recyclers are held to dispose recyclable material stored in selected centres for treatment and valuation.

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In the same context, Tiller et al. [8] considered that drop off recycling centres are financial and environmental options which were adopted by local government to increase the rate of recycling and develop this sector.

Concerning Snyder et al. [9], they treat a case study of Ohio EPA which contains the greatest participation of private collectors who dispose the waste in recycling centres to facilitate the task for recyclers. Within the same framework, Domina and Koch [10] suggested that setting up a recyclable material in specific centres is the most important factor for recycling program.

Callan and Thomas [11] found a positive relationship between the drop off recycling services and the rate of recycling by using a cross sectional data of 351 municipalities in Massachusetts.

In order to develop and promote the growth and sustainability of recycling sector, unit-based pricing of recyclable material is another factor that can increase the rate of recycling. In this context, Wertz [12] showed that the pricing is an important tool that should be considered in waste reduction by modelling the demand of residential, industrial, commercial and institutional sectors for waste management services.

A study conducted by Podolsky and Spiegel [13] demonstrated that the pricing variable can reduce transportation costs, temporary storage of waste recyclable and make recycling a viable option for the country.

Similarly, Hong [14] has examined the impact of unit-pricing for recyclable material on recycling rate by using data gathered from statistics of Korean's ecological general survey. He found that unit pricing program was more effective for minimizing the generation of recyclable waste than reducing household waste.

A recent study made by Calvin [15] analyses the efficacy and significance of PAYT (Pay As You Throw) program in rising the rate of recycling and promoting waste diversion by using panel data from municipalities in Ontario, Canada.

This present paper focuses on these previously studies by using temporal data surrounding the effects of policy variables for waste management such as price, curb side and drop off recycling services on regenerating rate from Tunisian Company of Lubricants.

Institutional framework for a regeneration system of used lube oils in Tunisia

Lubricating oils, like many consumer products have a short shelf life. Accordingly, they are found as hazardous waste. Faced with the wide geographic dispersion of the lubricating oil deposit, the multiplicity of oil owners and the dangers oil poses to the environment and to the health of individuals, the Tunisian legislature enacted, in April 2002, the 2002 - 693 Decree which establishes the conditions and procedures for recovering the lubricating oil and the used oil filters as well as their management.

Before the publication of this decree, many advances have been made in the management of waste oils since the creation of the Tunisian Company of Lubricants in 1979, which is a company that provides collection and regeneration of waste oils.

The unit of waste -oil regeneration in the Tunisian Company of Lubricants has been working since 1980. It was originally designed by an acid-earth process. This method soon proved unsatisfactory from an environmental point of view due to the accumulation of used oils and acid tar on the plant site, which could not be disposed of or processed. Since the early 90s, the Tunisian Company of Lubricants has begun research and has managed to develop a new technology for regenerating oils waste using a simpler technical configuration reconciling the environment with the economy. After the laboratory trials and the pioneering phase, this technology has been successfully tested in the existing facility, which has also undergone some changes by incorporating some new equipment. Since its creation, and in anticipation of the future, the Tunisian Company of Lubricants is dedicated to protect the environment by tackling a waste which is considered to be very harmful due to the complexity of its constituents. The following Table 1 summarizes the distribution of the field of used lube oil by different sector.

From this Table 1, we find that the service stations and car washes were holding about half of the deposit of used lube oils. Thus, thanks to the expertise of its staff, the company has been able to control and treat problems related to collecting, storing and recycling waste oils. Therefore, the company has confirmed that regeneration is the most viable way because it happens at competitive prices for quality products designed mainly for the oil sector. The cooperation between the Tunisian Company of Lubricants and multinationals at the leading edge of innovation has greatly contributed to develop the enterprise spirit of research that has hitherto been directed towards the survival of the regeneration activity. This cultural heritage has already yielded its fruit since the Tunisian Company of Lubricants could develop a new balancing method between the environmental and economic aspects and would be responsible for boosting the regeneration activity which has also undergone a total slackening internationally in the recent decades.

In Tunisia, there are no studies on the proportion of waste oil generated from the marketed quantities. In order to fix a rough estimate, we consider the hypothesis of a ratio of 50% until getting more accurate studies. Based on the data from the Tunisian Company of Lubricants (TCL) related to collecting oil and considering the ratio of 50% proposed above, we can draw up the following graph that summarizes the performance of the collection for used lube oils (Figure 1).

Through this graph, we note that slightly more than half of the deposit of waste oil is being collected. It seems very important for SOTULUB (Society Tunisian of Lubricants) in particular as a recycling sector and for economic Tunisian in generally.

Variable and Data Descriptions

The data used for this research are collected from three different sources. First, the recycling and waste management data are obtained from the National Agency for Waste Management (NAFWM) data base, the National Agency of Environmental Protection (NAFEP), and the Ministry of Industry, energy and Mining. Tunisia began a state-wide recycling effort in 1980 after the adoption of legislation based

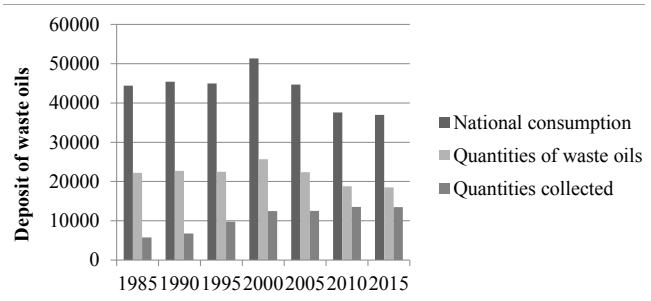

Figure 1: Evaluation of the system of collecting waste of used lube oils [16].

on NAFEP and NAFWM recommendations, under the supervision of the Ministry for Environment and Sustainable Development. The legislation provides state funding for waste reduction, recycling program management and household hazardous waste management. The waste management and recycling program for used lube oils in Tunisia deemed to be one of the most successful state-level programs in this country considering the local government investments and private participation.

The NAFWM data base compiles data from annual surveys of waste management and recycling in Tunisian Company of Lubricants. The NAFWM survey is administered by the Tunisia Pollution Control Agency and is completed by county solid waste officers. The survey collects information on Municipal Solid Waste (MSW) generated, materials collected for recycling, solid waste collection system, recycling programs and management, price collection, source reduction programs and other MSW policy initiatives.

The current study augments the recycling and waste management data with institutional and policy data for Tunisian Company of Lubricants (TCL) from the NAFWM and MIEM data base covering the period from 1980 to 2015. The data sources combine to create a temporal model of complete variables for 36 observations representing Tunisian Company of Lubricants. The variables selected for the analysis are defined in Table 2.

Based on the Table 2, we show that regenerating rate is computed by dividing the amount of residential regenerating of used lube oils by marketed amounts of lube oils. Price is the waste disposal pricing variable representing whether the National agency for Waste management under the supervision of Ministry for Environment and Sustainable development and Ministry of Industry, Energy and Mining had a pricing variable for the collection oil waste. Also, we use curb and drop which represent recycling programs for Tunisian Company of Lubricants.

Therefore, the waste recycling deserves the involvement and interaction of several actors (households, communities, collectors, screening machines, creators, authorities, municipal, etc.).

Econometric Methodology

We define the temporal series that are a continuation of numerical values representing the evolution of a specific quantity in time. Such variables can be mathematically expressed to analyse the behaviour, generally to understand its past evolution and to plan the future behaviour. Such a mathematical transposition uses most of the time concepts of probability and statistics. The object of the temporal series is to study the evolution of variables in time. Its main objective is to represent the determination of trends within these series as well as the stability of the values and their variation in time.

In this study, we model the Tunisian Company of Lubricants regenerating rate of used lube oils as a function of waste management policy and institutional variables. The linear econometric specification of the society recycling rate function is specified as follow:

$$\log rate_t = \beta_1 + \beta_2 \log price_t + \beta_3 \log curb_t + \beta_4 \log drop_t + \beta_5 \log curb_t . \log drop_t + u_t$$

Estimate Results and Interpretations

Since the model is estimated on temporal data, we need to think about building and assessing an Error-Correction Model (ECM)

Sector	Percent
Service stations and car washes	49.74
Garage and selling homes	21.13
Industry	10.16
Transport	6.02
Civil engineering	4.73
Government	3.80
Agriculture	1.76
Tourism	0.98
Mine	0.85
Ports	0.84

Table 1: The distribution of used lube oil by manufacturing sector [16].

Variable	Definition
Rate	Regenerating rate of used lube oils for TCL
Price	Price collection of used lube oils
Curb	Number of private collectors for used oils
Drop	Number of drop-off regenerating centers

Table 2: Description of variables [16].

[16,17] because the above model variables suffer from a problem of stationarity. In fact, the ECM models require that my first passes by the non-stationary tests.

The ADF and KPSS tests [18] show that all the variables in question are non-stationary in terms of level while their first difference is stationary. The degree of integration of order 1 of the model variables allows applying the Johansen [19] and Juselius [20] co-integration test to check the potential existence of one or more long-term relationships between these variables. Given the strong correlation between the composite log. curb-log. drop variable, we have considered two groups of variables: on group comprising all the above model variables except the composite variable, and a second one consisting of all model variables in question except the log. drop variable. Considering these two groups of variables, the Johansen test shows in both cases the existence of one long-term relationship admitting the following expressions:

$$\log rate_t = 0.41 \log price_t + 0.17 \log curb_t + 0.43 \log drop_t - 1.53$$

$$\log rate_t = 0.37 \log price_t + 0.06 \log curb_t + 0.04 \log curb_t . \log drop_t - 0.22$$

In the long run, we see that in both long-term relationships the annual rate of regenerating used lubricating oils is not so elastic with respect to its determinants; sometimes it is even marginal. Indeed, the long-term elasticity of regenerating lubricating oils in relation to the number of collectors seems to be low compared to other elasticities (elasticity in relation to price (0.41) and elasticity with respect to the number of central deposits (0.43 seems)). As regards the composite variable, it seems in the long term, no significant effect on the annual rate of regenerating lubricating oils since this estimated elasticity rate with regards to the composite variable elasticity is equal to 0.04. The existence of these two long-term relationships [21] has allowed us according to the theorem of Engle and Granger to estimate two ECMs whose econometric results are the following ones:

$$\Delta \log rate_t = \underset{(1.53)}{0.19}\Delta \log rate_{t-1} + \underset{(2.8)}{0.39}\Delta \log rate_{t-2} + \underset{(2.04)}{0.33}\Delta \log price_t + \underset{(5.37)}{0.87}\Delta \log price_{t-2}$$
$$+\underset{(0.73)}{0.24}\Delta \log curb_t + \underset{(3.33)}{1.11}\Delta \log curb_{t-2} + \underset{(3.34)}{0.31}\Delta \log drop_t + 0.23\Delta \log drop_{t-1}$$
$$+\underset{(2.91)}{0.16}\Delta \log drop_{t-2} + \underset{(1.29)}{0.07}\Delta \log drop_{t-3} - \underset{(-6.09)}{0.64}ECT1_{t-1} - 2.07$$
$$DW = 1.63 \quad R^2 = 0.805$$

$$\Delta \log rate_t = \underset{(1.53)}{0.19}\Delta \log rate_{t-1} + \underset{(2.8)}{0.39}\Delta \log rate_{t-2} + \underset{(2.04)}{0.33}\Delta \log price_t + \underset{(5.37)}{0.87}\Delta \log price_{t-2}$$
$$+\underset{(0.73)}{0.24}\Delta \log curb_t + \underset{(3.33)}{1.11}\Delta \log curb_{t-2} + \underset{(3.34)}{0.31}\Delta \log drop_t + 0.23\Delta \log drop_{t-1}$$
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$$DW = 1.63 \quad R^2 = 0.805$$

The variables ECT1 and ECT2 are the error-correction terms, in other words deviations from the annual rate of regenerating used lubricating oils compared to its equilibrium level. These variables are calculated as follows:

$$ECT1_t = \log rate - 0.41 \log price_t - 0.173 \log curb_t - 0.432 \log drop_t + 1.5$$
$$ECT2_t = \log rate_t - 0.377 \log price_t - 0.0617 \log curb_t - 0.04 \log curb_t \log drop_t$$

The estimation ECM models of the absolute increase rate in the regenerating used lubricating oils shows an adjustment process of this rate because the two recalling estimated forces are negative, between 0 and 1 in absolute value, and statistically significant. What is interesting to note is the importance of the process of adjustment since we notice that on average 64% of the imbalance in the annual rate of regenerating lubricating oils is corrected. The weak exogeneity test shows that the variable price, curbs, drop and drop. Curb variables are weakly exogenous and therefore contribute to the adjustment process. Also, the above ECM models show that the short- term elasticities of the regeneration rate, in question, with respect to the various explanatory variables (price, curb and drop – to a certain extent –) are significantly greater. For example, in the short term, the elasticity of the regeneration rate compared to prices is 0.88 while it is 0.41 in the long term. The same remark can be made for the number of collectors since in the short run curb - rate of regeneration elasticity is around 1 while it is estimated at a value which is around 0.1 (0.17 in the first long-term relationship and 0.067 in the second long-term relationship). The short-and-long-term elasticities of the variables drop and regeneration rate are statistically equal (0.31 and 0.42 in the short run and in the long run, respectively).

The short-and long-term elastacities of the composite variable through the variable drop or variable curb are marginal (The 0.04 log. drop or 0.04 log. curb in a long period and 0.02 Δ log drop or 0.02 Δ log curb in a short period). The DW statistics lead to the conclusion about the absence of a problem of autocorrelation, which allows showing the efficiency of the estimators. The multiple values of correlation coefficients permits concluding that the explanatory variables are generally significant which has been confirmed by the Fischer test 1.

Analysis of the evolution rate of regenerating used lube oils for Tunisian company of lubricants

Based on Figure 2, we notice that the curve representing the regeneration rate of used lube oils, made by the Tunisian Company of Lubricants, is strictly increasing with a very steep slope during the period of 1980-2007. However, the steepness of the curve slope has declined over the previous years before falling throughout the remainder of the period. This decrease is mainly caused by a lower tonnage collected between 2008 and 2010.

This is mainly due to three factors:

- The first required factor is the full recovery of the removal threshold of used oils from 200 to 600 which initially led to storage behaviour among all owners.
- The second one is the reduction of the deposit of used engine oils due to the increase in mileage intervals between oil changes, thanks to a better performance of professional and private vehicles. Thus, the progressive fleet renewal should lead to stability or a progressive decline in quantities.
- The third one is the collection lack which is explained by the capacity limit of the regeneration plant which corresponds to 65% of the potential deposit of used oils. In addition, for economic efficiency, the effort of current collection falls on the "profitable deposit" i.e., it is

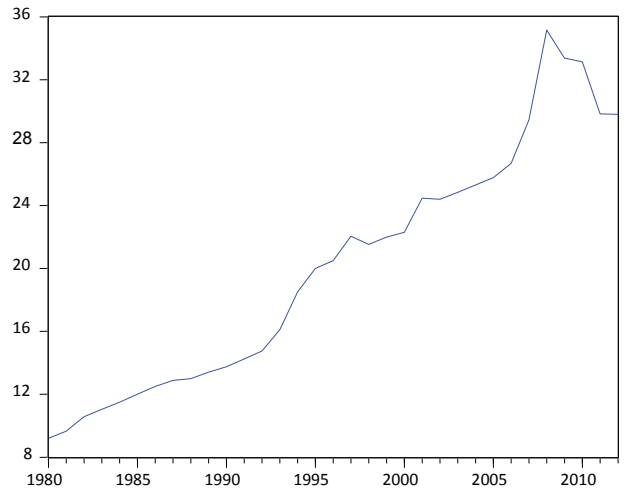

Figure 2: Regenerating rates of used lube oils for TCL (1980-2010) [16].

easy to mobilize and not necessarily on priority areas where an environmental threat arises.

Therefore, a portion of the non- collected deposit corresponds to used oils produced by those who are themselves emptying their vehicles, but there are no data to estimate the amounts of this practice. Furthermore, we are witnessing a market skimming because the collection focuses on the easiest and most cost effective making it a more expensive collection of the remaining portion of the deposit. Absolutely, the need to day is thought to strengthen and organize the management of these waste categories.

Discussion

This study highlights the role of policy waste management variables to raise the rate of recycling made by Tunisian Company of Lubricants. The importance given to these determinants varies from one factor to another. First, we found that the collection services and drop off recycling influence positively and significantly this rate. Our result is in line with the analyse reached by Gonzalez -Torre et al. [5]. This confirms the predictions of the Theory of Thermodynamic of Antoine Laurent of Lavoisier "Nothing is lost, nothing is created, everything is transformed". Second, we have succeeded, through this research, to show that these two factors (collection and drop off recycling) have influenced positively and significantly the rate for recycling when they are made conjointly not separately.

Finally, our results also reveal that there is a positive and significant effect of unit-based pricing of recyclable material on the rate of recycling. We note that our results are in line with the literature. This result is in agreement with Wertz's work [12] which showed that the pricing is an important tool for waste management services. This confirms that it has a positive and significant relationship between pricing and recycling attitude. Our results demonstrate that this unit-pricing is most factors to increase the rate of regenerating for Tunisian Company of Lubricating. Similar to theory of Calvin [15] which analyses the efficacy and significance of PAYT (Pay as You Throw) program in raising the rate of recycling and promoting waste diversion.

Conclusion

Our empirical results demonstrate that the explanatory variables such as unit pricing, curb side recycling and drop off centres increase significantly the rate of regenerating of used lube oils for Tunisian Company of Lubricants. This confirms that these variables are considered as principal factors of the success for this society.

Consequently, this industrial and hazardous waste treatment centre can be regarded as a potential source of energy. So, it is important to encourage the growth of this society which is a labour-intensive recycling sector in Tunisia. This would contribute to the realization of three objectives: reduction of the unemployment rate, reduction of poverty incidence and minimization of waste. Tunisian Company of Lubricants presents an interesting opportunity for creating employment especially for young people who live underprivileged conditions.

Therefore, it is recommended that this society should take into account many other factors in order to ameliorate and enhance its performance. As results, other variables could be introduced into future modelling to improve the research on this subject.

This fact prove that it is essential to change the pattern of how we produce and consume, in order to create a model of waste recycling consistent with the principles of sustainable development of the entire country; especially that environment is not perceived yet as an economic sector in developing countries.

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Author's contributions

All authors contributed equally to this work. Lamia Ben AMOR wrote the main paper and Sami Hammami wrote the supplementary information. They discussed the results and implications and commented on the manuscript at all stages. All authors contributed extensively to the work presented in this paper.

Competing interests

I declare that I have no significant competing financial, professional or personal interests that might have influenced the performance or presentation of the work described in this manuscript. Information provide by authors will remain confidential during the review process and will be published with the article.

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