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Municipal Solid Waste and Development: The Environmental Kuznets Curve Evidence for Mediterranean Countries

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Abstract - The application of the Environmental Kuznets Curve (EKC) to Municipal Solid Waste (MSW) in Mediterranean countries is particularly challenging given the sensitivity of these economies to a lot of environmental constraints due to socio-economic factors such as population growth, urbanization, tourism and economic development. We aim to fill the lack of literature for these countries by testing the EKC for 19 Mediterranean countries over the period 1990-2010 and to identify the main determinants of MSW through a panel data model. Several original control variables are included, such as socio-economic factors, working women, education, technology and climate. Another original aspect of our research is the management of the missing data through the imputation method developed by Honaker and King (2010). Results show that the EKC hypothesis only holds for developed countries with very high turning points. The main policy implication for Mediterranean countries is that in the short or medium run, policy makers cannot use growth and development policies as a means of reducing MSW. This problem is even more acute because the model shows that some economic and socio-demographic factors will go on to have a detrimental impact on pollution by increasing MSW. These factors are the rise in the working women ratio, the rise in urbanization, the increase in the share of industry in Mediterranean economies (displacement effect) and the role of international trade (detrimental technological and scale effect). Consequently, policy makers should urgently implement ambitious public policies that are dedicated to the reduction of MSW in these countries.

JEL Classification

Q53, Q56

Key Words

Municipal solid waste
Mediterranean countries
Environmental Kuznets Curve
Imputation method

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1. INTRODUCTION

For several reasons, promoting sustainable development has recently become a key challenge for all Mediterranean countries. First, these countries are particularly vulnerable to environmental constraints, particularly climate and climate change (Péridy, Brunetto, & Ghoneim, 2012). In this regard, water management and agriculture are particularly constraining for these countries due to high temperatures and scarce precipitation. Furthermore, air, water and land pollution reinforce the environmental constraints related to the quality of available natural resources. The strong rise in the population, especially urban population in the South, is an additional major constraint that impacts the availability and the quality of these resources. Finally, the economic development of Southern Mediterranean countries has already produced severe damage on the environment. For all these reasons, the pollution issue is particularly acute in Mediterranean countries. As shown Croitoru & Sarraf (2010) and Doumani (2014), this environmental degradation is estimated to cost several GDP percentages. Among the six pollution factors identified by the World Bank,[1] economists and policy makers are increasingly paying attention to Municipal Solid Waste (MSW) for two reasons: first, because of the transverse effects of this waste on other pollution factors (land, air, water) and second, because of their effect on human health (OECD, 2009). Mediterranean countries are particularly concerned with this issue because of a very strong increase in this pollution stock due to population growth and economic development, especially in Southern countries.

Although the economic literature has explored the determinant of MSW as early as the 1970s, a new set of studies has emerged more recently through the test of the Environmental Kuznets Curve (EKC) (Grossman & Krueger, 1991; Shafik & Bandyopadhyay, 1992; Beckerman, 1992). This curve is based on the assumption that there is an inverse U-shape relationship between pollution and income. When we consider a low-income country, any rise in growth and economic development leads first to an increase in pollution, up to a certain threshold (inflection point), above which pollution starts decreasing.

The theoretical foundation of the EKC can be highlighted by both traditional and new growth theories, i.e. the standard neoclassical growth theory (Selden & Song, 1995 and Kelly, 2003), the endogenous growth theory (Stokey, 1998 and Hartman et al., 2005) and overlapping generation growth models (John & Pecchenino, 1994 and Lieb, 2004). These theories make it possible to conclude that the EKC assumption mainly depends on the tradeoff between the costs and benefits of depollution as well as on the elasticity of the demand for the quality of the environment with regard to income. Empirically, the existence of the EKC depends on various factors (which are not necessarily independent) such as i) scale, technology and composition effects; ii) international trade (pollution haven hypothesis); and iii) the role of State, institutions and regulation policies (Dinda, 2004). Moreover, these theories tend to conclude that the EKC hypothesis does necessarily hold naturally, i.e., without policy regulation (especially for pollution stock), and that when appearing naturally, the outcome is not Pareto-optimal, which in turn justifies policy regulation.

The application of the EKC to MSW in Mediterranean countries is particularly interesting given the sensitivity of these economies to the environmental constraints mentioned above. In particular, the significant demographic growth (especially in urban areas) and the touristic pressure (which accounts for 15% of GDP in these countries) may significantly increase the pollution and the costs due to MSW.

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[1] Water, land, air and coastal areas' pollution, climate change and MSW.

In addition, this region includes heterogeneous countries both in terms of per capita GDP and in terms of public management of MSW. This heterogeneity may lead to differentiated income-MSW relationships in relation to the slope heterogeneity assumption (Nourry, 2007 and Dinda, 2004).

These particularities of Mediterranean countries raise several questions. First, does the EKC assumption hold for these countries? If so, this would suggest that the rise in MSW will be stopped once Southern Mediterranean countries reach a certain income level. Second, what is this level and is this level the same for all countries? The lower this level, the earlier the production of waste is expected to decline. Third, what are the other variables that explain the production of MSW? In particular, what are the effects of international trade, policy regulation, the sectoral composition of GDP (role of manufacturing industries), education, etc.? Identifying these control variables makes it possible to select alternative tools for reducing the stock of waste in these countries.

The existing empirical literature is still very scarce and incomplete. To our knowledge, only two studies focus on a single Mediterranean country, i.e., Italy (Mazzanti et al., 2009a and 2009b) whereas some Mediterranean countries are included in some studies in a much larger sample of countries, namely the EU or the OECD (Iafolla et al., 2010; Mazanti & Montini, 2009; Mazzanti & Zoboli, 2009; Cole & Bates, 1997). In particular, no specific study has been dedicated so far to Southern Mediterranean countries, which are particularly concerned with the rise and the management of MSW.

The present study is aimed at filling this lack of literature by i) testing the EKC for 19 Mediterranean countries over the period 1990-2010, and ii) identifying the main determinants of MSW. In order to highlight the specificity of Mediterranean countries, 77 other countries are also included as reference countries. One contribution is an extension of the empirical analysis on EKC to developing countries, which renders possible the comparison of the MSW-income relationship between developed and developing countries. In particular, the specificity of Mediterranean countries will be analyzed. Another important contribution is related to the management of missing data through the imputation method developed by Honaker & King (2010). The advantage of this method is the use of all the information available in the dataset. This improves the robustness of the results and leads to more significant parameter estimates, especially for secondary variables. As an additional contribution and in order to control the isomorphism assumption, two estimations are provided: one for high-income countries and the other for intermediate-income countries. Furthermore, several original control variables are included such as socio-economic factors, urbanization, technology and climate. Finally, several estimators are implemented in order to address econometric problems such as heteroskedasticity, serial correlation, endogeneity and multicollinearity in panel data.

This article is organized as follows. Section 2 presents a short summary of the empirical literature related to the application of the EKC to MSW. Section 3 develops the model, and describes the data and the econometric procedure, including the imputation method used for dealing with missing data. Section 4 is dedicated to the discussion of the results. Section 5 focuses on the conclusion and the policy implications of these results.

2. WHAT DO WE KNOW ABOUT THE MSW-INCOME RELATIONSHIP? A BRIEF LITERATURE REVIEW

The empirical literature dedicated to the EKC for MSW is recent and still incomplete. Table 1 summarizes the conclusions of the main articles. A first wave of research emerged in the mid-1990s. It mainly focused on *cross-country* analysis. Using cross-section or panel data analysis, these studies generally invalidate the EKC hypothesis and conclude that the production of MSW increases with GDP[2] (monotonous relationship). More recently, another set of research has emerged based on data at national, regional or urban level for a single country (*within country* studies). These articles provide different conclusions than those relying on cross-country data. As a matter of fact, they all validate the EKC hypothesis. For example, Lim (1997), Song et al. (2008), Mazzanti, et al. (2009), Ichinose et al. (2011) and Khajuria et al. (2012) test the EKC for, respectively, South Korea, China, Italy, Japan and India, and find the inverse U-shape relationship between income and waste, thus validating the EKC hypothesis. If we exclude Lim (1997) and Khajuria et al. (2012) because of a very small number of observations, all the other studies highlight the existence of an inflection point. This point is located around the average income for the Japanese regions, whereas it is located around the maximum income for Italian and Chinese regions. This suggests an absolute and relative decoupling respectively, i.e., there is more evidence of the existence of the decreasing part of the EKC in Japan than in Italy and China.

Table 1. A summary of the empirical studies related to the MSW-income relationship

Authors	Sample	Estimator	Nb. obs.	Independent variables		Income effect	EKC assump.	Turn. point
				Income indicator	Other var.			
Within country level								
Khajuria et al. (2012)	India (1947-2004)	Time series	8	Gross dom. saving (% GDP)	no	Positive	Valid	26.7%
Ichinose et al.(2011)	Japanese municip. (2005)	Cross-section	1,796	Taxable income (million yen)	yes	Positive	Valid	4.25
Mazzanti et al. (2009a)	Italian regions (1996-2005)	Panel	180	GDP/cap. (euro)	yes	Positive	Valid	-
Mazzanti et al. (2009b)	Italian cities (2000-2004)	Panel	515	Value added/cap. (const. euro 2000)	yes	Positive	valid	22,8-25,9
Lim (1997)	South Korea	Time series	11	GDP/cap.	yes	Positive	valid	n.a
Song et al. (2008)	29 Chinese prov. (1985-2005)	Panel	-	GDP/cap (real yuan 2000)	no	Positive	valid	31,668
Cross-country level								
Iafolla et al. (2010)	EU (15) (1997-2007)	Panel	195	Household final consump. spending/cap (euro)	yes	Positive	Not valid	-
Mazzanti and Zoboli (2009)	EU (25) (1995-2005)	Panel	275	Household final consump. spending/cap (euro 1995)	yes	Positive	Not valid	-
Cole and Bates (1997)	13 countries OECD (1975-1990)	Panel	52	GDP/cap. ($ ppa)	yes	Positive	Not valid	-
Shafik (1994)	39 countries (1985)	Cross-section	39	GDP/cap. ($ ppa)	no	Positive	Not valid	-
Shafik and Bandyopadhyay (1992)	39 countries (1985)	Cross-section	39	GDP/cap. ($ ppa)	yes	Positive	Not valid	-

The isomorphism hypothesis is one way to explain the differences in the results provided between cross-country and within-country studies. In other words, we assume that isomorphism amounts to considering that all countries have the same waste-income relationship. If this is so, using cross-country data that include a large set of countries with a large range of income levels, should validate the EKC

[2] See, Shafik & Bandyopadhyay (1992), Shafik (1994), Cole et al. (1997), and more recently, Mazzanti et al. (2009a), Iafolla, Mazzanti & Nicolli (2010).

hypothesis, by showing that low-income countries are generally located on the increasing part of the curve, middle-income countries are located around the inflection point, and high-income countries appear on the decreasing part of the curve. This isomorphism hypothesis is rejected by many authors who fail to validate the EKC using cross-country data for both MSW (Table 1) and alternative pollution indicators (List & Gallet, 1999; Stern & Common, 2001; Lee et al., 2009; Brock & Taylor, 2010).

One interesting study is Iafolla et al. (2010) which tests the slope homogeneity of the EKC in a panel data model by using the Seemingly Unrelated Regression estimator. These authors clearly reject the isomorphism assumption and highlight three country groups: the first includes countries that show an absolute decoupling, e.g. Austria, Germany, Greece, Portugal and Spain. In this country group, the strong differences in the inflection points (from 1,633 to 16,646 euros) can be explained by the differences in standard of living and differences in the efficiency of environmental policies related to waste. The second group includes the UK and the Netherlands, that show a relative decoupling, i.e. the existence of a small decreasing part of the ECK curve. Finally, the last group includes heterogeneous countries in terms of income and shape of the income/waste curve. However, for all these countries (Belgium, Denmark, France, Italy and Sweden), the EKC hypothesis is rejected. To sum up, most authors reject the isomorphism hypothesis. This can be a first explanation for the differences between cross-country and within-country studies in terms of EKC.

Another explanation of these differences can also be found in the geographical aggregation level of data. One illustration is the various articles for Italy (Mazzanti & Zoboli, 2009; Mazzanti et al., 2009a; Mazzanti et al., 2009b; Iafolla et al., 2010) which alternatively use data at urban, regional or national levels. These articles reject the EKC, except for the article (Mazzanti et al., 2009b) which uses data for urban areas. Other explanations for the mixed results with regard to the EKC assumption can also be found in methodological issues such as in the choice of the estimator (cross-section, time series or panel), in the way income is measured (value added, taxable revenue, GDP per capita, domestic saving, etc.), in the existence or the absence of control variables (missing data bias), in the choice of these control variables (especially international trade), and in the existence of a significant number of missing observations and the way they are managed.

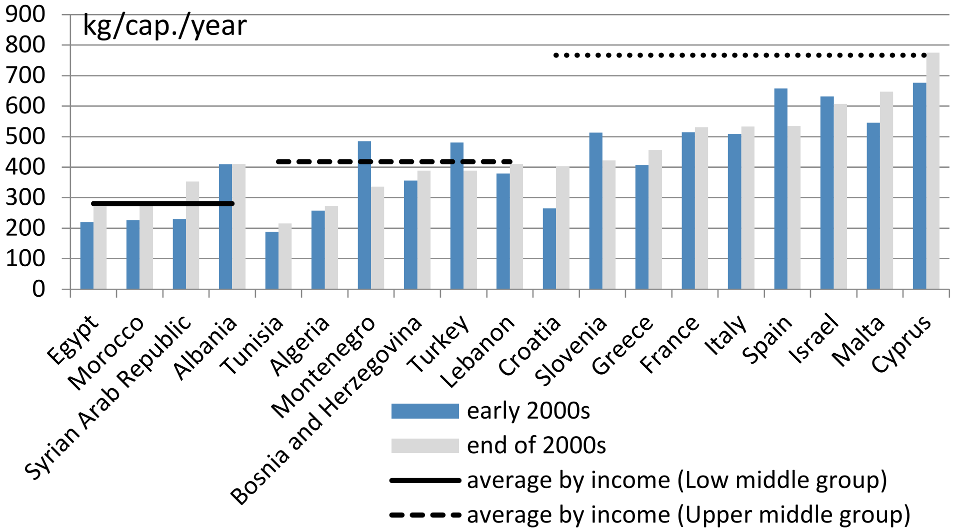
To conclude, the differences in the results concerning the waste/income relationship can be explained by a wide range of factors. This justifies the necessity to use a large set of sensitivity analysis tools in the empirical analysis. In addition, the number of studies available remains very scarce, particularly for Mediterranean countries. The model developed in the next section aims to fill this gap by proposing an appropriate and original methodology, especially regarding missing data and the selection of country groups.

3. THE MODEL, DATA AND ECONOMETRICS SPECIFICATION

The model proposed here intends to test the income/waste relationship (EKC) and to identify the other main determinants of the production of MSW. It is measured as the quantity of MSW per inhabitant and per year, often called the intensity of waste production (refer to data sources in Table 3).

Starting with stylized facts, we first compare the quantity of MSW at the beginning and end of the period 1990-2010. Figure 1 shows this variable for 19 Mediterranean countries (due to data unavailability, Libya and the Palestinian territories are excluded). Unsurprisingly, the countries that show the lowest income levels, i.e., Southern Mediterranean countries, also show the lowest production of waste per capita, whereas high-income countries generally produce more waste.

Figure 1: Per capita MSW in Mediterranean countries



Source: Eurostat/Medstat, OCDE, UN, Hoornweg & Bhada-Tata (2012).
Note: Average level of MSW per capita are based on overall sample of 96 countries, i.e. 19 Mediterranean countries plus 77 other countries.

However, it is interesting to observe that countries with the highest income levels (France and Italy) do not produce the greatest quantity of waste because they are surpassed by Malta and Cyprus. Another interesting point is that the rise in the quantity of waste per inhabitant (from 2000 to 2010) is generally very significant in intermediate-income countries, whereas it is more limited or even decreasing for high-income countries. These observations provide a first insight about the relationship between income and waste[3].

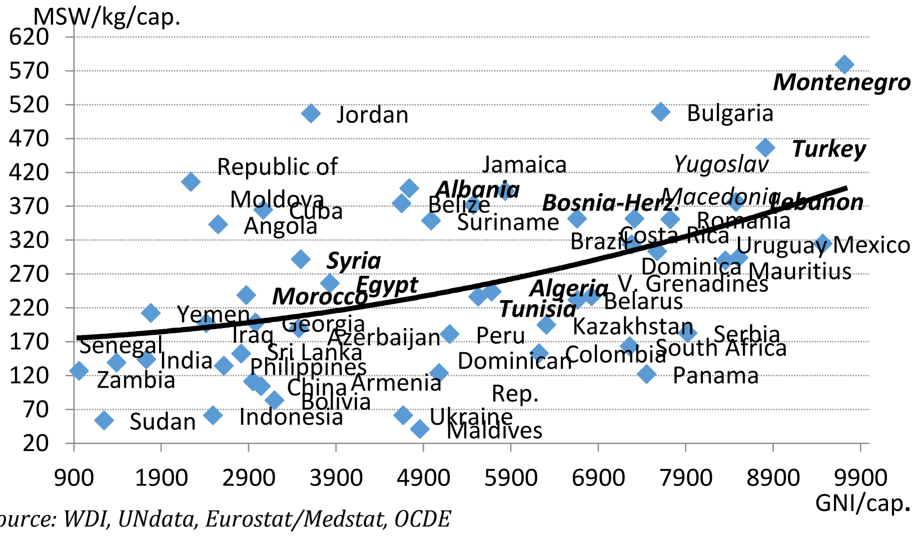
Second, we examine the link between MSW and income averages (over the period 1990-2010) of Mediterranean countries within two country groups. Figures 2 and 3 confirm the positive relationship between MSW and income in Mediterranean countries, as they are all on the increasing part of the curve. However, we observe that a turning point seems to appear for high-income countries.

All these stylized facts require further investigation by appropriate econometric modeling. In this regard, the model specification raises several problems and constraints: i) country heterogeneity related to the isomorphism hypothesis, ii) the choice of the control variables, and iii) the management of missing observations. Regarding the heterogeneity across countries, as shown in Table 2, we separate the country sample into two homogeneous groups, i.e., high-income countries and intermediate-income countries (given that Mediterranean countries do not involve low-income countries), In order to identify the specificities of Mediterranean countries and to increase the number of observations, the total number of countries is extended to 96 (see Figure 1 & 2). Following the existing literature, e.g., Brock and Taylor (2010), we assume that countries within each group share common endog-

[3] Figure 1 also shows that MSW per capita for high income Mediterranean countries is lower than for the full sample average of this country group.

enous characteristics with regard to the EKC. In addition, the introduction of control variables makes it possible to capture the remaining differences within each group. We must observe that Mediterranean countries belong to both country groups as both groups include high- and intermediate-income level countries.

Figure 2: MSW and income relationship in intermediate income group (Mean over period 1990-2010)[4]



Source: WDI, UNdata, Eurostat/Medstat, OCDE

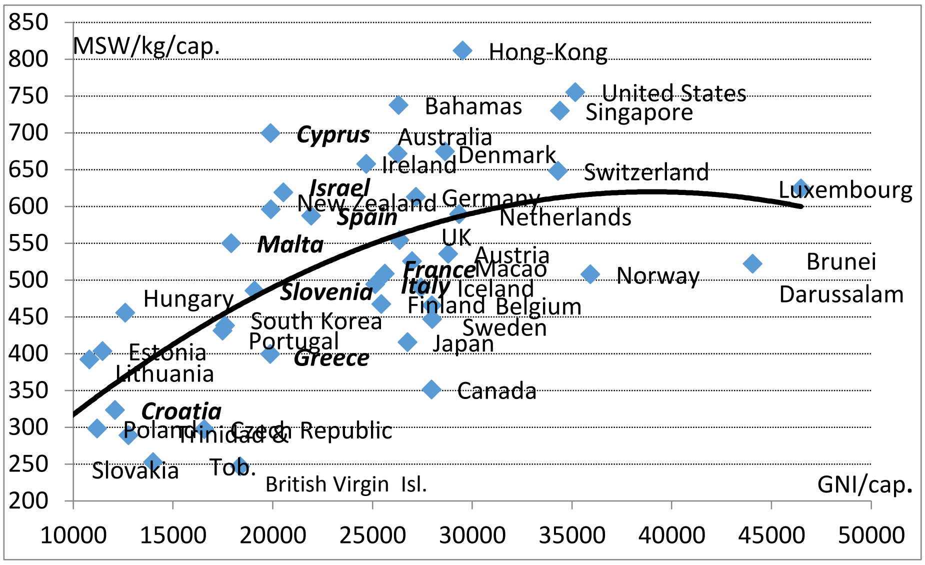
The choice of the appropriate control variable is based on the extension of the existing literature. These variables are necessary in order to avoid the missing-variable bias that could, in turn, alter the estimation of the EKC. They include economic factors, socio-demographic variables, technology, environmental policy and factor endowment. All these variables are fully described in Table 3.

Concerning economic factors, the present study goes further than the existing literature by including not only GNP per capita and its square, but also additional variables related to the sectoral composition of the economy, such as the share of industry or services in total GDP. We expect that the higher the proportion of services, the lower the production of waste. This can be explained by the fact that services use intensive human capital (less polluting) and less intensive physical capital (Hartman & Kwon, 2005). Conversely, the higher the share of industry (proxy of manufacturing goods), the higher the production of waste (Spiegelman & Sheehan, 2006) as is also shown by the composition effect or the specialization effect (Grossman & Krueger, 1991).

Another key economic variable is related to international trade (or openness). In this regard, Antweiler, Copeland, and Taylor (2001) show that its global effect on pollution is ambiguous because of three contradictory partial effects on pollution: the scale, composition and technological effect. Applied to MSW, the global effect is also ambiguous depending on the price and the composition of imports, as well as on the technology used for exports. In addition, the composition effect can be more precisely tested through the import/GDP ratio that mainly includes manufactured consumer goods.

[4] Available data.

Figure 3: MSW and income relationship in high income group (Mean over period 1990-2010)[5]



Source: WDI, UNdata, Eurostat/Medstat, OCDE.

Turning to socio-demographic effects, we test five variables in this model. The first includes the ratio of working women (except in agriculture). We expect that as women increasingly participate in the labor market, the time dedicated to household work, and particularly to cooking, is reduced and thus families tend to consume more manufactured products and prepared food that, in turn, leads to an increase in waste (Getahun et al., 2012).

Table 2: MSW and income per capita in each country group (Mean over period 1990-2010)

Country sample	Number of countries	GNI/cap. ($ PPP)		MSW (annual kg/cap)	
		Mean	S.d.	Mean	S.d.
High income	45	22,245	11,104	499	149
Intermediate income	51	5,009	3,023	250	147
Total	96	13,622	12,081	410	190
Of which Med Countries	*19*	*12,792*	*8,854*	*476*	*137*

Source: WDI, Eurostat/Medstat/UNdata/OCDE. S.d.: Standard deviation.

Education is another key variable but its impact on waste is also ambiguous (Getahun et al., 2012; Monavari et al., 2011; Sujauddin et al., 2008). On the one hand, the higher the education level, the more people are aware of environmental issues and the less they are likely to produce waste. On the other and, since MSW is "transportable", the location of the production of waste differs from the place where waste is transformed. Consequently, people do not physically undergo the pollution due to waste in the place they live in.

[5] Available data.

Table 3: Data and sources

Variables		Definition	Mean[6]	S.d.	Exp. sign	Miss. obs.
Dependent variable	MSW	MSW (annual kg/cap)	410	190		47%
Economic variables	Income	GNP/cap. $ ppp	13,622	12,081	+	3%
	Industry	% GDP	31	10	+/-	9%
	Services	% GDP	59	13	-	9%
	Openess	Intensity of international competition[7] (%)	0.50	0.19	+/-	7%
	Imports/GDP	Imports (% GDP)	46	27	+/-	4%
Socio-demographic	Working women	Women labor participation rate (% total population)	47	13	+	3%
	Age	Population 0-14 (% total population)	26	9	-	1%
	Education	Educational HDI component[8]	0.67	0.17	+/-	9%
	Population Density	People/km^2	426	1,907	+	0%
	Urbanization rate	% total population	65	19	+	0%
Technology	R&D Spending	% GDP	1.1	0.96	+/-	56%
Policy	Public Spending	% GDP	29	12	+/-	44%
Climate	Precipitations	Average mm (1961-1990)	1,093	733	+/-	0%
	Temperature	Average °F (1961-1990)	59	15	+/-	0%

Sources: Eurostat, Medstat, UNdata, OECD, WDI.

Age also has an impact on waste. According to McCollough (2012), working people are more likely to produce excessive waste because they tend to buy more disposable products, whereas young people and old people generally produce less waste (Johnstone & Labonne, 2004; Ichinose et al., 2011). In the present model, the proxy used is the 0-14 population share. We expect a negative sign for this variable. The two final socio-demographic variables are population density and urbanization rate that are generally expected to increase the production of waste (Mazzanti & Zoboli, 2009; Johnstone & Labonne, 2004; Iafolla et al., 2010).

To our knowledge, no study has tested the impact of technology on the production of MSW, although a few articles since the theoretical work developed by Grossman and Krueger (1991) have tested its impact on air pollution (Cole, Rayner & Bates, 1997; Lindmark, 2002). In the present article, technology is measured by

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6 Available data for all countries over 1990-2010.

7 Internationalization rate $= \frac{X}{GDP} + \left(1 - \frac{X}{GDP}\right)\left(\frac{M}{GDP+M-X}\right)$, where X and M respectively reflect exports and imports. Alternatively, a standard openness indicator has also been tested (X+M)/GDP.

8 Human Development Indicator 2005-2010.

the R&D spending ratio. Its impact on waste can be negative (for example, if innovation makes it possible to reduce the weight of packaging for the products) or positive (for example, if it leads to the production of new polluting consumer goods or the reduction of the lifetime of these products).

Policy regulation is another crucial variable for explaining the production of waste. We expect that an appropriate and efficient environmental policy will reduce pollution, in particular MSW. For instance, incentive price policies, appropriate tax, or investment policies can efficiently reduce the production of waste. However, specific data at the international level are unavailable. Therefore, policy regulation is measured here by an imperfect proxy, defined as the public spending ratio.

The final set of variables includes climate variables such as temperature and rainfall. These variables have only been recently tested in empirical models dedicated to MSW (Getahun et al., 2012; Keser et al., 2011). In a low-income country, a rise in precipitation is likely to increase putrescible MSW due to problems related to the storage of agricultural products. Another possible explanation lies behind heating systems that are usually based on firewood and coal in most developing countries. Conversely, an increase in rainfall in a high-income country generally leads to a reduction in waste because of the fall in consumption due to bad weather. With regard to temperature, warmer weather in a low-income country is likely to reduce agricultural production and thus waste, whereas it leads to a rise in consumption (and thus waste) in developed countries. In these countries, the good weather favors tourism, walks and picnics that favor the consumption of packaged goods.

Summing up, the model proposed here includes a large number of control variables that are expected to provide more precise and less biased results related to the EKC test.

The last preliminary constraint is related to the management of missing observations. As shown in Table 3, 47% of the observations concerning the production of MSW are missing. Disregarding these missing data would lead to a drastic reduction in the number of observations in the model which may lead to potential biases (Honaker and King, 2010). The most numerous missing observations involve intermediate-income countries, although four databases have been used and combined, i.e., UN (1990-2009), Eurostat-Medstat (1995-2010), OECD (1990-2010) and the Sweep-net reports (2010). Basically, the countries selected include all high- and intermediate-income countries for which at least one observation of MSW is available over the period 1990-2010. As also observed in Table 3, some independent variables also include a significant number of missing observations (equal to or greater than 1% of the total number of observations), especially R&D spending, public spending and education.

The analysis of the dataset shows that the pattern of missing observations is monotone and the missing mechanism is MAR (Missing At Random). That means when the variable j_1 is missing, j_2 is always missing as well and the probability of a particular value being missing depends only on the observed data. In this case, the most appropriate way to manage these data is the use of the multiple imputation approach. This makes it possible to estimate missing observations while correcting the bias concerning the estimation of the variance (that is commonly found in simple imputations models) by accounting for the uncertainty related to missing observations. Basically, there are several models available for multiple imputations, e.g. Markov Chain, Monte-Carlo and Predictive Mean matching. Honaker and King (2010) have recently developed a model that is specific to panel data.

This model can be summarized as follows. Starting from a matrix of data (D) that includes p variables (column) and n rows, each component x_{ijt} corresponds to the value of variable j (j=1, …, p) for country i at year t. D includes both observed and missing variables. Therefore, it is transformed into a matrix for missing values M and one for observed values D^{obs}. M is composed of elements that are equal to 1 if the observations are missing, and 0 for observed values, and vice-versa for matrix D^{obs}. Hence, D^{obs}=D*(1-M).

D is assumed to have a multivariate normal distribution: D~N (μ, σ) where μ and σ are the Gaussian unknown parameters (mean and standard deviation) and missing values are assumed to follow a MAR distribution. In other words, the probability of getting missing values only depends on observed values. Consequently, the relationship between observed and missing values is the following:

$$x_{ij}^{mis} = \beta_j x_{i,-j}^{obs} + \gamma_j t + \delta_{ij} + \delta_{ij} t + \epsilon_{ij} \quad (1)$$

where x_{ij}^{mis} are the missing values that must be estimated for observation i and variable j. $x_{i,-j}^{obs}$ are all other observed values for observation i and all variables, except j (we have omitted the time index for simplicity). β_j is the parameter corresponding to the cross-section between variable j and all the covariants (-j). $\gamma_j t$ corresponds to the trend, δ_{ij} is the fixed-effect and $\delta_{ij} t$ is the interaction term between the trend and the fixed-effect. This makes it possible to specify the temporal trend for each country-observation. Finally, ϵ_{ij} is the error term of the model. Because D is made of p variables, the imputation model is also made of p equations, i.e., one corresponding to each variable. Finally, the unknown parameters μ and σ are estimated through iterative processes until the convergence of the Expected Maximization (EM) algorithm (for additional details, refer to Honaker & King, 2010, p.576). Once the various constraints related to data are addressed, the following equation must be estimated:

$$\ln MSW_{it} = \beta_0 + \beta_1(\ln Y_{it}) + \beta_2 (\ln Y_{it})^2 + \beta_3 (ln\, X_{it}) + \beta_4(\ln Z_{it}) + \beta_5 (\ln V_{it}) + \beta_6(lnW_{it}) + \beta_7 U + \beta_8 T_t + \beta_9 F_i + \varepsilon_{it} \quad (2)$$

with MSW being the sum of annual MSW per capita, Y refers to GNP/cap (in PPP US$), X denotes the vector of the other economic variables (described above), Z is the vector of socio-demographic variables, V refers to technology, W to climate, U to public policies, and T, F and ε are, respectively, the time, country fixed-effects and the error term.

This equation is estimated for two country groups (45 high-income and 51 intermediate-income countries) over the period 1990-2010. The appropriate panel data estimators have been selected after preliminary tests that concern heteroskedasticity (Breusch-Pagan test), autocorrelation (Baltagi-Li) and endogeneity (Hausman test). Given the significant number of independent variables, multicollinearity has also been checked through the VIF statistics that are below the upper limit generally accepted (10). Given all these tests, the selected estimator is the Hausman–Taylor to address the problem of endogeneity. As a sensitivity analysis, the estimation with different estimators, such as Baltagi-Li (1995) and Baltagi-Wu (1999) estimators for Heteroskedastic and corrected GLS have also been implemented. Because results do not strongly differ across these various estimators, the Hausman–Taylor only is presented in order to save space. However, complete results are available on request.

As a last sensitivity analysis, the model is estimated with three options related to the way Mediterranean countries are taken into account. Option 1 provides results for all countries in each group (no interaction variables for Mediterranean countries). Option 2 includes an interaction term between GNP and Mediterranean countries. This allows us to identify a potential specificity of these countries with regard to the relationship between GNP and waste. Finally, option 3 includes an interaction variable between openness and Mediterranean countries in order to test the effect of openness on waste concerning these countries, specifically (scale, composition and technological effect).

4. EMPIRICAL RESULTS

Results are presented in Table 4 for high- and intermediate-income countries, respectively. When accounting for missing data, the Hausman and Taylor estimator has been preferred to other estimators in order to account for the possible endogeneity bias related to the imputation method. As a comparison, the estimation which disregards missing data is presented in Annex 1. In this regard, it is worthwhile mentioning that the imputation method does not change the MSW-income results to a large extent, especially for developed countries for which the rate of missing data is low. However, the significance of the other variables, especially secondary variables, is improved, as expected. Concerning intermediate income countries, the imputation method improves the significance of all variables and the sign of the corresponding parameter estimates are those theoretically expected. Thus, the advantage of the multiple imputation method is to use all the available information which makes possible an improvement of the results.

A first interesting result shows that the EKC assumption is accepted for high-income countries with a high turning point, which ranges from 56,000[9] to 133,000 US$ PPA/capita depending on the specification of the model and the selected estimator. This suggests that there is a relative decoupling for high-income countries. These results correlate the stylized facts presented previously. In addition, results show that the relationship between GNP and municipal waste is monotonous for intermediate income countries. Thus, the EKC hypothesis is not observed, even with relative decoupling.

Basically, this result is consistent with those already observed for pollution (cross-country level) and is also consistent with the theoretical model developed by Lieb (2004) for pollution stocks, specifically. A second crucial result is that there is no specificity of Mediterranean countries compared with the other countries, given that the income interaction variable is insignificant for these countries. These results suggest that a policy based on growth only is not appropriate to reduce the production of waste in Mediterranean countries, especially in the short run. This policy implication will be further discussed in Section 5.

As a third interesting set of results, it is striking to observe that the global-trade effect of MSW is negative in high-income countries whereas it is positive (although barely significant) for intermediate-income countries. One reason for this difference is that high-income countries may enjoy a favorable technological effect due to openness through FDI and the emergence of a demand for clean technologies (Dinda, 2004; Stern, 2007). However, the composition effect (import/GNP ratio) is rather positive (although barely significant) for high-income countries. This means that high-income countries have started importing polluting consumer goods that originate from intermediate and low-income countries, whereas the remaining industries or services in high-income countries domestically pollute much less in terms of municipal waste (see the negative sign of the industry/GNP ratio and service/GNP). This result correlates with the displacement hypothesis that states

[9] For the Fixed-effect estimator whose results are not presented here in order to save space. These results are available upon request.

that manufacturing industries are progressively transferred from Northern to Southern Mediterranean countries. However, there is no specific effect of openness for Mediterranean countries, as the corresponding interaction term is insignificant.

Table 4 : Empirical Results (Hausman and Taylor estimator)

	High income countries			Intermediate income countries		
	(1)	(2)	(3)	(1)	(2)	(3)
Income	1.16**	1.17**	1.18**	0.40***	0.41**	0.42***
Income square	-0.05*	-0.05*	-0.05*	-0.00	-0.00	-0.00
Openness	-0.18*	-0.18*	-0.17*	0.07**	0.07*	0.08*
Imports (% GDP)	0.19*	0.18*	0.19*	-0.01	-0.01	-0.01
Industry (% GDP)	-0.25**	-0.25**	-0.25**	-0.23	-0.22	-0.23
Services (% GDP)	-0.43*	-0.41*	-0.43*	-0.39	-0.38	-0.38
Urbanization rate	0.08*	0.12*	0.08**	0.21*	0.19*	0.22*
Pop density	0.07*	0.10*	0.09*	0.28	0.25	0.27
Working women (%)	0.51***	0.51***	0.51***	0.23*	0.21*	0.22*
Precipitation	-0.16*	-0.15*	-0.15**	-0.24*	-0.24*	-0.24*
Temperature	-0.04	-0.07	-0.07	-0.14*	-0.16*	-0.14*
Policy (pub spend)	0.01	0.01	0.01	-0.09	-0.09	-0.09
R&D	0.20	0.20	0.20	-0.15	-0.15	-0.15
Education	-0.01	-0.01	-0.01	-0.10	-0.11	-0.10
Age	-0.02	-0.02	-0.02	-0.25	-0.23	-0.26
Interaction variables						
Med-countries	-	0.34	0.31	-	-0.43	0.19
Income*med	-	-0.03	-	-	0.05	-
Openness*med	-	-	-0.06	-	-	-0.05
Nb. of observations	940	940	940	1176	1176	1176
R-square	0.70	0.71	0.71	0.70	0.70	0.70
Turning point	**109,000**	**120,000**	**133,000**	**-**	**-**	**-**

Regarding environmental policy regulation, the time period selected in this paper (1990-2010) coincides with the development of specific policies dedicated to improve MSW management in the EU. These policies are based on regulation or political incentives related to the "polluter-pays" principle (Responsibility Enlarged to the Producer, tax on the landfill of waste, etc.). Given that the management of MSW is a public policy, the proxy used in the model corresponds to public spending. The assumption is that a constraining MSW policy leads to higher costs due to MSW management, and consequently higher public spending. However, the main problem with this proxy is that spending due to MSW accounts for a very small part of total public spending. Thus, the relationship between the two variables is not straightforward and unsurprisingly, the corresponding parameter estimate is insignificant. In this regard, there is an urgent need to get more precise data about the cost of waste management at country level.

The last set of results concern i) the positive relationship between municipal waste and urbanization and, to a lesser extent, population density (in developed countries only). This means that the persistent trend of rural-urban migration in intermediate countries is a phenomenon that mechanically increases municipal waste in these countries; ii) the working-women parameter is positive and strongly significant, as expected theoretically. This suggests that the more women participate in the labor market, the more they buy prepared food and hence, the more the production of waste; and iii) climate has a significant impact on municipal waste. As a matter of fact, a rise in precipitation, that can be perceived a bad weather in high- and intermediate-income countries, leads to a decrease in consumption, and thus waste. Conversely, a rise in temperature in the intermediate-income country level gives rise to a reduction in waste, because as the weather becomes too hot, agricultural production (and thus waste) decreases (in intermediate-income countries only).

Finally, the other variables are insignificant. These are age, education and technology. This result can be explained either by the poor quality of some proxies (e.g., technology) and/or the ambiguous sign expected for these variables, in particular technology and education.

5. CONCLUSION AND POLICY IMPLICATIONS

This article shows that the EKC hypothesis holds only for developed countries with a turning point that is very high. In the case of intermediate-income countries, the income-waste relationship is monotonous. The main methodological contribution is the implementation of the multiple imputation method which uses all the available information in the dataset, including missing data. It has been shown that the quality of the results and the significance of some economic and socio-demographic variables (i.e. international trade, the sectoral composition of the economy, women participation in the labor market and weather) have been improved.

The main policy implication is that in the short or medium run, policy makers cannot use growth and development policies as a means of reducing municipal waste in these countries. In particular, GDP per capita in Southern Mediterranean countries is still too low to expect to reach a potential turning point in the near future. Consequently, if the objective of policy makers is really to reduce municipal waste in these countries, alternative policies must be implemented. This problem is even more acute when we consider that some economic and socio-demographic factors will go on to have a detrimental impact on pollution by increasing municipal waste. These are the rise in the working-women ratio, the rise in urbanization, the increase in the share of industries in their economies (displacement effect) and the role of international trade (detrimental composition effect).

In other words, given the current GDP per capita (too low) in these countries, the main variables that are likely to boost their economic development (growth, openness, specialization, urbanization and the role of women in labor markets) will have a strong negative impact on environment through the rise in MSW. Over the same period of our study, the cost of environmental degradation is, on average, 4.9% of GDP in the Mediterranean intermediate-income countries (Doumani, 2014).

The only policies that must be carried out in order to counteract these variables are the following. The first is an appropriated and ambitious public policy dedicated to MSW. In this regard, these countries should start thinking about the efficiency of some policies applied in developed countries (polluter-pays rule, tax on landfill waste, etc.). A second and complementary policy is related to technology. This policy could be first used as a means of reducing the production of waste by the industries. It requires a selected R&D policy with public incentives. This policy could also be used in the management of waste (recycling, etc.) as a means of reducing the quantity of ultimate waste and providing an appropriate transformation of this ultimate waste.

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Annex 1: Empirical Results Composition for observed-data (Listwise deletion technique)

	High income countries			Intermediate income countries		
	fixed effects	random effects	HT estimator	fixed effects	random effects	HT estimator
Income	2.5430*	1.2247	2.17***	17.8377***	10.6212**	16.66***
	(1.91)	(1.00)	(0.52)	(4.48)	(2.15)	(1.89)
Income square	-0.1129*	-0.0463	-0.09***	-0.9600***	-0.5660**	-0.90***
	(-1.71)	(-0.76)	(0.03)	(-4.54)	(-2.14)	(0.10)
Openness	-0.1233	-0.1485*	-0.12*	0.8263**	0.5921*	0.73**
	(-1.33)	(-1.72)	(0.05)	(2.71)	(1.80)	(0.27)
Imports (% GDP)	0.0497	0.0696	0.03	-0.5351*	-0.3662*	-0.34
	(0.62)	(1.05)	(0.06)	(-2.05)	(-1.77)	(0.22)
Industry (% GDP)	-0.1485	-0.0683	-0.13	-1.3923**	-1.1995*	-1.35***
	(-0.88)	(-0.37)	(0.09)	(-2.53)	(-1.90)	(0.35)
Services (% GDP)	-0.2509	-0.0232	-0.22	-1.2133*	-0.6524	-1.07*
	(-0.51)	(-0.05)	(0.24)	(-1.86)	(-1.15)	(0.55)
Urbanization rate	0.5334	0.2150*	0.40	-2.4063	0.0449	-3.39**
	(0.84)	(1.92)	(0.28)	(-1.06)	(0.07)	(1.21)
Pop density	0.9381*	0.0159	0.64***	-3.3021*	-0.0047	-1.24*
	(1.88)	(0.39)	(0.17)	(-1.93)	(-0.02)	(0.53)
Working women (%)	-0.4558	-0.0687	-0.19	1.0034	0.1771	1.30*
	(-1.47)	(-0.25)	(0.14)	(1.00)	(0.32)	(0.54)
Temperature	-	-0.1777	-2.21	-	-0.3126	-0.06
	-	(-1.27)	(1.49)	-	(-1.50)	(3.36)
Precipitation	-	0.3927**	-0.99	-	0.0101	-0.18
	-	(2.08)	(0.79)	-	(0.01)	(0.83)
Policy (pub spend)	-0.2249**	-0.1626**	-0.23***	0.0152	0.2109	0.00
	(-3.24)	(-2.80)	(0.04)	(0.07)	(1.20)	(0.17)
R&D	0.0099	0.0308	0.04	0.1930**	-0.1391	0.19
	(0.15)	(0.59)	(0.03)	(2.28)	(-1.14)	(0.11)
Education	-0.0826	-0.1086	-0.02	1.2159	-0.5669	0.89
	(-0.75)	(-0.94)	(0.09)	(1.69)	(-1.37)	(0.48)
Age	0.4446	0.3807	0.45***	1.8101	0.1892	0.70
	(1.45)	(1.53)	(0.12)	(1.50)	(0.43)	(0.93)
Constant	-12.0374	-3.0574	5.85	-50.3570**	-36.0131*	-47.16**
	(-1.54)	(-0.53)	(6.54)	(-2.88)	(-1.78)	(16.40)
Med-countries	-	2.60***	3.03**	-	0.52	6.86
		(0.57)	(0.99)		(3.33)	(4.13)
Income*med-countries	-0.33***	-0.25***	-0.28***	-0.53	-0.11	-0.70
	(0.05)	(0.05)	(0.05)	0.49	(0.34)	(0.39)
Openness*med-countries	0.22	0.07	0.15	-0.92	-0.51	-0.80
	(0.13)	(0.12)	(0.13)	(0.64)	(0.63)	(0.57)
Nb. of observations	374.0000	374.0000	374	107.0000	107.0000	107.0000
R-square	0.3748	0.3448	-	0.6766	0.5626	-
Turning point	**77,821**	**-**	**172,053**	**10,834**	**11,880**	**10,462**

Production de déchets municipaux et développement : l'existence d'une courbe environnementale de Kuznets dans le cas des pays méditerranéens ?

Résumé - Cette étude a pour objectif de compléter la littérature sur la validité empirique de l'hypothèse de la courbe environnementale de Kuznets pour la pollution des déchets municipaux. Elle s'intéresse aux pays méditerranéens dont l'environnement est très sensible à la pollution des déchets municipaux en raison du tourisme, de l'urbanisation, de la croissance de la population et du développement économique. A partir de données en panel sur la période 1990-2010, nous analysons la relation revenu-intensité des déchets municipaux et identifions les principaux déterminants économiques et sociodémographiques de la production des déchets municipaux. L'originalité de cette étude réside, d'une part, dans la prise en compte des effets de nouvelles variables explicatives telles que la participation des femmes au marché du travail, l'ouverture au commerce international, l'éducation et le climat. D'autre part, cette étude prend en compte le biais des données manquantes par l'application du modèle d'imputation de Honaker and King (2010). Nos résultats confirment l'hypothèse de la courbe environnementale de Kuznets mais uniquement pour les pays développés de la région méditerranéenne et pour des revenus très élevés. En outre, les résultats montrent que la participation des femmes au marché du travail, l'urbanisation et l'ouverture au commerce international intensifient la production des déchets municipaux. Sur le plan politique, ces résultats indiquent la nécessité dans la région méditerranéenne d'un contrôle des déchets municipaux du fait des différents facteurs qui poussent à leur croissance.

Mots-clés

Pays méditerranéens
Courbe environnementale de Kuznets
Déchets municipaux
Imputation multiple