ECONOMIC RESEARCH FORUM

منتدى البحوث الاقتصادية

2011

working paper series

MITIGATING INDUSTRIAL SOLID WASTE IN TUNISIA: LANDFILL USE VS. RECYCLING

Chokri Dridi and Naceur Khraief

Working Paper No. 590

MITIGATING INDUSTRIAL SOLID WASTE IN TUNISIA: LANDFILL USE VS. RECYCLING

Chokri Dridi and Naceur Khraief

Working Paper 590

June 2011

The authors wish to thank participants of the regional conferences on environmental challenges in the MENA region— which took place in Cairo, Egypt in December, 2009 and in Beirut, Lebanon in June, 2010—for their helpful comments. In particular, we wish to thank three reviewers for their useful comments and suggestions.

Send correspondence to:
Chokri Dridi
University of Alberta
cdridi@ualberta.ca

First published in 2011 by
The Economic Research Forum (ERF)
7 Boulos Hanna Street
Dokki, Cairo
Egypt
www.erf.org.eg

Abstract

This paper reviews the Tunisian legislation on the management of solid waste and assesses the effectiveness of economic instruments in controlling its generation. We set up a conceptual model to establish the short-run equivalence between economic instruments to regulate the generation of industrial solid waste. A simplified model is then calibrated to the Tunisian context to illustrate the gains in welfare, increase in recycling, and decrease in landfills use if Pigouvian taxes are used to internalize the externalities associated with landfills.

ملخص

تستعرض هذه الورقة التشريع التونسي في مجال إدارة النفايات الصلبة ويقيم فعالية الأدوات الاقتصادية في السيطرة على جيلها. أنشأنا نموذج نظري لتحديد المدى قصير التكافؤ بين الأدوات الاقتصادية لتنظيم توليد النفايات الصناعية الصلبة. ثم يتم معايرة نموذج مبسط للسياق التونسي لتوضيح المكاسب التي تحققت في الرعاية، وزيادة إعادة التدوير ، والانخفاض في استخدام المدافن إذا تم استخدام نمط الضرائب والذي يقترحه *بيغو* لاستيعاب العوامل الخارجية المرتبطة بمقالب القمامة.

1. Introduction

The concept of solid waste management (municipal, agricultural, and industrial) in Tunisia is recent. With support from the European Union, the World Bank, and bilateral funds, Tunisia over the last few years has put in place a coherent and progressive program to manage waste through control, elimination and recycling. Over the period 2000-2004, the average per capita generation of solid waste in Tunisia was 38 kgs/year in the form of industrial solid waste and 230 kgs/year in the form of municipal solid waste (Zein, 2005). Solid waste in Tunisia is expected to increase fivefold by 2025 (Fersi and Müller, 2006). Since the late 1980s the Tunisian government has enacted a comprehensive set of laws and decrees to manage and mitigate pollution in general and more particularly to encourage the sustainable management and recycling of municipal and industrial waste, which with economic development is becoming a concern for the regulator as it can endanger both the human and the natural capital of the country. The protection of the environment in general and waste management in particular is currently a priority in Tunisia, where investments in the protection of the environment reach 1.2% of the GDP (Ferchichi, 2008; Toumi, 2008).[1]

Tunisia's national strategy for waste management consists of the following (Toumi, 2008): (i) creation of regional controlled landfills and transfer centers, (ii) closure and rehabilitation of uncontrolled landfills, (iii) creation of integrated systems of waste management (collection, sorting, treatment, and valorization of waste), and (iv) development of recycling and valorization capacities. Waste management is seen as an opportunity to improve the citizens' quality of life and to develop a new sector in the economy (Toumi, 2008); the dividends of better waste management are ecological (through a more sustainable approach to the management of waste and its effects on the natural environment), social (through the creation of new employment opportunities), and economical (through the use of recycled products).

In order to encourage industrial waste reduction and management, the Tunisian government has set up tax incentives for firms to reduce waste. Firms can manage waste by either: (i) collecting it and recycling it themselves or by outsourcing it to private waste management firms, or (ii) through the public system of waste collection, although the latter has a lower recycling rate than the former. Tax breaks for waste reduction are paid for from a de-pollution fund (*Fonds de Dépollution*) created in 1992 and is financed from the national budget, taxes and fines levied on violating environmental regulations.

The achievements made by Tunisia in the area of environmental management are notable in comparison to many countries in the MENA region. The cornerstone legislation under the framework of the Waste Management Act was enacted in 1996 (Republic of Tunisia, 1996). Under that framework, the country's direction regarding the management of solid waste was formulated around three principles: the polluter-payer principle, producer-take-back principle, and citizens' right to information. Essentially, the 1996 law stresses the firm's responsibility in waste generation and handling.

The purpose of this paper is to provide a review and an assessment of the regulatory framework and the programs under which industrial solid waste is managed in Tunisia. This constitutes a first attempt to quantify the effects of the use of economic instruments to curb the generation of industrial solid waste in Tunisia. Section 2 provides the regulatory framework of waste management in Tunisia. Section 3 provides a model to explain the firm's decision to recycle and to use landfills to dispose of industrial solid waste. Section 4 provides an evaluation of the impact of using economic instruments on industrial solid waste

[1] Italy and Spain 0.82%, France 1.2%, USA 1.6% (Ferchichi, 2008; Toumi, 2008).

generation as well as an assessment of practices in some industries. Section 5 concludes the chapter.

2. Background

Nationwide, the generation of industrial waste in Tunisia is estimated at close to 320 thousand tons per year (European Commission, 2007).[2] According to *Ministère de l'Environnement et du Développement Durable* (The Ministry of the Environment and Sustainable Development, 2010), the breakdown of industrial solid waste is as follows: Steel industry (28%), agriculture and food industry (16%), extraction and processing of quarry products, cement industry, glass industry, ceramic industry (12.5%), textiles, carpets and clothing industry (9.5%), metallurgy industry (9%), chemical industry (5.5%), and other industries (19.5%).[3]

Aware of the linkages between economic development and protecting the environment, the Ministry of the Environment and Sustainable Development has put in place an emergency program for the cleanup and restoration of areas severely affected by industrial pollution, with a long-term objective of containing pollution levels within acceptable norms. Currently, Tunisia has 14 controlled and one hazardous waste processing plant (Jeneyah, 2009). Since 1993, the Ministry of the Environment and Sustainable Development has put in place a National Program for Solid Waste Management (*Programme National de Gestion des Déchets Solides*- PRONAGDES) with the objectives of promoting solid waste management as well as the prevention and reduction of solid waste generation and containment of their effect on health.

Environmental legislation in Tunisia is relatively recent. In 1988, Law 88-91 (Republic of Tunisia, 1988) was enacted for the creation of the National Agency of Environmental Protection (*Agence Nationale de Protection de l'Environnement*-ANPE), and defining its purpose and powers. However, in that law no specific mention of waste management is made. Law 88-91 was amended by Law 92-115 (Republic of Tunisia, 1992); this amendment further clarified the powers of the agency and placed it under the control of the Ministry of the Environment and Sustainable Development. What is interesting in this amendment is that the regulator allows for negotiation to solve differences regarding transgressions but without absolution from responsibilities. This offers a cost effective way to achieve the environmental goals and objectives set by the National Agency of Environmental Protection.

The cornerstone legislation on waste and its management was enacted in Law 96-41 (Republic of Tunisia, 1996). The purpose of the law was to setup a framework for the management of waste with the following objectives: (i) the reduction of waste and its impact at the source, (ii) the recycling and recovery of waste and the reuse of some waste as an energy source, and (iii) the use of landfills only as a last resort, when no further recycling or recovery are possible. This law encompasses all entities that produce waste in a condition that may cause harm to public health, the natural environment, or the cultural capital. The section relating to sanctions and penalties in this law, gives authority to agents from the Ministry of the Environment and Sustainable Development with support from the relevant judicial authority to investigate and take samples from waste generating units for analysis. Depending on the gravity of the violation, jail sentences for up to 2 months and/or fines from 100 Tunisian Dinars to 50,000 Tunisian Dinars can be imposed on violators.[4] This law also allows for the courts to issue 'cease and desist' orders on any activity that causes damage until equipment or steps are implemented to bring an end to the polluting activity. The above law

2 Based on 2002 data.

3 Data on the phosphate industry is not included in this breakdown.

[4] 1 Tunisian Dinar is approximately 0.53 Euros.

also allows the Ministry of the Environment and Sustainable Development to enter into negotiations with offending parties before any judgment takes place, however that does not exonerate the offending parties from their obligations.

In 2001, Law 2001-14 (Republic of Tunisia, 2001a) amended both Law 92-115 and Law 96-41. Law 92-115 was amended to make it compulsory on new industrial, agricultural, and commercial projects to provide an impact assessment study before being allowed to operate. Law 96-41 was amended with the aim to simplify the procedures and to further clarify the offenses regarding the handling and disposal of waste. The amendment makes it compulsory for any firm handling waste to be permitted by the ministry of the environment to operate; the permit has a determined validity and can be obtained only after the conduct of an impact assessment study. This law also specifies that collected fines are to be deposited in the de-pollution fund created in 1992 in order to help finance pollution abatement activities. The objectives of the de-pollution fund are to help firms reduce industrial pollution through investments in abatement technologies, to encourage the creation of solid waste collection and recycling units within firms, and to encourage the private sector to invest in waste recycling projects. Upon the approval of any of the above projects, a cost-sharing scheme is adopted, where firms are required to invest 30% of the cost of the project, the fund provides a grant that covers 20% of the costs and the remaining 50% are financed through a bank loan at a preferential interest rate (Baban et al., 1999).

Law 97-1102 (Republic of Tunisia, 1997) enacted in 1997 (revised by Law 2001-843 in 2001; Republic of Tunisia, 2001b) to setup a system of public collection of packaging known as ECO-Lef outlines the conditions and modalities for the recovery and management of plastic bags and packaging. It is based on the polluter-pays principle and the producer-take-back principle. This puts the onus on the producer to recover packaging waste by (i) collecting it themselves, (ii) outsourcing it, or (iii) using the public system of collection ECO-Lef. Initially, in 1998, the system ECO-Lef was a voluntary program, that in 2001 was converted into a paying service, since then 200 centers of collection were setup. In 2001 ECO-Lef contributed to the collection of close to 2,000 tons, which grew to 15,500 tons in 2008 (ANGed, 2008). The National Agency for Waste Management (*Agence Nationale de Gestion des Déchets*- ANGed) was created by Law 2005-2317. This agency has financial autonomy but operates under the authority of the Ministry of the Environment and Sustainable Development. Other initiatives undertaken by ANGed that are similar to Eco-Lef, are Eco-Zit (for used lubricants and oils), Eco-Filtres (for used filters), and Eco-Piles/Eco-Batteries (for all kinds of used batteries). Electric and electronic waste as well as used tires are covered under other initiatives that are in progress (ANGed, 2008; Toumi, 2008).

Tunisia seems to have invested significant resources in the development of recycling programs and education initiatives, but there still seems to be a lack of use of economic instruments to manage waste and a lack of ongoing incentives that have the potential to induce firms to reduce their waste generation through in-house recycling. A stronger emphasis needs to be put in conforming to the polluter-payer and producer-take-back principles.

3. Model

According to Pearce and Turner (1994), in developing countries, a waste management policy should aim for: (i) an optimal waste reduction at the source, (ii) an optimal combination of the use of recycling and landfills,[5] (iii) the management of uncollected waste, and (iv) an

[5] Despite their lower external cost compared to landfills, incinerators do not seem to be a viable alternative in most developing countries due to the relatively low caloric content and nature of solid waste in those countries and to their higher private costs (Pearce and Turner, 1994; Fullerton and Raub, 2004).

appropriate regulatory instrument to induce waste reduction and optimal disposal. It is to be noted also, that maximizing recycling or minimizing waste despite their political appeal are not cost effective as they do not account for the abatement or recycling costs and benefits involved.

In both developed and developing countries the following economic instruments have been implemented as part of waste management strategies: (i) recycling credits, (ii) landfill tax, (iii) tax breaks, (iv) deposit-refund systems, (v) levy on specific raw materials, and (vi) product and user charges (Pearce and Turner, 1994). As discussed in Pearce and Turner (1994), some of the economic instruments provide an ongoing incentive to reduce waste and increase recycling, and can contribute to revenue raising (despite the administrative costs and distributional issues). In order for economic instruments to be effective they need to be coupled with the legislation and facilities to manage solid waste and limit uncontrolled (or anarchic) waste disposal options.

In this section we build on the work by Spulber (1985), Burrows (1979), and Baumol and Oates (1988) to establish the short-run equivalence between a set of economic instruments that are commonly used to regulate the generation and disposal of solid waste. The model we develop is in many ways similar to those developed by Palmer and Walls (1997) and Walls and Palmer (2001) for the regulation of municipal solid waste; although, our model is simpler and is concerned only by the firm's decision to generate and recycle industrial waste.

Consider a price-taking representative firm which uses three kinds of inputs; raw material (*x*), recycled new scrap (*s*), and recycled old scrap (*w*). New scrap is generated during the production process, in the form of byproducts (industrial solid waste) while old scrap is waste generated by consumers upon the use of products (municipal solid waste). The recycling of new scrap is cheaper than the recycling of old scrap, since the new scrap is most of the time clean, sorted, and is usually available in industrial complexes, so transporting it from one production unit to another is much cheaper if not null (Tietenberg, 2006).

The firm's objective is to solve the following problem:

$$\begin{aligned} &\max_{\{x,s,w\}\geq 0} \pi\left(x,s,w\right) = pf\left(x,s,w\right) - r_x x - r_w w - C\left(s\right) \\ &s.t. \\ &s \leq g\left(x,w\right) \end{aligned} \qquad (1)$$

where $g\left(x,w\right)$ is new scrap generated from raw input *x* ($g_x \geq 0$) and old scrap *w* ($g_w \geq 0$). The production function is $f\left(x,s,w\right)$, the output price is *p*, and the costs of inputs *x* and *w* are r_x and r_w, respectively. $C\left(s\right)$ is a cost response function for the collection of new scrap on site and it accounts for abatement effort ($C_s \geq 0$).

With λ being the Lagrange multiplier, the first-order conditions for an interior solution to the above problem are

$$pf_x - r_x + \lambda g_x = 0 \qquad (2)$$

$$pf_s - C_s - \lambda = 0 \qquad (3)$$

$$pf_w - r_w + \lambda g_w = 0 \qquad (4)$$

$$\lambda\left(s - g(x,w)\right) = 0 \qquad (5)$$

The firm does not internalize the social cost of the scrap that remains non-recycled and ends up in landfills. The social cost of non-recycled new scrap can be represented by a damage function $D\left(g\left(x,w\right)-s\right)$ with $D' \geq 0$. In this damage function only industrial solid waste (new scrap) is included; since this is a partial equilibrium model to regulate industries, the effects of non-recycled municipal (old scrap) waste is considered exogenous.

The regulator's objective is to maximize social welfare $\pi - D$, so the first-order conditions for an interior solution are therefore:[6]

$$pf_x - r_x + \left(\lambda - D'\right) g_x = 0 \qquad (6)$$

$$pf_s - C_s - \lambda + D' = 0 \qquad (7)$$

$$pf_w - r_w + \left(\lambda - D'\right) g_w = 0 \qquad (8)$$

$$\lambda\left(s - g(x,w)\right) = 0 \qquad (9)$$

To induce socially optimal behavior, the regulator may use the following economic instruments:

- A Pigouvian tax $\tau = D'$ representing the external marginal cost of industrial waste that is not recycled, $g\left(x^*,w^*\right)-s^*$. In the above equations the quantity $\lambda - D'$ represents the value of scrap to the firm. If all the industrial scrap is recycled then $D' = 0$ and $\lambda > 0$ if not then $\lambda = 0$ and $D' > 0$ which represents a disposal fee that is equal to the full external marginal cost of industrial waste. If the regulator levies a Pigouvian tax on industrial solid waste that ends up in landfills then the firm is induced to generate a socially optimal level of waste and pays a landfill tax. If levied beforehand on inputs, such tax can then be considered an advance disposal fee on scrap that ends up in landfills. Two major drawbacks of Pigouvian taxes on solid waste are: (i) the need for taxes on various goods (or at the very least for various categories of goods) that generate solid waste, and (ii) the need to monitor the use of controlled and uncontrolled landfills; Fullerton and Raub (2004), among other studies, argue that a disposal charge may lead to an increase in the illegal disposal of waste.
- A deposit/refund scheme, with a deposit set to $\psi = D'g_x$ per unit of input *x* and a refund of $\rho = D'$ per unit of recycled scrap. Notice that the regulator may also require a deposit $\phi = D'g_w$ to induce an optimal use of old scrap (*w*) and the recycling of its byproducts. The deposit/refund scheme is designed such that the firm is induced to adopt a socially optimal behavior. When implementation costs are low, a deposit/refund scheme may be preferable to a Pigouvian tax or a recycling subsidy (Palmer et al., 1997). The advantage of the deposit/refund scheme is that it is easier to enforce than a Pigouvian tax because it relies on easily observable decisions such as the use of inputs and recycling of scrap (Fullerton and Raub, 2004).
- A recycling subsidy δ can be given to the firm for recycling beyond a level of unregulated waste Δ. This scheme transforms the firm's profit into;

$$pf\left(x,s,w\right) - r_x x - r_w w - C\left(s\right) + \delta\left[\Delta - \left(g\left(x,w\right)-s\right)\right] \qquad (10)$$

The first-order conditions of the firm's problem become:

$$pf_x - r_x + \left(\lambda - \delta\right) g_x = 0 \qquad (11)$$

[6] Since we are considering a price-taking firm, the change in consumers' surplus is zero.

$$pf_s - C_s - \lambda + \delta = 0 \qquad (12)$$

$$pf_w - r_w + (\lambda - \delta) g_w = 0 \qquad (13)$$

$$\lambda\big(s - g(x,w)\big) = 0 \qquad (14)$$

In the short run, a subsidy $\delta = \tau = D'$ has the same effect as a Pigouvian tax or a deposit/refund scheme but not in the long run because of the lump sum transfer $\delta \cdot \Delta$ that the firm receives. The transfer may determine the entry and exit condition in the industry, and therefore the long-run optimal number of firms in the industry. If the firm recycles more than Δ then it receives the transfer $\delta \cdot \Delta$ but pays a charge $\delta\big(g(x,w) - s\big)$ for the non-recycled scrap, but if the firm recycles less than Δ then it ends up paying more charges than it receives from transfers.

In the above model the firm's decision is essentially that of deciding if industrial waste is to be recycled and used for the production of other goods or to be disposed of in the environment (i.e. landfills). This warrants the use of a simplified model where the decisions to recycle and to use landfills to dispose of industrial waste are made on the basis of marginal costs and benefits. In addition, the calibration of the above model would require a lot more information, such as the details of the production and cost functions, the waste generation function and input prices. Some of that information may not be available or just difficult to gather.

In figure 1, we provide the economic relationships that determine the levels of recycling (with origin at $\overline{W}$) and the use of landfills (with origin at *O*); in most developing countries these are the two main options available to manage solid waste. Indeed, as indicated above with the reduction at the source, recycling and the use of landfills are the main option for dealing with waste in Tunisia. In the above figure, the vertical axes depict the costs and the horizontal axis depicts the quantities of waste to be recycled or disposed of in landfills. The marginal cost of landfills is MC_L, assuming a constant marginal external cost of landfills, the marginal social cost is MSC_L. The net marginal cost of recycling is represented by $-MB_R$ (MB_R is the net marginal benefit) and it has a negative intercept because, initially, recycling produces revenues.

In the above figure, we consider that the initial level of generated waste is $\overline{W}$. Initially recycling has a lower marginal cost than using landfills and produces positive revenues, therefore a recycling level of $\tilde{R}$ is voluntarily achieved and the benefit is the area $\tilde{R}\overline{W}I$, the leftover waste is the segment $O\tilde{R} = \overline{W} - \tilde{R}$. Beyond the recycling level $\tilde{R}$, recycling still has a lower marginal cost than the use of landfills, but it generates negative revenues. If the firm does not account for the external cost of landfills, then recycling $\overline{R} > \tilde{R}$ takes place; the firm avoids a cost of landfill $CB\tilde{R}$, and the leftover waste is the segment $O\overline{R} = \overline{W} - \overline{R}$. In this case the total private cost of waste disposal is $OJC\overline{R} + \overline{R}C\tilde{R} - \tilde{R}\overline{W}I$ and the total social cost is $OKF\overline{R} + \overline{R}C\tilde{R} - \tilde{R}\overline{W}I$. When the firm accounts for the external cost of landfills, then recycling $R^* > \overline{R}$ takes place; thus society avoids the cost of landfill $EG\tilde{R}$, the leftover waste is $OR^* = \overline{W} - R^*$, in this case the total social cost of waste disposal is $OKER^* + R^*E\tilde{R} - \tilde{R}\overline{W}I$. When the firm does not account for the external cost of landfill, recycling is suboptimal and the total external cost is the difference between the total private cost and the total social cost of waste disposal; $JKEC$, in this case there is a deadweight loss (DWL) equal to EFC. If we denote by τ the external cost, then in the absence of information on the marginal cost of recycling, the deadweight loss can be approximated by assuming that the segment EC is linear; in which case, with a target P^* of waste that is disposed of in landfills, the deadweight loss is approximated by $DWL \approx 0.5\tau\left(\overline{P} - P^*\right)$. However, due to the convexity of the marginal cost of recycling the approximation of the deadweight is an underestimation; as the difference $\overline{P} - P^*$ increases, the underestimation increases as well.

As demonstrated in the analytical model, the use of a Pigouvian tax equal to the marginal damage from waste that ends up in landfills leads to the same short-run outcome as a deposit-refund scheme or a recycling subsidy. In this case, if the regulator imposes a waste disposal fee equal to the marginal external cost then the optimal level of recycling can be achieved and industrial solid waste is reduced.

4. Model Calibration and Evaluation

In many developing countries the use of (controlled and often uncontrolled) landfills is still popular because they are often the cheapest option available. Except for hazardous waste, industrial and municipal solid wastes end up in the same landfill, indeed the legislation in Tunisia does not distinguish between municipal and (non-hazardous) industrial solid wastes. As mentioned above, Tunisia has invested in controlled landfills and transfer centers, but controlled landfills without fuel recovery is still the norm. The regulator is considering the reduction of energy imports by using fuels produced from waste, refuse derived fuel (RDF), and the construction of controlled landfills with fuel and biogases recovery which are underway (ANGed, 2008; Lechtenberg, 2008; Jeneyah, 2009).[7] In what follows, we consider controlled landfills without RDF.

In the context of Tunisia, the lack of reliable data implies the necessity to extrapolate from various sources of data and the use of consumer price indices (CPIs) to make adjustment to the data.[8] Using data collected from European countries, Tsilemou and Panagiotakopoulos (2006) derive initial cost and operating cost functions for landfills. They are presented in table 1 and they represent cost functions expressed in 2003 prices; we use that year as the base year throughout this study.

The above cost functions need to be calibrated for the Tunisian context, to that end we use the information provided in Dagh-Watson (1994). In Dagh-Watson (1994) it is stated that for a landfill with the capacity of 66 thousand tons/year the total unit cost is 27.112 Tunisian Dinars/ton.[9] Assuming that that figure is expressed in 1994 prices, we use consumer price indices of 1994 and 2003 to convert the total unit cost of industrial solid waste disposal to 2003 prices.[10] Using an average rate of 0.8070 Euros/Tunisian Dinar in 2003 we convert the total unit cost of industrial solid waste to 2003 prices of 29.31 Euros/ton.[11] For a capacity of 66 thousand tons/year the correspondent total unit cost using the cost functions in table 1 is 41.94 Euros/ton, the difference between that value and the corresponding value for Tunisia can be attributed to land value, labor cost, capital cost, and additional costs that are due to the differences in standards and regulations regarding the disposal of solid waste. For the

[7] Under the Kyoto Protocol's Clean Development Mechanism (CDM).

[8] This implies that results from this research should be used with caution.

[9] Dagh-Watson (1994) refers to "special solid waste", however in the chart flow they provide (figure 1, p. 4), the industrial solid waste is lumped with and goes through the same treatment as the special solid waste. The definition of special waste used by Dagh-Watson (1994) applies to waste that requires additional measures during handling and processing.

[10] Tunisia's CPI (base year 2005) for 1994 and 2003 are 70.6 and 94.6, respectively (Source: International Monetary Fund).

[11] Using exchange rate data from the International Monetary Fund.

purposes of this calibration we apply an adjustment coefficient of 0.70 to the cost functions in table 1.

The cost functions in table 1 do not include the external cost of landfills that are associated with leachate effects, methane emissions and the aesthetic value of neighborhoods among others.[12] In the context of the Netherlands, Dijkgraaf and Vollebergh (2004) provide year 2000 estimates of the net environmental costs of landfills that are of 22.14 Euros/ton. That value needs to be adjusted by a factor of 1.10 to account for the change in prices in the Netherlands between 2000 and 2003.[13] The marginal social cost of landfills can therefore be approximated by $MSC_L(q) = MC_L(q) + \tau$, where $\tau = 24.32$. Admittedly, the figure from the Netherlands may be higher or lower than the true external cost applicable to Tunisia, however there seems to be some concordance with the average value of 20 Euros/ton reported by the European Commission (2000). The European Commission (2000, p. 59) study provides two average values for the external cost 11 Euros/ton and 20 Euros/ton; the lower value corresponds to a landfill that meets the European Commission directives while the higher value corresponds to a more usual landfill.[14] Differences in the external costs of landfills between countries can be explained by differences in climates and natural capitals as well as by differences in the economic conditions between countries. In the absence of additional data to support a further adjustment of the external cost provided by Dijkgraaf and Vollebergh (2004), we use the above value but provide a sensitivity analysis with respect to changes in that value.

A 2002 figure, evaluates the industrial waste in Tunisia to be about $\overline{P} = 320$ thousand tons, that figure seems to exclude quantities recycled by the firms themselves. In the absence of additional information on the cost and the benefits of waste disposal then with a target P^* of waste that is disposed of in landfills, the deadweight loss is approximated by $DWL \approx 3891.2 - 12.16P^*$ in thousand Euros. The deadweight loss increases as the socially optimal level of industrial solid waste that ends up in landfills decreases. The magnitude of deadweight loss will depend on the true values of the marginal external cost and the marginal cost of recycling. Larger value of the marginal external cost would lead, ceteris paribus, to larger deadweight losses. Higher marginal cost of recycling would lead, ceteris paribus, to smaller deadweight losses.

In the absence of information on the marginal cost of recycling, we derive a level of landfill use, and the deadweight loss associated with it, that has a total social cost that is equal to the total private cost of the initial level of landfill use, $\overline{P} = 320$. At the initial level of landfill use, the firm's total cost is given by $\int_{60}^{\overline{P}} MC_L(q)\,dq$; the idea is to find a landfill use level that leads to a total social cost that is equal to the firm's total cost, this consists in solving the following equation for P^*;

[12] Porter (2002, p. 57-59) gives a more extensive discussion of the external costs of landfills, such as their effect on property value, groundwater contamination and their contribution to greenhouse gases.

[13] The Netherlands' CPI for 2000 and 2003 (base year 2006) are 87.41 and 96.03, respectively (Source: Statistics Netherland).

[14] Rabl et al. (2008) give external cost values for France that range between 10 and 13 Euros/ton; however their study is not inclusive of all sources of external cost. Still, their values are within the estimates of the European Commission (2000). Eshet et al. (2005) survey various studies and the external cost reported show a lot of variability that are due to context and assumptions.

$$\int_{60}^{P^*} MSC_L(q)\,dq = \int_{60}^{\overline{P}} MC_L(q)\,dq \qquad (15)$$

The solution to the above equation gives a socially optimal value of landfilled industrial solid waste of P^*=301.81 thousand tons, leading to a deadweight loss of 266.56 thousand Euros.

This shows that the use of an economic instrument to account for the external cost of landfill use leads to a reduction in the volume of waste that ends up in landfills in the order of 18 thousand tons. Ultimately, the reduction in industrial solid waste hinges on the value of the external damage that is used as well as the initial level of waste. In figure 2, we provide the reduction in industrial solid waste as function of the initial (unregulated) industrial solid waste; it shows an increasing convex relationship—although almost linear due to the weak curvature in the marginal cost function. In figure 2, we consider only a limited range of values for $\overline{P}$, as it is unlikely that the volume of industrial solid waste in Tunisia would change drastically in the near future at least. Over the displayed range, this figure shows that a reduction in landfill use in the order of 84 tons per thousand ton (8.37%) of generated waste is possible.

In figures 3 and 4, we show the sensitivity of the optimal level of industrial solid waste and the deadweight loss to changes in the external cost of landfill use, both relationships are almost linear. Figure 3 shows a decreasing relationship where an additional 1 Euro worth of internalized externality has the potential of reducing the generated waste by about 723 tons. Figure 4 shows that higher values of external cost lead to higher deadweight losses, and thereby more inefficiency. An additional 10,600 Euros in DWL can be expected from an additional Euro worth of externality that is not internalized. In the absence of additional information, it is difficult to determine if the external costs in Tunisia are higher or lower than those for the Netherlands. For instance, the warmer weather in Tunisia may contribute to the unpleasantness of having a landfill close to a residential area and therefore, ceteris paribus, leads to a higher external cost than for the Netherlands. Conversely, the closer proximity of the Netherlands to water bodies may, ceteris paribus, lead to higher external cost due to leachate and water contamination.

In Tunisia, sorting of waste is seldom undertaken in production units, and when it does take place it is only to recover waste that still has market value. Dagh-Watson (1994) observed that, in Tunisia, the principal side products or wastes that are usually recovered are:

- Containers and miscellaneous packaging: In general package and wrapping of raw products are often resold. It is not uncommon, to find that some of those packages were used to bundle dangerous or toxic products such as paint and solvents.
- Paper: Sorting of this kind of waste is usually done only at large printing shops in the capital in order to be sold to paper manufacturers.
- Textile waste: Although easily recyclable, there is no established system to recover this kind of waste. In the case of textile destined for export, it has been known that waste is incinerated in order to fulfill custom regulations.

The main problem is that often firms do not declare certain waste as such or do not declare certain categories of waste, this makes the quantities declared questionable. In addition, industries have little incentives to sort waste because of the lack of space, therefore mixed waste would be of limited interest to any potential recycling industry (Dagh-Watson, 1994). At the firm level, the lack of financial support from the banking system discourages a better waste management or investments in pollution control in general.

An environmental study of the leather industry in Tunisia (Palacios et al., undated) shows that in Tunisia generally the processing of 1 kg of animal skin produces 450 grams of solid waste.

Palacios et al. report that 47% of the surveyed tanneries have storage areas for waste. In some tanneries waste is removed daily while in some others it is removed on a monthly basis, but only 43% of the interviewed tanneries have their waste ending up in a controlled site for the treatment or elimination of waste. The above study reports that on average the tanneries' cost of waste management is 47.2 Euros/ton. Among the studied tanneries, none has developed any special process to reduce waste beyond the internally optimal use of raw materials. The conclusion of Palacios et al. study suggests that in general, tanneries in Tunisia are not aware of environmental legislations and standards, and do not manage their waste (all kinds) appropriately.

Industrial solid waste in Tunisia, is not confined to manufacturing industries but also originates from the agri-food industries; Baban et al. (1999), report that in Tunisia industrial waste from olive oil extraction produces a large volume of waste that has a high content of organic and inorganic pollutants as well as heavy metal that remain unassimilated into the environment for long periods of time. Generally, these pollutants end up being disposed of through burial into the ground or disposal in nearby water bodies, which either way leads to a pollution of the groundwater.

5. Conclusion

Tunisia is going through rapid economic growth, population growth, and increased urbanization that ostensibly lead to an increased stress on its ecosystems, natural resources, and natural capital. One of the stressors on Tunisia's natural capital is waste, both municipal and industrial. This paper provides a survey of the regulatory framework used to manage solid waste in Tunisia and relying on secondary data attempts to quantify the effects of the use of economic instruments to induce socially optimal levels of industrial solid waste reduction.

While the legislation and advancement in the integrated management of solid waste in Tunisia are notable within the context of the MENA region, the lack of use of (appropriate) economic instruments to reduce industrial solid waste seem to limit the incentives for firms to recycle beyond what is beneficial to them. Indeed, the external costs of landfills are not internalized. The use of economic instruments to manage solid waste requires an integrated approach to waste management and a reduction of uncontrolled landfills. Compared to uncontrolled landfills, controlled landfills are a costly but necessary option to limit spillovers and ensure a sustainable development (Jeneyah, 2009).

The conceptual model developed in this paper is perhaps more suitable for industries where solid waste is more or less homogenous, such as steel and metallurgy industries, extraction industries, and textile industry. For industries such as the agrifood industry or chemical industry their by-products are often at the end of their transformation cycle, not easy to sort, and present little to no value for recycling; for those industries a more sector specific analysis may be required. However, in the context of Tunisia the lack of reliable, published data on costs and recycling rates as well as estimates of external cost makes an evaluation of waste management policies daunting. More specific and concerted efforts to collect data on setup and operating costs of landfills and studies to determine the external cost of landfills and the economic benefits of recycling are needed for any thorough analysis of the regulation and management of solid waste in Tunisia.

References

ANGed (2008). *Rapport d'Activité 2008*, Agence Nationale de Gestion des Déchets, Ministère de l'Environnement et du Développent Durable, République Tunisienne.

Baban, S.M.J, I.D.L. Foster and B. Tarmiz. 1999. Environmental protection and sustainable development in Tunisia: An overview. *Sustainable Development* 7: 191–203.

Baumol, W.J. and W.E. Oates. 1988. *The theory of environmental policy*. 2nd edition. Cambridge: Cambridge University Press.

Burrows, P.B. 1979. Pigouvian taxes, polluter subsides, regulation, and the size of a polluting industry. *Canadian Journal of Economics* 12(3): 495–501.

Dagh-Watson. 1994. *Etude sur la Gestion Industrielle en Tunisie*, Agence Nationale de Protection de L'Environnement, Tunisia.

Dijkgraaf, E. and Vollebergh, H.R.J. 2004. Burn or bury? A social cost comparison of final waste disposal methods. *Ecological Economics* 50: 233–247.

Eshet, T., O. Ayalon and M. Shechter. 2005. A critical review of economic valuation studies of externalities from incineration and landfilling. *Waste Management and Research* 23: 487–504.

European Commission. 2000. *A study on the economic valuation of environmental externalities from landfill disposal and incineration of waste*. October 2000.

European Commission. 2007. *Euro-Mediterranean Statistics*, Eurostat.

Ferchichi, M. 2008. *La Gestion des Déchets en Tunisie: Réalisation et Synthèse de Financement des Projets*. Technical Seminar on Integrated and Sustainable Management of Waste, Products and Resources, June 16, Rabat, Morocco.

Fersi, S. and J. Müller. 2006. *La Gestion des Déchets Solides en Tunisie: Un Marché Attractif pour les Entreprises Allemandes.* AHK Tunesien - *Partenaire & Developpement* Summer 2006: 13–15.

Fullerton, D. and A. Raub. 2004. Economic analysis of solid waste management policies. in *Addressing the Economics of Waste*, Organization for Economic Co-operation and Development, Ch. 3.

Jeneyah, M. 2009. *Projets MDP des Décharges Contrôlées en Tunisie*. MENA Carbon Forum 2009, 6–7 May, Cairo, Egypt.

Lechtenberg, D. 2008. Tunisia: Waste management and the cement industry. *Global Fuels Magazine*, May: 18–19.

Ministère de l'Environnement et du Développent Durable, République Tunisienne. 2010. *Améliorations de la Qualité de Vie – Déchets Solides*, République Tunisienne. http://www.environnement.nat.tn/dechets.htm >, Web. 17 Nov. 2010.

Palmer, K. and M. Walls. 1997. Optimal policies for solid waste disposal: Taxes, subsidies, and standards. *Journal of Public Economics* 65: 193–205.

Palmer, K., H. Sigman and M. Walls. 1997. The cost of reducing municipal solid waste. *Journal of Environmental Economics and Management* 33: 128–150.

Palacios, J.F. et al. (undated): *Environmental Situation of the Tunisian Leather Industries*, Unpublished.

Pearce, D. and R. K. Turner. 1994. *Economics and solid waste management in the developing world*. Centre for Social and Economic Research on the Global Environment, Working Paper WM-1994-05.

Porter, R.C. 2002. *The economics of waste*. Resource for the Future.

Rabl, A., J.V. Spadaro and A. Zoughaib. 2008. Environmental impacts and costs of solid waste: A comparison of landfill and incineration. *Waste Management and Research* 26: 147–162.

Republic of Tunisia. 1988. Loi n. 88-91 du 2 aout 1988, portant création d'une agence nationale de protection de l'environnement. *Official Journal of the Republic of Tunisia*, N. 52, August 2, 1988.

Republic of Tunisia. 1992. Loi n. 92-115 du 30 novembre 1992, modifiant la loi n. 88-91 du 2 aout 1988, portant création d'une agence nationale de protection de l'environnement (1). *Official Journal of the Republic of Tunisia*, N. 81, December 4, 1992.

Republic of Tunisia. 1996. Loi n. 96-41 du 10 juin 1996, relative aux déchets et au contrôle de leur gestion et de leur élimination (1). *Official Journal of the Republic of Tunisia*, N. 49, June 18, 1996.

Republic of Tunisia. 1997. Loi n. 97-1102 du 2 juin 1997, fixant les conditions et les modalités de reprise et de gestion des sacs d'emballages et des emballages utilizes. *Official Journal of the Republic of Tunisia*, N. 47, June 13, 1997.

Republic of Tunisia. 2001a. Loi n. 2001-14 du 30 janvier 2001, portant simplification des procédures administratives relatives aux autorisations délivrées par le ministère de l'environnement et de l'aménagement du territoire dans les domaines de sa competence. *Official Journal of the Republic of Tunisia*, N. 10, February 2, 2001.

Republic of Tunisia. 2001b. Loi n. 2001-843 du 10 avril 2001, modifiant le décret n° 97-1102 du 2 juin 1997, fixant les conditions et les modalités de reprise et de gestion des sacs d'emballage et des emballages utilisés. *Official Journal of the Republic of Tunisia*, N. 31, February 17, 2001.

Republic of Tunisia. 2005. Loi n. 2005-2317 du 22 aout 2005, portant création d'une agence nationale de gestion des déchets et fixant sa mission, son organisation administrative et financière, ainsi que les modalités de son fonctionnement. *Official Journal of the Republic of Tunisia*, N. 68, August 26, 2005.

Spulber, D.C. 1985. Effluent regulation and long-run optimality. *Journal of Environmental Economics and Management* 12(2):103–116.

Tietenberg, T. 2006. *Environmental and natural resource economics*. 7th edition. Pearson-Addison Wesley, Ch. 9.

Toumi, M. 2008. *La Gestion Intégrée et Durable des Déchets en Tunisie*. FORUM 2008 sur le Développement Durable, April 9-11, Abidjan, Cote d'Ivoire.

Tsilemou, K. and D. Panagiotakopoulos. 2006. Approximate cost functions for solid waste treatment facilities. *Waste Management and Research* 24: 310–322.

Walls, M. and K. Palmer. 2001. Upstream pollution, downstream waste disposal, and the design of comprehensive environmental policies. *Journal of Environmental Economics and Management* 41: 94–108.

Zein, K. 2005. *Gestion Rationnelle des Déchets au Maghreb-Contexte Général, Projets et Perspectives.* Maghreb Symposium for the Rational Management of Waste, May 7–9, 2005, Algiers, Algeria.

Figure 1: Optimal recycling and landfill use

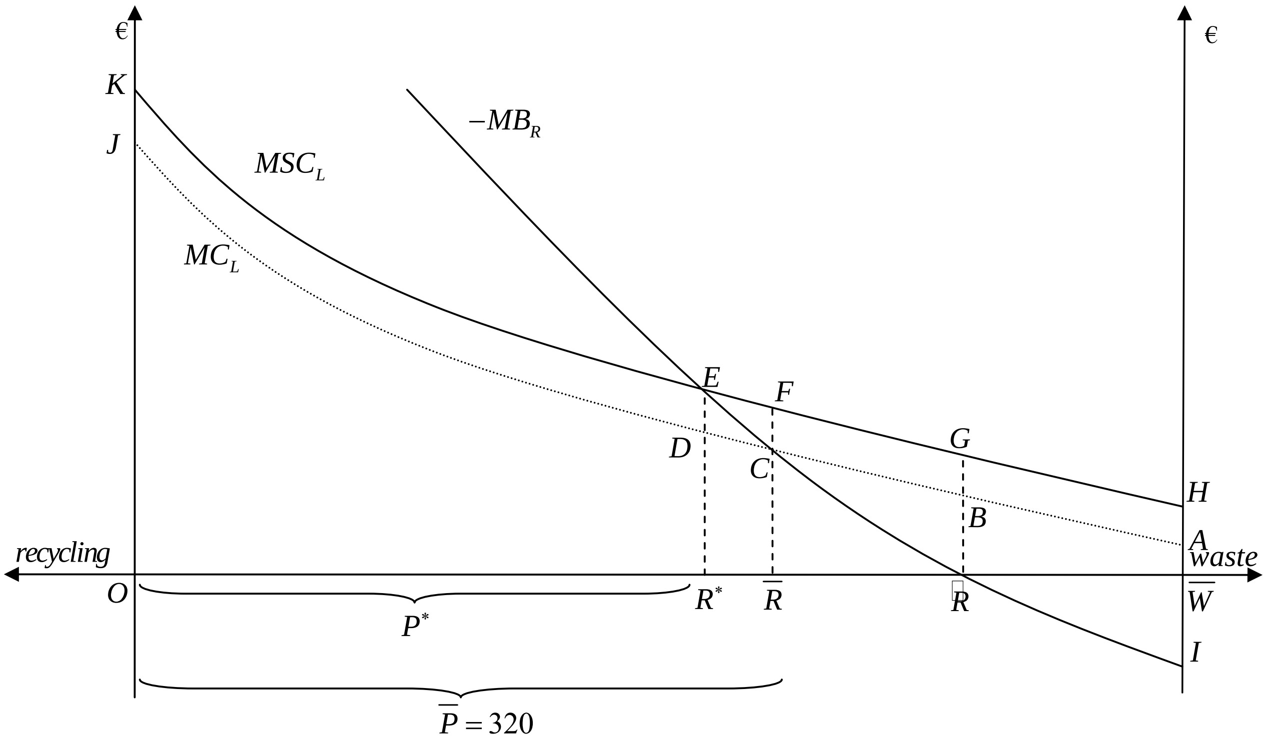

Figure 2: Reduction in industrial solid waste as function of unregulated waste level

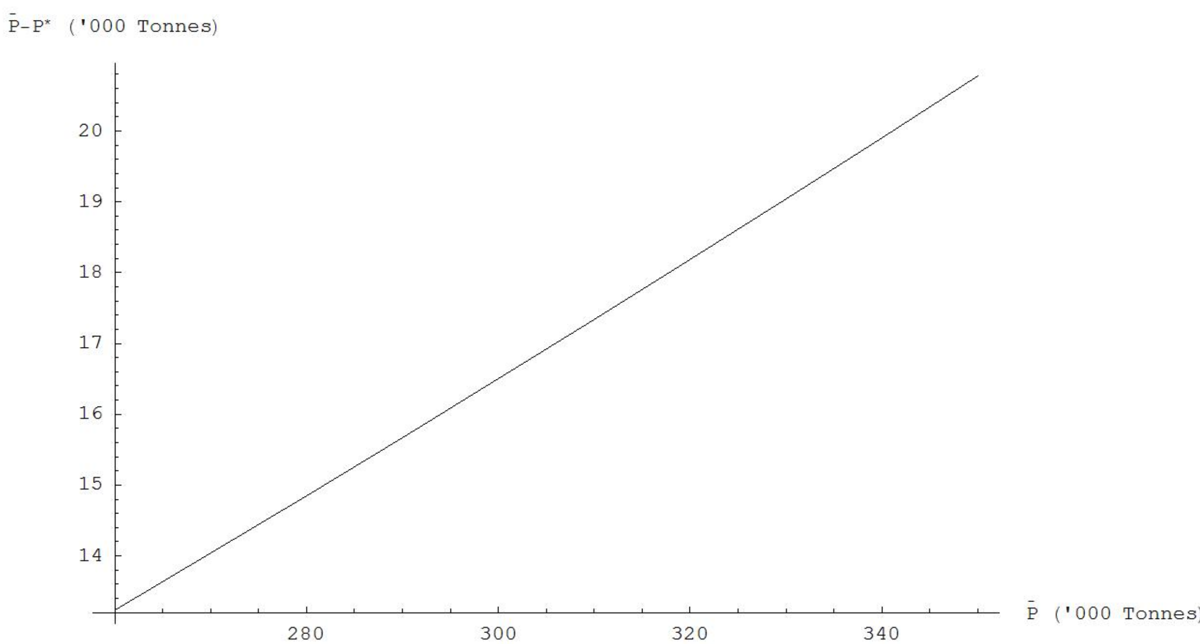

Figure 3: Sensitivity of the socially optimal level of industrial solid waste to the external cost

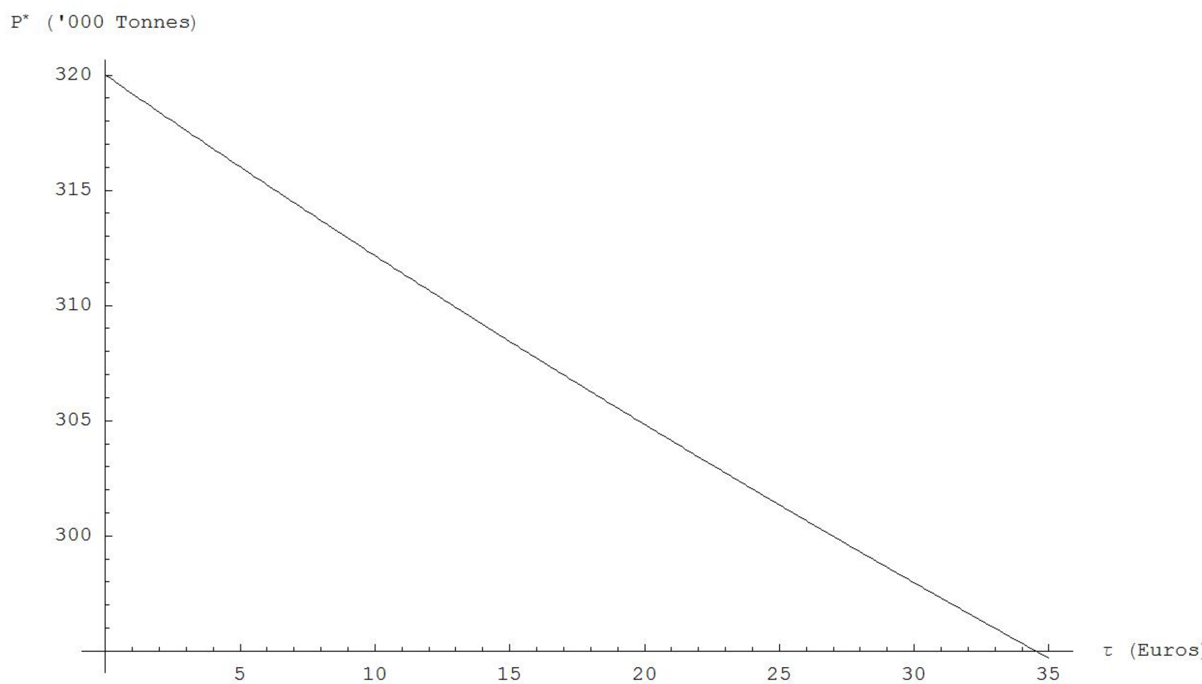

Figure 4: Sensitivity of the deadweight loss to the external cost

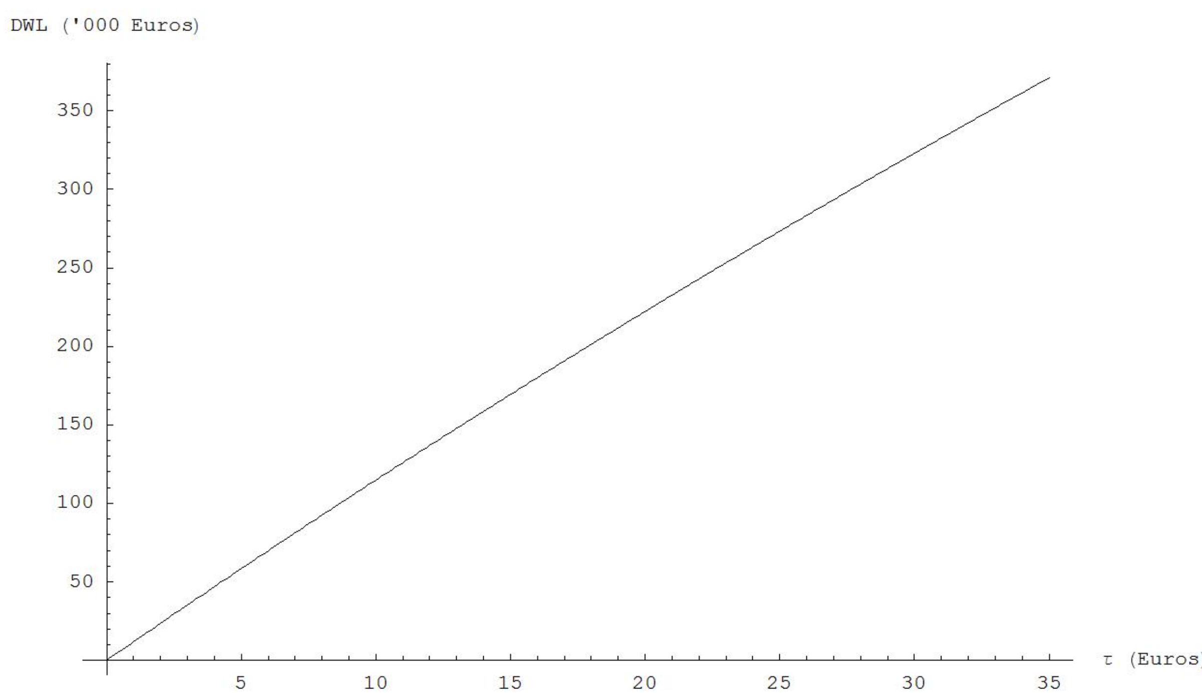

Table 1: Initial cost and operating cost functions of landfills

Capacity ('000 ton/year)	Initial Cost (million €)	Operating Cost (€/Ton)
0.5-60	$0.0057q^{0.61}$	$103.86q^{-0.30}$
60-1,500	$0.0033q^{0.71}$	$132.37q^{-0.28}$

Source: Tsilemou and Panagiotakopoulos (2006).