The Environmental Kuznets Curve in the Municipal Solid Waste Sector

Graziano Abrate, Matteo Ferraris

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Fondazione Collegio Carlo Alberto
Via Real Collegio, 30
10024 - Moncalieri (TO)
Tel: 011 670 5250
Fax: 011 6705089
info@hermesricerche.it
http://www.hermesricerche.it

The Environmental Kuznets Curve in the Municipal Solid Waste Sector*

Graziano Abrate

(Università del Piemonte Orientale and HERMES, graziano.abrate@eco.unipmn.it)

Matteo Ferraris

(Università del Piemonte Orientale and HERMES, matteo.ferraris@eco.unipmn.it)

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Abstract

This paper provides a specific application of the Environmental Kuznets Curve (EKC) theory in order to explain the correlation between income and household waste generation. The main purpose is contributing to enhance the connection between theoretical and empirical analysis. We develop a theoretical model that highlights a U-shaped path of income-refuse relationship depending on the environmental effort of households in recycling and consumption. The existence of delinking also depends on other socio economic variables that affect the shape of the curve. The econometric analysis finds evidence supporting the existence of EKC relationship using Italian data at the municipality level.

Keywords: Environmental Kuznets Curve, Waste Management, Waste Policies, Delinking, Non Linear Regression

Code: C20, C61, Q38, Q53, Q56

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1. Introduction

Post consumption environmental impact has become an important issue all over the world. Waste volumes are predicted to continue rising unless action is taken in order to keep down the problem. There is a need to take appropriate measures in order to reduce the amount of waste for final disposal. Further, in the last two decades refuse collection and waste disposal industry have been affected by some important changes. On the one hand, the increasing amount of refuses in developed countries could generate a collapse of this sector, by engendering a landfill crisis and decreasing of environmental quality. On the other hand, the structure of landfill has recently moved from local sites to regional ones, such that negative externalities of refuse disposal could be reduced. The attention over landfills and recycling is increased a lot, encouraging households to separate refuses and opening a market of recycled materials (an example of this attention is that many countries begin to make 'per bag' price policy). As a consequence, many economists were induced to pay their attention to this sector.

This paper focuses on environmental aspects of refuse collection and disposal by drawing on delinking literature between income and pollution. Many theoretical and empirical economists argued the evidence of relationship between these two fundamental economic variables. Instead, there is empirical evidence that some pollutants follow an inverse-U-shaped pattern relative to countries income. This type of relationship is called "Environmental Kuznets Curve", EKC. Kuznets [21] was the first economist that studied the particular relationship between economic growth and unemployment. He showed that unemployment increases until a some level of income after which level it begins to decrease.

As a consequence of his work, many economists modified the original formulation by analyzing the relationship between economic growth and pollution of a country arguing the existence of delinking between growth and environmental quality. However, many researchers think that delinking can not be automatically shown. Economic growth can be only a part of the environmental problem solution.

The contribute of this paper is to deepen the understanding of EKC with a specific application to the municipal solid waste sector. The causes of the relationship between income and refuses are defined in a theoretical framework considering different type of wastes: total, non separated and separated refuses. The second step is to implement it empirically.

The paper is structured as follows. Section 2 and 3 present the theoretical and empirical literature about EKC, respectively. Section 4 describes the theoretical model in order to define the optimal refuse function as a function of income and other socio-economic variables. Section 5 describes the dataset and Section 6 defines the empirical model and comments on the empirical results regarding waste generation, comparing both linear and non linear specifications. Section 7 concludes.

2. Theoretical Literature

The EKC literature is connected to the delinking (decoupling) theory as indicator of environmental effectiveness with respect the economic activity. The intuition of these indicators is to separate the economic activity trend from the pollution generation.

Economists have proposed several reasons for the relationship of the income-pollution path which can be classified into three categories: increasing economic scale, structural change[1] and increasing demand for environmental quality as household income increases. While the first category provides an explanation for a positive income-pollution relationship, the other two categories can explain positive as well as negative relationships[2].

The models in the literature that study inverse-U-shaped relationship between income and pollution assume that pollution is a by-product of either consumption or the capital stock and that the consumer can affect the level of pollution either by choosing less productive technologies with lower emission or through pollution abating environmental effort (see Highfill & McCasey 2001, Huntala 1997).

At the present, theoretical studies of EKC are rather scarce. These studies generally try to explain dynamics in terms of type of technological investments, endogenous spill over, changing preferences and policy factors. Other authors provide a theoretical underpinning for EKC dealing with dynamic optimal investments in waste management and waste disposal options.

One of the most interesting theoretical interpretation is given by the model of Andreoni and Levinson [1]. They develop a static model in which the EKC can be derived directly from the technological link between consumption of a desired good and the abatement of its undesirable by-product (generic pollution). The inverse-U-shaped relationship does not depend on the dynamic of

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[1] That is, changes in the output mix of the economy or deriving from the economic growth of a country, such as the transformation from agricultural to industrial economy and, at last, to industry of services have some positive effects on the environment. The first change may generate increasing pollution, while the second may generate a reduction of pollution. In other words, there is an effect of an adoption of techniques and technologies that require less intensive resources and generate less pollution for unit of output. By supporting this concept, free trade theory suggests that developing countries would specialize in the production of goods that are intensive in the factors that they are endowed with relative abundance: labour and natural resources. Developed countries would specialize in human capital and manufactured capital intensive activities. Part of the reduction in environmental degradation levels in the developed countries and increases in environmental degradation in middle income countries may reflect this specialization. Moreover, environmental regulation in developed countries might further encourage polluting activities to gravitate towards the developing countries.

[2] Other additional explanations, such as technological change can be due to the increasing civil and political liberties, and changes in environmental and trade policies are simply the meaning through which changes in the demand for environmental quality are realized into changes in pollution levels.

growth, political institutions, or even externalities, and can be consistent with a decentralized economy as well as Pareto efficient policy.

An extension of the latest model is given by the recent paper of Khanna & Plassmann [23] in which they use the agent model to analyze the mechanism of EKC. They decompose the analysis in two frameworks. On the one hand, the allocation of resources to consumption and environmental effort, on the other hand, the relationship between the specific resources and the environmental quality. Moreover, they use a simple model in which they do not assume specific functional forms, it permits to apply the model to a wide range of utility and pollution functions. The model recover the model of Andreoni and Levinson that for its simplicity makes easy to examine the driving forces behind the EKC. Consumer preferences can either foster or prevent a reduction in pollution. For example, if consumers do not exercise enough environmental effort as they get richer, then the most sophisticated and effective abatement technologies cannot prevent pollution from increasing. But, conversely, consumers do not need to have very "green" preferences for pollution to ultimately fall with income if abatement is sufficiently effective.

As to the literature concerning specifically the waste sector, Fullerton and Kinnaman [15] and Podolsky and Spiegel [32] describe the substitution possibilities between waste disposal and recycling as part of household waste management. They develop models in which households maximize utility subject to a budget constraint that incorporates a unit price for waste collection. The models are the basis for a solid waste disposal and recycling demand equations[3].

There is an interesting part of the environmental literature that studies costs and benefits of municipal solid waste recycling. For example, Kippenberg [24] tries to explain the heterogeneous consumer behaviour in recycling some materials and to value the benefits in terms of cost of time and money spent in this activity. The time and the heterogeneity of consumers are two key factors for their behaviour since the choice of recycling could be due in part to voluntary behaviour (independent to money incentives), in part of monetary incentive. In fact, much people recycle even without monetary incentive.

Moreover, even if recycling does not imply particular monetary costs, it is also true that there could be implicit costs for individuals in terms of time spent to recycle and, for this reason, there should be an adjunctive benefit in order to compensate this cost.

Recycling can be seen as a private or a public good. The private economic benefit for the consumer is to reduce the marginal cost of municipal solid waste disposal, while the benefits of the

[3] These equations have three types of independent variables: characteristics of goods whose consumption generates waste (include the price of consumption goods and the amount of waste generated per unit of good); description of the local waste management system (price per unit of waste disposal, a vector of recycling program features); socioeconomic factors (household size, income and education). Instead each material has unique characteristics that could affect relationship between recycling and exogenous variables.

public good on recycling are the environment preservation and the reduction of landfill (public bads).

Summarizing, the variables affecting recycling decisions can be grouped in three categories: time variable, moral motivation and passive-use value.

In the first case, recycling is a “non market good”. Then, for analyzing the price of recycling, the cost of opportunity of time is taken as a explicative variable. Recycling is an activity of the household production that requests an effort in terms of time spent to it. In the case of moral motivation or incentive variables, many consumers have a preference to behave in a environmentally friendly way, that is, there exists a desire to voluntary contribute to public good. In this case, consumers take value from two factors: the utility deriving by participation to recycling programs (use-values) and the utility deriving by the reduction of negative externalities, associated to an increasing of recycling. In fact, the benefits of the environmental preservation are not excludable and not rival (since they increase independently on the recycling behaviour of a single consumers).

This analysis about the consumer behaviour in recycling activity denotes how motivational aspects are important for the choice of recycling and to understand how factors affects in a significant way on the delinking.

3. Empirical Literature

The empirical assessments of the income-environment relationship usually are not based on a specific theoretical model and the empirical papers use different environmental indicators and variables since there is not a general consensus about them neither about the empirical regression has to be used. The main hypothesis that support the EKC are the following: first, the greater is the income the higher are the emission of pollutants until some level; second, the increasing of income has a positive effect on the composition of activity in the gross domestic product (GDP) of a country, that is, there is a technological and policy effect on the market strategies.

At first, economists focused on some particular pollutants that could create damage to wealth of the people[4]. Then, they begun to analyze the empirical evidence about the existence of EKC in refuse sectors and, in particular, for the municipal solid waste.

The existence of delinking is supported by the concept of 'positive' (relative or absolute) elasticity between income and environmental quality. Instead, the consequences of economic

[4] Shafik [38] and Khanna & Plassmann [18] have proposed empirical models to provide the existence of EKC for some pollutants and, in particular, they showed the existence of EKC for air pollution like sulphur dioxide (SO_2), particular matter (PM_{10}), carbon monoxide (CO), ground level ozone (O_3) and nitrogen oxides (NO_x). Moreover, they identified the exact level of income, said turning point, at which the pollution begins to decrease.

activity associated to increasing income are to generate structural changes on production and consumption.

In some empirical analyses it is difficult to separate the impact of technological factors from the influence of consumer preferences, since most analysts use GDP as a measure of country income[5]. Changes in GDP reflect the effect of economic structure as well as changes in income, and many analyses provide information about the relationship between economic growth and pollution but do not analyze the consumer preferences. Some authors argue that, because of the greater local benefits of abatement, local pollutants tend to decline with income when countries reach the middle income level, while global pollutants continue to increase. However, all these models use aggregate and multicountry panel data that combine the effects of structural change, technology and changes in the demand for environmental quality [38].

Instead, the change of consumer behaviour with respect to higher income is an important aspect of the EKC theory (i.e., [33], [10]). Consumption, like technology and population growth, is one of the most important determinants of the environmental changes. If "environmental quality" is a "normal good" such that the higher is the income the higher is the demand of good, the structure of preferences has a direct effect on the economy through market behaviour and an indirect effect through the pressure on governments in order to take measures.

Khanna and Plassmann [23] analyze the impact of the demand for environmental quality on the income-pollution relationship. They focus on whether it is possible for consumers to 'spatially separate' themselves from the source of pollution[6]. They find that, given consumer preferences and technologies, the location of the turning point - the income levels at which the reduced form income-pollution relationship turns from positive to negative - does not depend on whether a pollutant has deleterious local or global effects but on the cost of reducing exposure to pollution, on the ability to spatially separate the production and consumption of pollution-generating activities.

The first empirical studies about refuses was limited to some macroeconomic analysis. The 1997 study by Shafik [38] provides the existence of an increasing monotonic relationship between waste generation and income, while for other quality indicators there exists a U-shaped relationship[7].

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[5] GDP per capita is the independent variable for the majority of regressions that study the income-waste relationship.

[6] Instead, the possibility to spatially separate production and consumption plays a decisive role in the consumer's decision to reduce his exposure to pollution as income increases. So that, income-pollution relationship turns negative at lower income levels for goods which spatial separation is possible. They use cross-sectional census track-level data for the United States to isolate the effects of differences in consumer income from changes in the other factors.

[7] He uses a panel database of 149 countries and a log-linear model for the years between 1960-1990. The results of a monotonic relationship between growth and waste generation derive from both the difficulty to find significant dataset on the urban solid refuse and from the intrinsic nature of local environmental problem. According to the authors the per capita refuse disposal can be considered as a local problem, in particular in the areas where there is a low density or a

A study of Johnstone and Labonne [20], that retrieves a model of Fullerton and Kinnaman [17], provides evidence on the economic and demographic determinants of generation rates of household solid waste that are consistent with results found in previous studies. Using a cross-sectional time-series database of solid waste OECD countries, they estimate the burden of household waste generation on the consume expenditure per capita, on the urbanization, on density of population and on the share of children. They find positive elasticity, but lower than one. Waste generation rates are anelastic with respect to the household consumption expenditure. Population density and urbanization degree have a positive effect on the waste generation. Finally, they find children share has a negative and significant effect on waste generation[8]. They conclude that the composition and size of the household seems to have an effect on household MSW generation with a significant negative influence, that is, there are household diseconomies of scale in waste generation[9]. Population density and the degree of urbanization appear to have positive effect on household MSW generation.

Many other empirical studies control the demographic and income variables about assessment of waste generation and waste recycled of household. For example, real wage can have a positive income effect if greater income involves greater consume and waste, negative effect if major income implies people goes to eat out or longer holidays, then household waste can decrease with income [32]. The effect of demographic variables are estimated by Kinnaman [16] and Podolsky and Spiegel [32] that provide empirical evidence that the greater is household size the lower is the waste disposal. Moreover, an increasing of household median age implies waste generation decreases.

Some economists have estimated relationship between education and household refuse. Household with higher education can be more careful to waste sorting and have an higher attention

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low income, therefore high income and generated refuse are not positively related. The local problem with low social costs and higher private costs - in terms of custom changes - tend to increase with the increased income.

[8] Their model considers the maximization of household utility function as a function of consumption, household municipal solid waste collection services, average household size, number of children in a family, number of working age people in a household, proportion of population which lives in urban areas. This function is submitted to the constraint of income, price of collection services and consumption goods. The household maximization problem is the following:

$$Max\{C, hsc, hssize, child, workage, urban\}$$
$$s.t.$$
$$Income = consumption * p_S(ctry, popdens)msw$$

where C is consumption, hsc is the household municipal solid waste collection service, hssize is a demographic variable like the average household size, child is the number of children in the household, workage is the number of working age people in the household and urban is the proportion of population which lives in urban areas. The price of olid waste collection service that depends on countries in which household is located (ctry) and the density of population (popdens).

[9] This could be due to the tendency to conserve on packaging for consumer items such as food and beverages which are purchased for larger family sizes.

to environment and health. Hong (1993), Callan and Thomas (1997), Judge and Becker (1993), Reschovsky and Stone (1994) and Duggal et al. (1991) estimate that education increases recycling, while Fullerton and Kinnamann [17] estimate that household with higher education generate lower refuses. There are studies that on the one hand analyze the composition of household finding that median age decreases waste generation, on the other hand show how rural households may have a number of alternative management strategies (i.e. composting, burning, illegal disposal). Further, there are some empirically evidences about how education levels can have a positive effect on solid waste generation rates and about how the price factor can affect solid waste generation[10].

Concu [10] shows an other aspect of the environmental problem. He find that there does not exist complementarities between touristic specialization and environmental preservation, that is, the touristic specialization does not help to improve so much the environmental quality[11].

A recent study of municipal solid waste (MSW) in Malaysia [30] shows some behavioural factors affect the waste generation: lifestyle, eating habit, housing characteristics (i.e. length of stay in a particular home, home cooking marital status and family size) that tend to generate more wastes and demographic background (i.e. the socioeconomic status of the population and the solid wastes handing practices, the use of rural drop off and burning, or dumping into holes). Surprisingly, income level does not influent the amount of waste generation in this study area.

An interesting paper of Moraes et al. [7] highlight UK and Brazilian consumers' behaviour with respect to the waste disposal. They explore how a few UK consumers dispose of their unwanted goods and contend that consumers from countries with a distinct levels of economic development will dispose of goods in different ways, by comparing the varied paths to disposal adopted by middle-class British and Brazilian consumers and by examining any difference between consumers' disposal attitudes and practices in both countries. This qualitative study (they interview UK and Brazilian people) shows how waste is seen as a source of economic opportunity for poor people in Brazil, so that the upper classes relies to domestic services of housekeepers and general household consumption and disposal practices are mediated by such employees: housekeepers and scrap mongers collect the recyclable waste from households and public spaces. In UK, instead, the policy about waste derives from the perceived need to combat environmental issues rather than from economic need, so that, UK consumers are in charge of their own disposal. This difference is important since the perceived effort is a relevant attitudinal component in the responsible disposal decision making process. UK and Brazilian participants presented divergent concerns about waste,

[10] For example the "pay-as-you-throw" scheme may result in reduced waste generation and increased recycling.

[11] In particular, the existence of Kuznets curve is sensible both to the data-set and to the adopted specification. The touristic specialization is not an environmental friendly strategy and, on the strength of its indicator, the growth does not contribute to solve the problem of environmental degradation.

and articulated distinct symbolic roles for disposal, which emanate from their economically distinct contexts. British participants see the disposal cycles as burdensome, even if necessary and responsible. Brazilian see them as a duty. Both make the connection between irresponsible disposal and natural environment degradation. Brazilian disposal practices seem more intricate and geared towards charity and non-wastefulness than UK participants. Conversely, UK participants avidly reuse and purchase recycled and second-hand products, practices that are not adopted by the Brazilian participants. Although Brazilian local media embrace the waste-as-opportunity viewpoint, this seem to reproduce the social inequalities idiosyncratic of the country.

Karousakis [21], by using a panel data from 30 OECD countries over a period of 30 years, analyses the main trends in MSW generation, disposal and recycling, by including waste policy analysis. From the "generation" point of view, urbanization has a positive impact on the generation of solid waste (and this is discouraging, since the trend of population living in cities will grow in the future). On the side of disposal, urbanization and real landfill tax imposed by the national governments have negative impacts (this implies that though urbanization is associated with higher amount of waste, the waste is managed in a more environmental friendly way, such as incineration or recycling). On the side of recycling of paper, cardboard and glass, the main determinants are the growth and the population density, with a negative effect.

A study of Jenkins et al. [19] concerns the analysis of two solid waste programs: residential kerbside recycling and volume based pricing (or unit pricing) in 20 metropolitan statistical areas in US according to the recycled material. They study five different materials: glass bottles, plastic bottles, aluminium, newspaper and yard waste. They find that kerbside recycling has a positive and significant effect on the share of the five recycled materials, while the mandatory recycling has not a significant effect (the effect of unit pricing is not clear).

A recent paper of Gellynck and Verhelst [18] identifies the factors of the policy mix that has the greatest impact on the amount of mixed household solid waste. They find that population density is positively correlated with waste generation and the higher is the annual average income of people in a municipality the higher is the amount of waste (positive income elasticity of demand for waste collection services is around 0.326). However, the income variable is out of control of local authorities. The authorities, instead, may operate in the service level to lower the amount of refuse, for example, a less frequently collection of waste, an implementation of kerbside collection program for organic waste and collection of organic waste have a significant impact. Pecuniary incentives (i.e. the annual fee over unit-pricing by the bag or price-per-bag systems, the weight-based systems, the fixed annual fee for waste collection services) are effective instruments in reducing the amount of waste. The higher are the direct costs for waste service borne by households, the lower is amount of waste collected. As a consequence, an implementation of the 'polluter pays' principle may be an effective instrument. One of the major components of household waste is organic material, therefore, an incentive to participate in composting yard and food waste is likely to encourage waste reduction. Home composting has the potential to make a significant contribution to household waste minimization.

Mazzanti et al. ([26], [27]) show an empirical evidence about delinking and about existence of an Environmental Kuznets Curve for the waste generation in Italy. In particular, indicators of delinking are used to measure improvements in environmental/resource efficiency with respect to economic activity. Instead, the generation of waste in EU25 since 1980 is increased more than the landfill because waste volume in the EU are growing driven by the production and consumption patterns ([28], [29]).

A general critique concerning empirical studies on EKC, given by Arrow [3] and resumed in Stern [39], is the lack of considering the feedback from environmental damage to economic production as income is assumed to be en exogenous variable. Instead, it is clear that the levels of pollutants per unit of output in specific processes have declined in developed countries over time with increasingly stringent environmental regulations and technical innovations, however, the mix of effluents has shifted from sulphur and nitrogen oxides to carbon dioxide and solid waste so the aggregate waste is still high and per capita waste may not have decline. Economic activity is inevitably environmentally disruptive in some way. Moreover, satisfying the material needs of people requires the use and the disturbance of energy flows and material stocks.

4. The Theoretical Model

The purpose of this paper is to study the municipal solid waste management by considering how a representative household can be stimulated to recycle. Instead, there are some factors like local policy, presence of tax or tariff, degree of education and income that affect the behaviour of the consumer in order to pay more attention to the environmental aspect derived by not recycling urban solid waste. According the neoclassic theory, the effort of a household should be to maximize its own utility function and, at the same time, to minimize the waste generation. We start by assuming an economy with a single consumer or household[12] and with no externalities.

Literature on environmental economics evaluates the effectiveness of the instruments used by public authorities to reduce the amount of waste and encouraging the amount being recycled.

[12] The consideration about the different interpretation about consumers and household can have some important implications in the empirical tests, since the single consumer has a different behaviour with respect to the household. But, for now, it is not so important in order to explain the meaning of the simple model.

Instruments of public authorities to reduce waste can be divided into three groups[13]: pecuniary incentives (going from fixed annual fee over unit-picking by the bag to weight-based fees), provided service level (availability if kerbside recycling or through a drop-off centre and organic waste collection) and measurements to stimulate prevention and waste reduction. Beside the policy mix, the amount of generated waste depends on the characteristics of the community, as there are income and population density.

Let consider an utility function $U(c, R_{tot})$ as a function of consumption of a private good ($c > 0$) and of non recycled urban waste/refuse[14] (R_{NS}), such that it is increasing in c and decreasing in R_{NS}.

Non recycled waste is a public "bad" and it can be interpreted as a degree of environmental pollution that generates disutility to the single consumer, as in the model of Andreoni & Levinson[15][1].

On the other hand, let consider R_S as an indicator of reduction of pollution, that is, it represents the portion of recycled refuse with respect to the total waste generation. We assume the refuse function is the following linear function:

$$R_{tot} = R_{NS} + R_S \tag{1}$$

so that, we consider the household utility function as a function of consumption and refuse:

$$U(c, R_{tot}) = c - zR_{tot} \tag{2}$$

where $z > 0$ represents the constant marginal disutility of refuse.

Since non recycled refuse has been considered as a pollution factor, it is a by-product of consumption, so the greater is the consumption of a household the higher is the pollution degree. Moreover, suppose the consumer has a means by which he can alleviate pollution - non recycled refuse by expending resources to clean it up or to prevent it from increasing. Let call these resources environmental effort to recycle (*E*). Refuse function is then a positive function of consumption and non recycled wastes, while it is a negative function of the environmental effort.

As said before, the generation of waste is a function of two variables, $R = f(c, E)$, where E is the effort to abatement the quantity of refuse generated from the consumption of a good.

Then, let suppose that the total amount of refuse is given is only by a fraction γ (with $0 < \gamma < 1$) of the total consumption[16], such that $R_{tot} = \gamma c$, while the quantity of separated waste can

[13] As listed in a recent paper [18].

[14] We take a definition of Municipal Solid Waste similar to the OECD questionnaire and reported in the paper of Johnstone and Labonne [20].

[15] See in Appendix of [39].

[16] Pallmer et al.(1996) say that the amount of waste disposed, W, equals total consumption of the good, Q, minus the amount that is recycled, R, that is W=Q-R. I suppose that only a percentage of consumption generates waste.

be described like a Cobb-Douglas function, that is, $R_S = c^{\alpha} E^{\beta}$, where the effort to reduce the pollution from the non separated refuse affects only on the portion of consumption that can be appointed to be recycled. As a consequence, equation (1) can be rewrite in the following way:

$$R_{NS} = R_{tot} - R_S = \gamma c - c^{\alpha} E^{\beta} \tag{3}$$

with $c, E > 1$ and $0 < \alpha, \beta < 1$.

The variable c^{α} represents the share of consumption that is "designed" to recycling. In fact, each good consumption is characterised by a technological component from which derive its own possibility of recycling. The α parameter represents this technology. The extreme case in which $\alpha = 1$, then $R_S = cE^{\beta}$, implies that all consumption is differentiable and represents the maximum of recycled good quantity, fixed consumption effort. While in the case of $\alpha = 0$, $R_S = E^{\beta}$ represents the minimum of differentiable wastes (ceteris paribus), so that the effort on recycling affects less than the previous case. The conclusion is that the higher is α parameter the greater is the separated refuse collection and the lower is the not separated waste (equal effort).

Similar intuition is for E^{β}. In this case, when β parameter increases, separated collection increases while the not separated waste decreases, because higher is the weigh of effort on the separated refuses, equal differentiable consumption.

Equation (3) shows the existence of duplex effect of consumption on the refuse generation, since, at the one side, consumption causes proportional pollution in terms of non recycled waste implying an increased of total waste while, on the other side, the resources spent on environmental effort to abate pollution generates a reduction of total waste.

The household maximizes his utility function in the following way:

$$\begin{aligned} &Max U(c, R_{ind}) = Max\{c - z[\gamma c - c^{\alpha} E^{\beta}]\} \\ &s.t. \\ &W = cp_c + Ep_E \end{aligned} \tag{4}$$

where W is the stock of income of a representative consumer, p_c is the price of consumption and p_E is the price of effort (let assume $W > p_E$).

The budget constraint for household means the wealth can be divided in cost of consumption and cost of effort to recycle waste. The maximization problem can be solved by computing the first order conditions and substituting C^* and E^* in the utility function.

Case $z = \gamma = 1$

Let assume $z = \gamma = 1$. So that, the first order conditions are:

$$E^* = \frac{\beta}{\alpha+\beta}\frac{M}{\pi} \tag{5}$$

and

$$C^* = \frac{\alpha}{\alpha+\beta}M \tag{6}$$

The corner solutions are $C^* = 0$ and $C^* = M$ (but for $C^* = 0$ the consumption and the refuse generation are zero, by definition).

Now let put the solution of (5) and (6) into the equation (4) and we get the optimal quantity of non recycled refuse, that depends on the technology, the relative prices of the effort and mainly on the income:

$$\begin{aligned} R_{NS}^* &= \frac{\alpha}{\alpha+\beta}M - \left(\frac{\alpha}{\alpha+\beta}\right)^{\alpha}\left(\frac{\beta}{\alpha+\beta}\right)^{\beta}\frac{M^{\alpha+\beta}}{\pi^{\beta}} \\ &= \frac{\alpha}{\alpha+\beta}M - \left(\frac{\alpha}{\alpha+\beta}\right)^{\alpha}\left(\frac{\beta}{\alpha+\beta}\right)^{\beta}\frac{M^{\alpha+\beta}(p_c)^{\beta}}{\sum_{i=1}^{n}\left(\delta_i p_{E_i}\right)^{\beta}} \end{aligned} \tag{7}$$

where $M \equiv \frac{W}{p_c}$ is the relative income and $\pi \equiv \frac{p_E}{p_c}$ is the relative price of effort (this function is called "refuse function").

As a consequence, let compute the following recycled refuse function (see Figure 4 in Appendix A):

$$R_S^* = \left(\frac{\alpha}{\alpha+\beta}\right)^{\alpha}\left(\frac{\beta}{\alpha+\beta}\right)^{\beta}\frac{M^{\alpha+\beta}}{\pi^{\beta}} \tag{8}$$

(note that the separated refuse generation is a function positive in income and effort).

In particular, the path of income changes according to the values of the parameters. In fact, if $\alpha+\beta>1$ the function of not separated refuse is concave. It confirms the inverse U shaped path described in the Environmental Kuznets Curve.

The turning point is computed by the first order conditions of the new refuse function (equation (7)) and it represents the maximum of this function in the case of $\alpha+\beta>1$, that is, the point of income over which refuse generation begins to decrease. This point is:

$$\tau = \frac{1}{\alpha+\beta}\left[\frac{\alpha^{1-\alpha}}{\alpha+\beta}\left(\frac{\pi}{\beta}\right)^{\beta}\right]^{\frac{1}{\alpha+\beta+-1}} \tag{9}$$

Equation (9) shows that also the turning point is a function of the (relative) price of effort, π. Coherently with the idea of heterogeneity in consumer preferences and habits, the intuition is that the price of effort can vary individually and at community levels and may depend on socio-economic and demographic factors. For instance, the educational level, the life-style, household composition (number of people in a family, average age, etc.), demographic background, density of population as well as environmental policies like recycling program in a region (i.e., volume-based pricing, unit pricing) can cause a lower or a higher cost of separated refuse. Thus, the shape of the EKC and its turning point can be different for each community.

In order to account for this issue in the model, let S_i be a set of socio-economic, political and environmental variables ($i = 1,...,n$). Then, the value of π can be written as a function of the latter variables and this formulation can be tested empirically:

$$\pi = \frac{p_E}{p_c} \equiv f(S_i) \tag{10}$$

5. Data and variables.

The database is relative to 547 Italian municipalities which are observed from 2004 to 2006. Publicly available data from ISTAT were used as demographic and socio-economic indicators, while the information concerning the amount of waste collected were gathered from Ecocerved.[17] The presence of some missing data makes the panel not strictly balanced and the total number of observation equal to 1554. The geographical localization of our sample is uniformly distributed over the national area, with 171 municipalities in the Northern regions, 158 in the Centre and the remaining 218 in the South. More than one third of the Italian population is represented in the sample.

Table 1 presents the summary statistics of the variables used for our empirical analysis. The per-capita production of waste (R_{tot}) is on average around 470 kilograms per year (almost 1.3 kg per day), with a share of separated waste collection still below the 20 percent. There is however a high variability in the sample both in terms of the total amount collected and in the waste sorting policies. While some municipalities have not even started a serious recycling program (more than 100 municipalities below 5 percent of separated waste collection in 2006, mainly distributed in the South), others have reached very important targets, with a maximum value of more than 76.5 percent.

[17] EcoCerved is an Italian company that, among other functions, organizes and collects data on waste management from municipalities.

Table 1. Summary statistics

Variable	Variable description	Mean	Standard deviation	Min	Max
R_{tot}	Total amount of solid waste collected (Kg/year per-capita)	467.83	142.71	138.65	1427.06
R_{NS}	Total amount of non-separated waste collected (Kg/year per-capita)	383.54	153.45	60.36	1409.64
R_S	Total amount of separated waste collected (Kg/year per-capita)	84.29	71.62	0.21	391.06
M	Per-capita real income (€)	9749.23	3750.38	3000.08	21596.55
S_{ALT}	Altitude	193.02	185.22	0	1093
S_{POP}	Population	40,484	139,971	992	2,711,491
S_{DENS}	Population density	891.93	1230.04	23	9442
S_{HS}	Household size	2.56	0.28	1.93	3.56
S_{ED}	Share of adult population with high-school degree (%)	31.91	7.36	14.86	53.96

The per-capita municipality income (M) is expressed in real term (base = year 2006) and is based on fiscal data of the Ministry of Internal Affairs.[18] The average in the sample is less than 10.000 Euros. It is worth noting, as a term of comparison, that this measure of personal income is lower than the gross domestic product (*GDP*), which is often used in other EKC empirical studies but is not available at the municipality level. The other variables included in the study are time-invariant and are useful to capture spatial characteristics which may affect the amount of waste collected, such as the altitude (S_{ALT}), the municipality size measured in terms of population (S_{POP}), the population density (S_{DENS}) and the average household size (S_{HS}).[19] A particular interest is devoted to the effect of education (S_{ED}). We used a proxy represented by the share of adult population holding a high-school degree, which on average is equal to 32 percent.

6. Empirical analysis

In the following we test the EKC relationship in connection with the theoretical model developed in Section 4. Our empirical strategy is based on the comparison of two alternative approach. First, we develop a linear regression model, coherently with the existing literature; second, we provide a

[18] Data were accessed from the website of the economic newspaper "Il sole 24 ore".
[19] Information on the dynamic of such indicators was not available.

direct estimate of the theoretical relationship derived in Section 4, by means of non-linear least squares. All estimations were obtained using the statistical package STATA (version 10.0), and the significance of the parameters was tested at different levels (p<.01; p<.05; p<.10).

6.1. The linear regression model

Each type of waste collected (separated, non-separated, total) has been putted in relation with the income and the other explanatory variables. The model can be written as follows:

$$R_\phi = \alpha + \beta_M M + \beta_{MM} M^2 + \sum_i \beta_i S_i + \sum_j \beta_{Mj} M \cdot S_j \qquad (11)$$

with $\phi = \{TOT, NS, S\}$ and $i, j = \{ALT, POP, DENS, HS, ED\}$.

As usual in EKC empirical studies, the specification includes a linear and squared term for the income variable and the additional time-invariant covariates (grouped in the vector S). A peculiarity is the inclusion of the interactions between the vector of municipality characteristics S and the income. This implies that the (eventual) turning point can be heterogeneous across the sample, depending on the municipality characteristics. Such an assumption is coherent with the theoretical model, which suggests that the turning point depends on the (heterogeneous) price of the environmental "effort". Thus, the idea is that municipality characteristics can affect the total amount of collected waste in two ways: first, they can have a direct explanatory power of waste production via the coefficient(s) β_i; second, they can make it more (or less) costly to implement certain environmental policies related to delinking, moving the turning point at a higher (or lower) level of income via the coefficient(s) β_{Mj}.

All variables in the vector S have been normalized over the sample geometric mean, so that the coefficients have more immediate interpretation and can be used to derive the turning point for a hypothetical municipality with "average" characteristics. Equation [11] has been estimated using ordinary least squares (OLS), adding two dummies in order to identify more homogeneous territorial areas (North, Centre and South). The use of pooled data has been preferred to panel techniques given the strong prevalence of cross-sectional variability and the focus on the impact of time-invariant factors. Table 3 shows the results obtained using both the linear and log-linear specification. In all cases, a stepwise procedure was employed to gradually delete the least significant covariates from the full model, stopping only when all the estimated coefficients for retained regressors were significant at least at the 10% level.

A turning point within the range of observation was estimated both for the total amount of solid waste collected and for the non-separated waste. In the linear case, the value of 15,561 € falls in the upper decile of income distribution, indicating that very few municipalities has reached a point where the increasing trend of total waste generation has come to an end. This result is in line with Mazzanti et al. [27], who found evidence of EKC at the provincial level. Differently, the log-linear specification provides a lower estimate corresponding to slightly more than the average income. Results are more encouraging when looking at the non-separated waste, which shows a more clear decreasing trend thanks to the strong impulse given to recycling and waste sorting in the last years. One might see the EKC as decomposed in two environmental "delinking" levels: with a certain level of income the amount of non-separated waste start decreasing because it is substituted by separated waste; a remarkable additional level of income is necessary in order to register a reduction of waste generation.

The coefficients of the other covariates usually show consistent signs across the models and also the interactions with the income are in most cases significant. The most important effects have to be ascribed to the family size and the education level. The first is associated with lower level of waste generation and with lower delinking levels. This is not true for the education variable, which shows a controversial effect. For a given level of income, waste generation is lower – and the separated waste collection is more developed – in municipalities with higher degree of education. Nevertheless, municipalities with higher degree of education are also the ones achieving the EKC turning point at a higher level of income.

6.2. The non-linear model

The second step of our empirical analysis has been the implementation of the theoretical model derived in equation [7]. The aim is to strengthen the bridge between theoretical and empirical analysis, by focusing on non-sorted waste as the major pollutant. One common issue when using nonlinear least squares is related to the convergence of the model, the existence of local maxima to the assignment of appropriate initial values to the parameters [34]. In order to circumvent these problems, which increases with the number of parameters to be estimated, we further simplify the model by imposing $\alpha = 1$. Given the interpretation of this parameter, the assumption is basically that all consumption can be recycled. Virtuous cases of municipalities with share of collected waste around 80 percent supports such a simplification.[20]

Table 4 presents the findings, which are quite in line with those obtained with linear regressions. In particular, when estimating the model using the entire set of observations the average turning point is equal to 9,427 €, but it is lower in the North and higher in the South due to the impact of regional dummies on the estimated price of effort. However, when using the regional sub-samples, the North

[20] Setting the parameter to 0.9 does not change the turning point computation, even if it does impact on the values of single parameters.

highlights the highest turning point (10,345 €), followed by the Centre (9,724 €) and the South (8,251 €). This inconsistency is due to the fact that also the parameter B significantly differs across regional areas; the model using sub-samples seems however the most powerful in explaining the data (see Table 5).[21] As to the socio-demographic characteristics, the model confirms the significant impact of family size and education on the price of the environmental effort. The first has negative sign and indicates that the effort of reducing non-separated waste is less costly when the number of family components is higher, as an evidence of "domestic" scale economies. The education has instead an opposite impact, which moves the turning point to higher levels of income. The result can be explained in light of an increase of the cost opportunity of time and is significant in all sub-samples but the South. The other demographic control factors show significant effects only in some sub-samples. The negative and significant sign associated with altitude in the South and to less extent in the Centre might probably be due to the massive presence of coastal tourism in these regions, which can increase the cost of environmental effort.[22] Conversely, the population density has a negative and significant impact only in the Northern area, where there is a higher urbanization degree. Finally, the size of the municipality, measured in terms of total inhabitants, was never significant.

Table 5 shows the consistency of fitted values across different models with respect to the real data. The correlation with real data achieves a target of nearly 70% and the correlation across models is quite encouraging for future empirical applications.

[21] Further investigation is needed in order to clarify regional differences. In particular, in future empirical analysis we plan to explicitly include data accounting for territorial differentials in the price of consumption (p_c).
[22] An explicit consideration of tourist flows is in our research agenda.

Table 3. Results of the linear regressions

Dependent variable	R_{TOT}	R_{NS}	R_D	$\ln(R_{TOT})$	$\ln(R_{NS})$	$\ln(R_D)$
			Coefficients (standard errors in brackets)			
α	686.9915 *** (123.0999)	666.5739 *** (120.5143)	39.9006 ** (19.4381)	-8.1366 *** (5.3299)	-46.6482 *** (7.3000)	179.7851 *** (17.1985)
β_M	0.0685 *** (0.0148)	0.0649 *** (0.0145)	n.s.	3.0860 *** (1.1755)	11.8958 *** (1.6100)	-40.6727 *** (3.7959)
β_{MM}	-2.20e-06 *** (4.26e-07)	-2.75e-06 *** (4.21e-07)	6.98e-07 *** (1.28e-07)	-0.1661 *** (0.0648)	-0.6709 *** (0.0888)	2.3422 *** (0.2095)
β_{ALT}	-41.3644 *** (4.5691)	-42.6574 *** (4.4760)	n.s.	-0.7672 *** (0.1127)	-0.7218 *** (0.1543)	-1.6076 *** (0.3552)
β_{POP}	n.s.	0.9132 ** (0.4614)	n.s.	1.0252 *** (0.1651)	1.0207 *** (0.2262)	n.s.
β_{DENS}	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
β_{FAM}	-213.8853 ** (100.9518)	-164.5701 * (98.9768)	-68.5077 *** (18.8131)	-4.4882 ** (1.7940)	-14.7535 *** (2.4571)	-21.4653 *** (5.7425)
β_{ED}	-153.4046 *** (55.2209)	-179.2156 *** (54.5943)	42.6267 ** (20.7632)	-2.1493 ** (0.8509)	-5.3865 *** (1.1654)	26.5826 *** (2.6433)
$\beta_{M,ALT}$	0.0021 *** (0.0005)	0.0027 *** (0.0005)	-0.0005 *** (0.0001)	0.0777 *** (0.0123)	0.0732 *** (0.0169)	0.1625 *** (0.0389)
$\beta_{M,POP}$	n.s.	n.s.	n.s.	-0.1091 *** (0.0123)	-0.1058 *** (0.0247)	n.s.
$\beta_{M,DENS}$	-0.0004 *** (0.0001)	-0.0003 *** (0.0001)	-0.00015 *** (0.00004)	-0.0025 *** (0.0008)	-0.0035 *** (0.0010)	-0.0045 * (0.0024)
$\beta_{M,FAM}$	-0.0389 *** (0.0106)	-0.0487 *** (0.0104)	0.0121 *** (0.0016)	-0.6249 *** (0.1980)	-1.8205 *** (0.2712)	2.3491 *** (0.6334)
$\beta_{M,ED}$	0.0161*** (0.0052)	0.0252*** (0.0051)	-0.0110*** (0.0019)	0.2379 ** (0.0932)	0.6089*** (0.1276)	-2.9823*** (0.2891)
δ_{NORTH}	-132.5709 *** (9.2803)	-160.4162 *** (9.1726)	30.4733 *** (3.5223)	-0.2905 *** (0.0199)	-0.5462 *** (0.0272)	0.3832 *** (0.0635)
δ_{SOUTH}	58.2865 *** (12.3829)	64.1881 *** (12.1209)	-7.0785 (4.5970)	0.0724 *** (0.0243)	0.0827 ** (0.0333)	-0.0083 *** (0.0780)
F-Statistic	75.74 ***	110.97 ***	285.16 ***	74.32 ***	127.17 ***	204.93 ***
Adjusted R-squared	0.3461	0.4594	0.6222	0.3812	0.5146	0.5919
Turning point (€)	15,561	11,797	_	10,799	7,085	_

*** significant at 1% level; ** significant at 5% level; ** significant at 10% level
n.s.: not significant (and dropped in the stepwise procedure)

Table 4. Results of the non-linear regressions

Dependent variable is R	[1] Italy	[2] North	[3] Centre	[4] South
Number of observations	1554	476	447	631
A	1	1	1	1
B	1.1246*** (0.0148)	0.8579*** (0.0499)	1.1488 *** (0.0268)	1.5257*** (0.0685)
Determinants of P_E				
Constant	8.0532 *** (0.4297)	9.0690 *** (0.7194)	6.8320 *** (0.7729)	12.2227 *** (1.6446)
ALT	-0.0278 * (0.0158)	0.0056 (0.0198)	-0.0910 * (0.0308)	-0.2036 *** (0.0405)
POP	0.0451 (0.0034)	0.0045 (0.0056)	0.0017 (0.0034)	-0.0183 (0.0273)
DENS	-0.0134* (0.0082)	-0.0392* (0.0101)	0.0474 (0.0350)	0.0383 (0.0273)
FAM	-4.5061*** (0.4076)	-6.9063*** (0.7003)	-2.4722*** (0.7726)	-6.0203*** (1.0827)
ED	1.3872*** (0.1083)	1.1947*** (0.1574)	0.7725*** (0.2166)	-0.0343 (0.0405)
NORTH	-0.8939 *** (0.0776)			
SOUTH	2.8991 *** (0.5342)			
Turning point (€)	9,427	10,345	9,724	8,251

Table 5. Correlation between fitted value of R from different models

	Real data	Fitted value with linear model	Fitted value with log-linear model	Fitted value with non-linear model (entire sample)	Fitted value with non-linear model (by macroarea)
Real data	1				
Fitted value with linear model	0.6801	1			
Fitted value with log-linear model	0.6653	0.9368	1		
Fitted value with non-linear model (entire sample)	0.5823	0.8343	0.7876	1	
Fitted value with non-linear model (by macroarea)	0.6779	0.9165	0.8575	0.91	1

7. Conclusions and future research

This paper represents a particular application of the Environmental Kuznets Curve theory, that highlights the relationship between income path and pollution.

In the model, we take this theory in order to verify a pattern of a particular polluter, that is, refuse generation. With respect to other empirical models, we use the not separated refuses as an indicator of environmental pollution. The assumption is that welfare improves by recycling and for this reason the effort of recycling is a key indicator to verify the effectiveness of delinking.

The contribute of this paper is to define a theoretical functional form of EKC in the refuse sector, starting from the theory of Andreoni and Levinson [1] and to implement it empirically.

The model takes a non linear form, that has been econometrically tested using data from Italian municipalities during the years 2004-2006. Results have been compared with the more traditional linear and log-linear EKC relationships, showing similarities across the results.

In our view, this represents a preliminary attempt to create a more strict connection between theoretical and empirical applications in the field, and future research will go in the direction of refining this link.

Findings highlight the existence of a turning point for the production of non-separated waste, especially thanks to the increasing attention devoted in last years to recycling and waste sorting policies. However, the level of turning point is also affected by socio-demographic municipality characteristics, since the latter may impact on the perceived costs of implementing environmental friendly policies.

In recent empirical approach [27], the separated refuse variable is included as dependent variable, in order to verify if recycling growth could imply also a reduction of the total refuse generation (and not only of not separated refuse). One future objective of this research is to follow also this direction, in the sense of finding evidence, both in the theory and in the empirical tests, if there is a negative correlation between separated and total waste, when income increases.

Appendix A

Equation (7) describes the refuse function. The shape and concavity change according to α and β parameters and the price of effort. In particular, the income – refuse pattern follows an inverse U shaped (EKC) if there are the following conditions: fixed income, the higher is the price of effort, the higher is the turning point since the refuse function shifts upward. The slope of the curve is increasing since first derivatives is positive for some value of α and β:

$$\frac{\partial R^*_{ind}}{\partial M} = \frac{\alpha}{\alpha+\beta} - (\alpha+\beta)\left(\frac{\alpha}{\alpha+\beta}\right)^{\alpha}\left(\frac{\beta}{\alpha+\beta}\right)^{\beta}\frac{M^{\alpha+\beta-1}}{\pi^{\beta}}$$

The second derivatives, instead, are important for the definition of convexity:

$$\frac{\partial^2 R^*_{ind}}{\partial M^2} = \begin{cases} 0 & if \quad \alpha+\beta=1 \\ -(\alpha+\beta)(\alpha+\beta-1)\left(\frac{\alpha}{\alpha+\beta}\right)^{\alpha}\left(\frac{\beta}{\alpha+\beta}\right)^{\beta}\frac{M^{\alpha+\beta-2}}{\pi^{\beta}} > 0 & if \quad \alpha+\beta<1 \\ -(\alpha+\beta)(\alpha+\beta-1)\left(\frac{\alpha}{\alpha+\beta}\right)^{\alpha}\left(\frac{\beta}{\alpha+\beta}\right)^{\beta}\frac{M^{\alpha+\beta-2}}{\pi^{\beta}} < 0 & if \quad \alpha+\beta>1 \end{cases}$$

In the first case, the function is linear and increasing (see Figure 1 in Appendix B). In the second case, the function is convex and does not represent the EKC (see Figure 2 in Appendix B). In the last case, when the technology of separated refuse abatement has increasing return on scale, the derivative is negative, sufficient condition for concavity of the function, so that, it represents an inverse U shaped curve (EKC) and has a turning point computed by the equation (10).

Appendice B

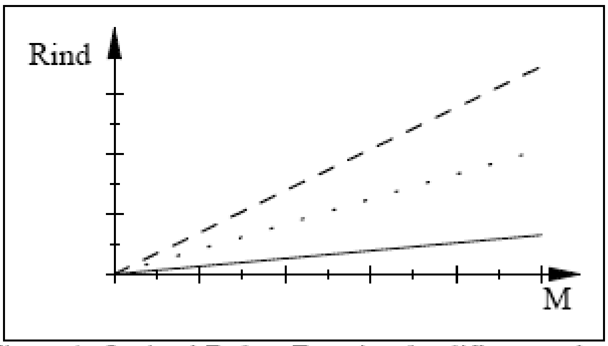

Figure 1: Optimal Refuse Function for different values of π_{E_D} and for $\alpha+\beta=1$. Solid line for $\pi_{E_D}=5$; Dot line for $\pi_{E_D}=10$; Dash line for $\pi_{E_D}=50$.

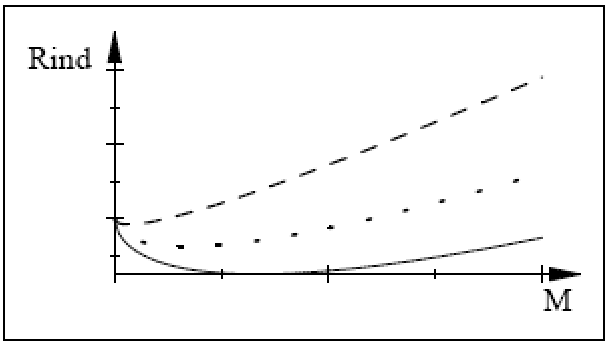

Figure 2: Optimal Refuse Function for different values of π_{E_D} and for $\alpha+\beta<1$. Solid line for $\pi_{E_D}=5$; Dot line for $\pi_{E_D}=10$; Dash line for $\pi_{E_D}=50$.

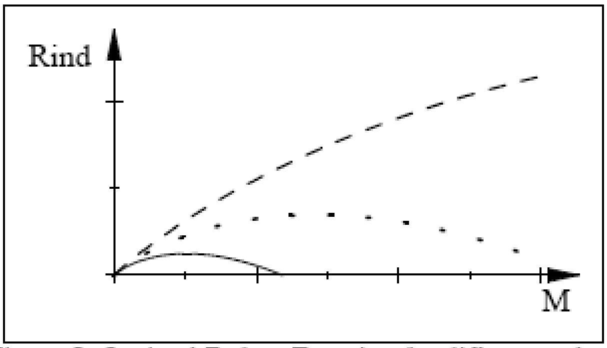

Figure 3: Optimal Refuse Function for different values of π_{E_D} and for $\alpha+\beta>1$. Solid line for $\pi_{E_D}=30$; Dot line for $\pi_{E_D}=50$; Dash line for $\pi_{E_D}=100$.

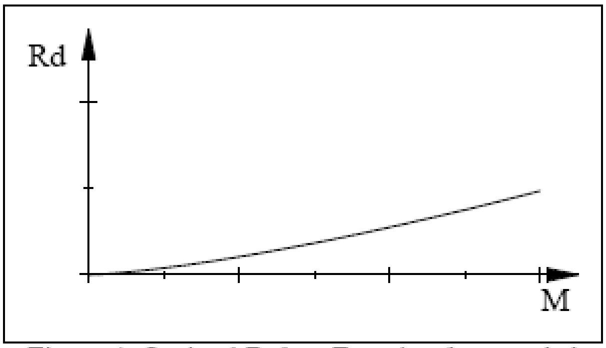

Figure 4: Optimal Refuse Function for recycled waste function ($\pi=30$)

References

[1] Andreoni J.; Levinson A. (2001) "The Simple Analytics of the Environmental Kuznets Curve", Journal of Public Economics, Vol. 80, Issue 2, pp. 269-286.

[2] Andreoni J. (1990) "Impure altruism and donations to public goods: a theory of warm-glow giving", The Economic Journal, Vol. 100 no 401, pp. 464-477.

[3] Arrow, K.; Bolin, B.; Costanza, R.; Dasgputa, P.; Folke, C.; Holling, C.S.; Jansson, B-O.; Levin, S.; Maler, K-G.; Perrings, C.A. and Pimentel, D. (1995) "Economic growth, carrying capacity, and the environment", Science, no. 268, pp. 520-21.

[4] Brèchet, T.; Jouvet, Pierre-Andrè (2006) "Environmental innovation and the cost of pollution abatement", CORE Discussion Paper no. 2006/40.

[5] Brèchet, T.; Jouvet, Pierre-Andrè (2008) "Environmental innovation and the cost of pollution abatement revisited", Ecological Economics, no. 65, pp. 262-265.

[6] Brekke, K. A.; Kverndokk, S.; Nyborg, K. (2000) "An Economic Model of Moral Motivation", Statistic Norway, Research Department, Discussion Paper no. 290.

[7] Carrigan, M.; Moraes, C.; Szmigin, I. (2009) "Responsible Waste Disposal: An Exploration Study of British and Brazilian Consumers", 2009 World Marketing Congress / Oslo, Norway.

[8] Chaudhruri, S.; Nye, Howard L.M.; Pfaff, Alexander S.P. (2004) "Household Production and Environmental Kuznets Curve", Environmental and Resource Economics, no. 27, pp. 187-200.

[9] Choe, C.; Fraser, I. (1999) "An Economic Analysis of Household Waste Management", Journal of Environmental Economics and Management, Vol. 38, pp. 234-246.

[10] Concu, N. (2000) "La tirannia del trade-off sconfitta? Turismo, ambiente naturale e rifiuti solidi urbani: la ricerca di una Environmental Kuznets Curve", Working Paper.

[11] Duggal, Vijaya G.; Saltzman, C.; Williams, Mary L. (1991) "Recycling: An Economic Analysis", Eastern Economic Journal, Vol. XVII, no 3.

[12] Egly, H; Steger, Thomas M. (2006) "A Dynamic Model of the Environmental Kuznets Curve: Turning Point and Public Policy", Environmental & Resource Economics, no. 36, pp. 15-34.

[13] Eriksson, C. (2008) "A Knife-Edge Property of Some Pollution-and-Growth Models", Working Paper.

[14] Favoino, E.; Santi, M.,; Tornavacca, A. (2002) "L'efficacia economica e quali-quantitativa dei nuovi modelli di raccolta differenziata integrata in relazione all'obiettivo di riduzione della produzione di RU", Working Paper.

[15] Fullerton, D.; Kinnaman, Thomas C. (1995) "How a fee per-unit garbage affects aggregate recycling in a model with heterogeneous households", A.L. Bovenberg, S. Cnossen (Eds.), Public Economics and the Environment in an Imperfect World, Kluwer Academic Publishers, Dordrecht, The Netherlands.

[16] Fullerton, D.; Kinnaman, Thomas C. (1995) "Garbage, Recycling and Illicit Burning or Dumping", Journal of Environmental Economics and Management, no. 29, pp. 78-91.

[17] Fullerton, D.; Kinnaman, Thomas C. (1999) "The Economics of Residential Solid Waste Management", Working Paper.

[18] Gellynk, X.; Verhelst, P. (2007) "Assessing instruments for mixed household solid waste collection services in the Flemish region of Belgium", Resources Conservation and Recycling, no. 49, pp. 372-387.

[19] Jenkins, Robert R.; Martinez, Salvador A.; Palmer, K.; Podolsky, Michael J. (2003) "The determinants of household recycling: a material-specific analysis of recycling program features and unit pricing", Journal of Environmental Economics and Management, no. 45, pp. 294-318.

[20] Johnstone, N. ; Labonne, J. (2004) "Generation of Household Solid Waste in OECD Countries: An Empirical Analysis Using Macroeconomic Data", Land Economics, Vol. 80, no. 4, pp. 529-538.

[21] Karousakis, K. (2006) "Municipal Solid Waste Generation, Disposal and Recycling: A Note on OECD Inter-Country Differences", School of Public Policy of UCL, Working Paper.

[22] Khanna N.; Plassmann F. (2004) "The demand for environmental quality and the Environmental Kuznets Curve hypothesis", Ecological Economics, no. 51, pp. 225-236.

[23] Khanna N.; Plassmann F. (2006) "Preferences, Technology and the Environment: Understanding the Environmental Kuznets Curve", American Journal of Agricultural Economics, Vol. 88 no. 3, pp. 632-643.

[24] Kipperberg, G. (2003) "An Investigation into Environmental Friendly Consumer Behavior: The Case of Household Recycling", Department of Agricultural and Resource Economics, Dissertation Prospectus.

[25] Kuznets, S. (1955) "Economic Growth and Income Inequality", The American Economic Review, Vol. 45 no. 1, pp. 1-28.

[26] Mazzanti, M.; Montini, A.; Zoboli R., (2007) "Economic Dynamics, Emission Trends and the EKC Hypothesis New Evidence Using NAMEA and Provincial Panel Data for Italy", Nota di Lavoro 24 -- Fondazione Eni Enrico Mattei.

[27] Mazzanti, M.; Montini, A.; Zoboli R., (2007) "Municipal Waste Production, Economic Drivers and New" Waste Policies: EKC Evidence from Italian Regional and Provincial Panel Data", Paper no. 12 -- Fondazione Eni Enrico Mattei.

[28] Mazzanti, M. (2008) "Is waste generation de-linking from economic growth? Empirical evidence for Europe", Applied Economic Letters, no. 15 , pp. 287-291.

[29] Mazzanti, M.; Zoboli R., (2009) "Municipal Waste Kuznets Curves: Evidence on Socio-Economic Drivers and Policy Effectiveness from the EU", Environment and Resource Economics.

[30] Mohd. Badruddin Mohd. Yusof; Mohd. Razman Salim; Othman, F. (2006) "A Note on the Influence of Household Behaviour on the Generation of Municipal Solid Waste in Johor Bahru Tengah", Malaysian Journal of Civil Engineering, no. 18, pp. 70-73.

[31] Perra, L. (2000) "Rifiuti solidi urbani: un'analisi economica dell'assetto produttivo", CRS - PROAQUA, Working Paper no. 00/34.

[32] Podolsky, M.J.; Spiegel, M., (1998) "Municipal waste disposal: unit pricing and recycling oportunities", Public Works Manage. Policy no. 3, pp.27-39.

[33] Princen, T. (1999) "Consumption and environment: some conceptual issues", Ecological Economics, no. 31, pp. 347-363.

[34] Ratkowsky, David A. (1990), “Handbook of non linear regression models”, New York: Dekker.

[35] Ricci, M.; Tornavacca, A. (2000) "Raccolta differenziata e tariffa: approcci, attrezzature ed esperienze".

[36] Samuelson, Paul A. (1954) "The Pure Theory of Public Expenditure", The Review of Economics and Statistics, Vol. 36 no. 4, pp. 387-389.

[37] Sbandati, A. (1998) "La gestione dei rifiuti urbani fra liberalizzazione e regolazione", Convegno organizzato dal Dipartimento di Scienze Economiche dell'Università di Firenze, IRPET e PROAQUA.

[38] Shafik, N. (1994) "Economic Development and Environmental Quality: An Econometric Analysis", Oxford Economic Papers, New Series, Vol. 46, pp. 757-773.

[39] Stern, David I. (2003) "The Rise and Fall of the Environmental Kuznets Curve", Rensselaer, Working Paper in Economics.

[40] Tiller, Kelly H.; Jakus, Paul M.; Park, William P., (1997) "Household Willingness to Pay for Dropoff Recycling", Journal of Agricultural and Resource Economics, no. 22(2), pp. 310-320.