DOMESTIC MATERIAL CONSUMPTION INDICATOR AND NATURAL RESOURCES: A EUROPEAN ANALYSIS OF THE ENVIRONMENTAL KUZNETS CURVE

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Abstract. *The study investigates the relation between per capita Domestic Material Consumption indicator (DMC) and per capita income. Economic literature focuses mainly on air, water and land pollution while we consider as environmental degradation the consumption on natural resources extracted from the environment. Using a cross–European panel of countries over the period 2000-2011, our results confirm the absence of an Environmental Kuznets Curve (EKC) between per capita DMC and per capita GDP both for EU-27 vs. 30 European countries and for Western vs. Eastern European countries. The turning points are so high that it is present a monotonic increasing relation between DMC indicator and GDP.*

Keywords: *Natural resource use, Environmental degradation, Environmental Kuznets curve, Domestic material consumption and economy-wide material flows accounts.*

1. INTRODUCTION

The increasing awareness about global warming, air and water pollution and other environmental disasters is becoming the main issue for both people and policy makers in these recent years. The stress on the environment has been carried on by developed countries because of their industrial structure and by developing countries because of the increase of their per capita income levels. The effects of the production and consumption activities on the environment could be subdivided

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into: i) *economic effects*; ii) *social effects*; iii) *environmental effects*. Country actions regard mainly the improvement of natural resource management or the adoption of sustainable development strategies.

The Environmental Kuznets Curve (EKC) analysis is the most important empirical result within the end-of-pipe approach. The EKC relationship is based on a rather intuitive assumption. In early stages of industrialization, pollution grows rapidly while in the later stage, after a turning point, pollution declines as the level of GDP increases, as the relationship between income inequality and economic development described by Kuznets (1955). For comprehensive overviews of theoretical and empirical studies on the EKC the reader can refer to Panayotou (2000), Borghesi (2001), Dinda (2004), and Kijima et al. (2010). The EKC literature does find different patterns for the same pollution indicators (see among others Shafik and Bandyopadhyay, 1992; Grossman and Krueger, 1995; Selden and Song, 1995; Azomahou et al., 2006; Vollebergh et al., 2009; Musolesi et al., 2010; Ordás Criado et al., 2011; Mazzanti and Musolesi, 2013a and 2013b).

Even if early authors find some evidence on the existence of an inverted-U-shaped pattern of the relationship between per capita income and emissions, some recently studies have criticised the reduced-form of the EKC model. For example Cole et al. (1997) have underlined that the reduced-form relationships reflect correlation rather than causal mechanism. Due to the feedback effect of environmental quality on income growth, Stern et al. (1996) and Pearson (1994) have concluded that reduced–form models are not appropriate to describe the mechanism of environmental degradation in terms of income.

Other authors, instead, are sceptical about the existence of EKC hypothesis because of the lack of adequate econometric techniques used. The analysis of unit root test, cointegration and related error correction model is implemented by Dinda and Coondoo (2006), Auci and Becchetti (2006) and Lee and Lee (2009) while the recent analyses of Mazzanti and Musolesi (2013a) and (2013b) focus on the simultaneously handle of three econometric issues: functional form bias, heterogeneity bias and omitted time related factors bias.

However, as underlined by Brock and Taylor (2010), economic growth and pollution are closely related. In fact, for the growth of an economy, more inputs and more natural resources are required in the production process. As a consequence, more pollution and negative effects for the environment are yielded. As Azomahou et al. (2006) underline, the study of this relationship is relevant for the definition of an appropriate joint economic and environmental policy.

Having in mind all these critiques of the ECK literature, our paper is close in spirit to the seminal works of Grossman and Krueger (1995) on the EKC analysis. We consider this relationship by not controlling for possible determinants like technological change, policy events, etc. Even if we do not deny the role of these determinants, our choice is based on comparability issue with the seminal studies. The originality of our study, in fact, is in the use of a different indicator, drawn by the Economy-Wide Material Flow Accounting (EW-MFA) belonging to Satellite Accounts System of National Accounting (EUROSTAT, 2001; 2002). This indicator, in line with result-oriented approach, putting emphasis on preventive and integrated policies, can: i) provide an integrated view of the material used; ii) capture indirect flows not embodied in products; iii) understand the effects on global environment of material flows among countries.

We hope that using this comprehensive indicator we could deepen the understanding of the '*driving forces'* behind environmental burden. Within the EW-MFA indicators, we have focused our attention on Domestic Material Consumption (DMC) indicator that measures the total amount of natural resources directly used in production and consumption processes of an economic system. This indicator should be considered as a proxy for *'potential environmental pressure'*. Knowing the methodological aspects, we are aware of the limits of the DMC, such as the high level of aggregation, covering important disparity within its items.

An advantage of our indicator is related to consumers' pressure. It is undeniable that environmental degradation can be affected by consumers' behaviour both directly and indirectly and in EKC literature several authors, Stern et al. (1996), Ekins (1997), Rothman (1998) and Suri and Chapman (1998), have emphasised the consumption–based approach as the more appropriate measure of global environmental impact.

Our empirical analysis is just another example within the EKC literature. Using a cross–European panel of countries over the period 2000-2011, the aim of our paper is to verify whether this measure of potential environmental pressure can follow an *EKC-like* path among European countries. Given the relative lack of empirical studies on the relationship between material consumption indicators and the level of per capita GDP, our purpose is to delineate some stylized facts through the use of a simple empirical model, whose results should highlight important issues that merit further investigations.

Our indicator belongs to the family of sustainability indicators based on a holistic approach. DMC related to GDP have been widely used in the decoupling analysis. Decoupling[2] occurs when the growth rate of an environmental pressure is

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[2] In literature, a distinction is often made between *absolute* and *relative* decoupling. In a growing economy, relative decoupling means a positive environmental pressure growth rate – in terms of resources required – but less than the growth rate of GDP. Absolute decoupling is said to occur when environmental pressure growth rate is decreasing while GDP is increasing.

less than GDP growth rate over a given period. Our results confirm a slight presence of relative decoupling among European countries considered.

In our empirical analysis, an inverted–U shaped relationship between per capita DMC indicator and per capita GDP within the EU-27 countries, the EU-30 enlarged to Norway, Switzerland and Turkey and the two macro-areas (West and East of Europe) is not present. The results are the same both in the panel estimations and in the robustness estimations. The turning points are so high that there is a monotonic increasing relation between per capita DMC indicator and per capita GDP as in the case of per capita CO_2 emissions and per capita GDP (Holtz-Eakin and Selden, 1995; Roberts and Grimes, 1997; Cole et al., 1997). These results are in line with Arrow et al. (1995) who have emphasized that EKCs for global pollutants with long-term costs and perhaps for some resource stocks have tended to be monotonically increasing.

The remaining of the paper is organized as follows. In the second section, we review Physical Measures of Environmental Impact developed by official statistics. The third section underlines some stylised facts about the DMC indicator in order to better understand its components and trend. In the fourth section, we describe the empirical model and illustrate the main econometric findings, while in the fifth we introduce the sensitivity analysis. Finally, in the last section, we conclude.

2. DOMESTIC MATERIAL CONSUMPTION INDICATOR

In the last fifteen years, official statistics have developed some indicators as physical measures of potential environmental impact to better understand and measure consequences of economic growth. Our analysis is based on Domestic Material Consumption (DMC) included in the construction of Total Material Requirement (TMR) indicator, that nowadays has gained in importance at international level within European countries (EUROSTAT, 2002).

A satellite accounting system has been adopted in the last decade in which a system of accounts are dedicated to measure raw resources extracted by nature and reintroduced as waste materials. All items are expressed in units of weight. Within Material Flow Accounts (MFA), EW-MFA is now (with air emission and environmental taxation accounts) one of the three top-priorities in European official statistics' environmental accounting, which are object of the EU Regulation n. 691/2011. Italy has very actively contributed to international statistic developments through Istat[3] (Femia and Vignani, 2005; 2010).

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3 In the framework of EW-MFA, Istat compiles accounts and derived indicators on yearly basis: the time series 1980-2011 are published in www.istat.continazionali

EW-MFA is the methodology for the construction of a system of accounts dedicated to measure natural resources based on a holistic approach. This system gives synthetic information on physical exchanges of an economy and on potential environmental pressures (Adriaanse et al, 1997). The anthropic system is looked at as a living organism whose activities need flows of natural materials extracted by the environment (inputs) to be processed in many ways such as manufacture, use reuse and recycling, accumulated in stocks or returned back to natural environment in an altered shape (outputs). Measuring inputs to socio-economic functioning gives an indication of all potential *"pressures"* to nature. The EW-MFA analysis can be carried out at different levels of detail, according to the set of activities and the type of materials[4]. Compared to other methodologies EW-MFA offers three advantages: i) certainty of the basis in units of weight; ii) accounting of actual phenomena; and iii) use of the main national accounting concepts.

Similarly to national accounts, in EW-MFA accounts the cycle of matter is divided into a series of steps, each illustrated by an account. The accounts are structured in waterfall and are all linked together, as to show the relationships among various measures of resources use. Material-flow-based indicators provide an aggregate picture by describing the evolution of the demand for natural resources by a country.

Among the EW-MFA indicators, highly significant is Total Material Requirement (TMR) that accounts for all material flows required at global level to satisfy domestic and foreign final demand of domestic and foreign products (Bringezu and Schütz, 2001). TMR, indicating the *Total Material Base*, is obtained by adding together the following items, all expressed in units of weight: i) *Domestic Extraction of Materials Used (DEU)*: all materials extracted from natural environment in a country; ii) *Imports* of raw materials and goods; iii) *Domestic Extraction of Materials Unused (DEUnused):* all materials flows extracted from nature intentionally but not used in final products i.e. materials from mining and quarrying activities; iv) *Indirect Flows Associated to Imports (IF):* quantities of materials, used and unused, removed from other countries' nature in order to produce goods imported by a country. IFs account materials not actually embodied in goods, because they are transformed in waste and emissions during the production process carried out abroad.

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[4] Due to heterogeneous, fragmentary and low-quality statistical data and metadata, Istat environmental accounting experts should have had reduce to coherence a large set of data (Costantino, Femia and Vignani, 2008, Femia and Vignani, 2010).

As this paper intends to analyse a panel of European countries by using EKC methodology, the lack of data on TMR forces to use another EW-MFA indicator DMC. Thus, we focus on DMC indicator because it is available for a large number of countries and years and is also one of the indicators used to assess the achievement of EU policy targets.

DMC measures the total amount of materials directly used by an economy and is defined as the annual quantity of raw materials extracted from domestic territory of an economy (*Domestic Extraction Used*) plus all physical imports minus all physical exports (*Physical Trade Balance*). This consumption-based indicator refers to the domestic use of natural resources and provides an assessment of consumption driven by domestic demand and by the export market. DMC can be seen as an indicator reflecting all materials that physically remain in a country, emitted by or accumulated in a given region (Bringezu and Schütz, 2001). All these materials will eventually turn into emissions and wastes, thus the value of DMC can also measure the potential waste of a given country (Moll et al., 2003). DMC and TMR are only rough proxies for measuring the overall environmental potential impact of resource use, as materials have very different impacts on the environment.

In this framework, EW-MFA is perceived as a very relevant decision tool by policy makers. For example, both EU Sustainable Development Strategy (EU-SDS) and EUROPE 2020 Strategy are based on DMC and a set of sustainable development indicators. Defining the targets to put the EU on a *path of sustainable development*, the EU-SDS puts incentives in managing efficiently natural resources, in protecting the environment and in promoting social cohesion. The Europe 2020 strategy, putting emphasis on the efficient use of resources, promotes the target of a low carbon economy.

EUROSTAT and all national statistical institutes have a leading role to play in providing indicators and monitoring to what extent the EU is on track to achieve the concrete goals for a sustainable growth based on a resource efficient economy. The EU-SDS indicators are more than one hundred and have been organised within a theme-oriented framework. One of them called *"sustainable consumption and production"* contains the sub-theme *"resource use and waste"* whose headline indicator is *Resource Productivity* (GDP/DMC) that measures efficiency in the use of natural resources in an economic system.

All these considerations strengthen the selection of DMC as an appropriate measure to analyse the relationship between environment pressures and economic activities by using the EKC methodology. This type of indicator helps to underline the change of the environment in which man lives due to production-consumption activities.

3. DESCRIPTIVE EVIDENCE

Before discussing our empirical results, we present some stylised facts on the DMC indicator and GDP in order to better understand its components, trend and its relationship with national production. In Figure 1, the first figure on EU-27 shows the two components of DMC. The EU–27's DEU is the first component because on average accounts for the 85% of DMC. In fact, in 2010 the DEU value is equal to 5,937 million of tonnes. Within DEU, non-metallic minerals – including sand, gravel and other inert materials – represent about the 56% of total with 3,343 million of tonnes. The importance of construction and infrastructure activities can be easily seen. Biomasses represent about the 27% of total while the remaining fossil energy materials and metal ores extracted are respectively 14% and 3%. DEU's trend shows a decrease of about 3% from 2000 to 2003, while it raises until to 2007 reaching more than 6,967 million of tonnes (+6.9% compared to 2000) and finally, in the last period (2007-2010) DEU diminishes by almost 14.7%.

As regard PTB, it presents a positive value in the period observed (2000-2010), the EU–27 can be considered as a net importer of materials. PTB raises almost constantly from 2000 to 2007 of about 27%, so it reaches the highest value of the period observed just in 2007 when foreign imports of materials exceed exports by 1,306 million of tonnes. Natural resources and products, needed to satisfy EU-27 countries' demand, are replaced by foreign sources.

Thus, as a whole, DMC undergoes a slight decreasing only 1.5% from 2000 to 2003. After 2003 it starts rising until 2007 up to almost 8,273 million of tonnes, that represents an overall increase just over 9.5% compared to 2000. A structural break takes place between 2008 and 2009 due to the financial and real crisis that reduces production and consumption activities and domestic demand of natural resources.

Focusing on the three NO–EU–27 countries - Norway, Switzerland and Turkey - their DMC is available only for the period 2000-2009. The overall value of DMC shows that the component PTB remains negative, meaning that aggregated exports of material flows overcome aggregated imports by an annual average of more than 100 million of tonnes (Figure 1). This is true especially for Norway and Turkey but not for Switzerland whose PTB is positive in all years. The negative value of PTB component contributes to reduce DMC in each year. However, DMC shows a positive trend from 2000 to 2009 with an overall increase of 29%. In 2009 it reaches the highest value of 1,122 million of tonnes of natural resources.

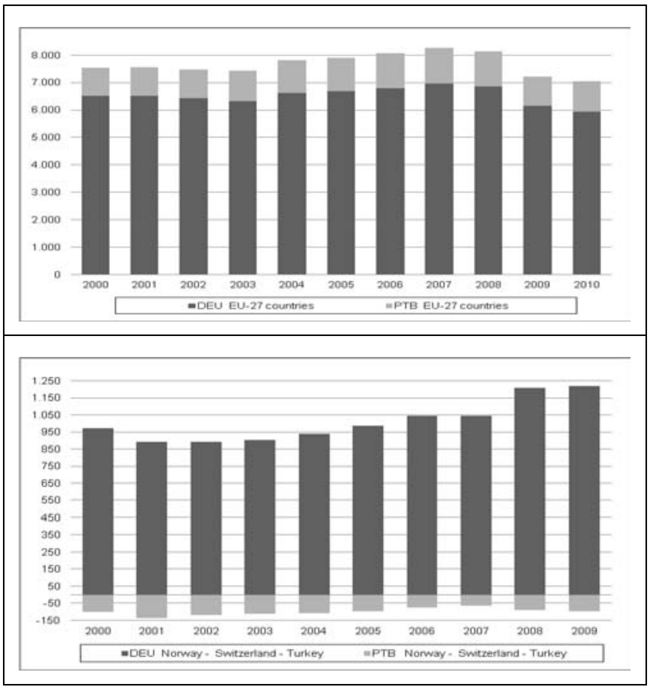

Figure 1: Domestic Material Consumption (DMC) by components, EU–27 and NO-EU-27 (million tonnes)

Source: data processed by EUROSTAT database
Note: a) Eurostat dataset does not present data available for Norway and Turkey in year 2010 and 2011. b) For all three countries PTB is negative, even if Switzerland PTB is positive in all years.

As far as a dynamic comparison between per capita DMC (DMCpc) and per capita GDP (GDPpc) of the EU-27 countries is concerned, as in Figure 2, only from 2000 to 2003 DMCpc seems to be relative decoupled from GDPpc (respectively 4.5% and +5%). Starting from 2003 up to 2007 GDPpc increases more quickly than in the previous four years (+9.9%) and DMCpc shows a similar rise (+8.4%).

Figure 2 shows a structural break for the EU-27 countries in the DMCpc series from 2007 onwards. The decreasing of DMCpc and GDPpc takes place (respectively -19% and -4.7%) and a relative *decoupling* occurred. In absolute values, DMCpc, that exceeds 20 tonnes of material flows in 2007, comes down to just over 16 tonnes in 2010 while GDPpc changes from 20,973€ to about 20,163€. For the three NO-EU countries a similar trend for GDPpc occurs. As regards DMCpc, in the period 2000-2003, is evident a decoupling with respect to GDPpc. What is interesting to highlight is that in 2001 DMCpc decreases (-13% over the previous year). However,

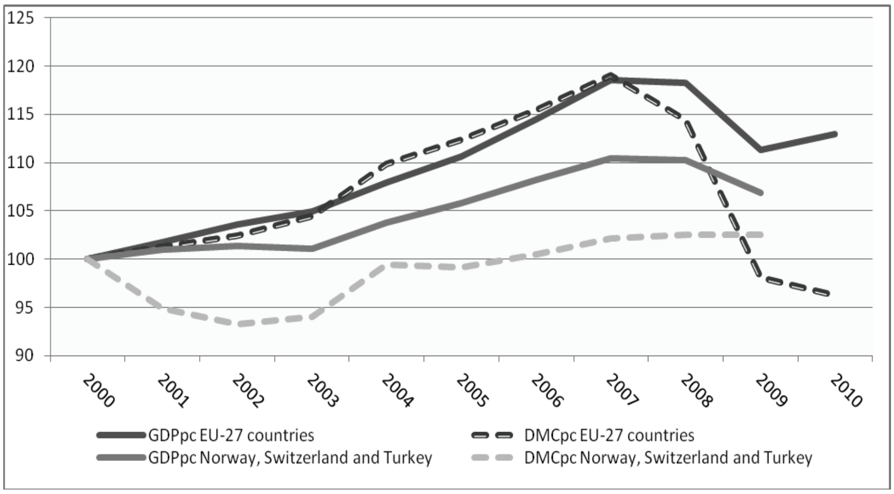

Figure 2: Per capita Domestic Material Consumption (DMC) and Gross Domestic Product (GDP), years 2000-2010, index 2000=100

Source: data processed by EUROSTAT dataset

starting from 2003 up to 2009 there is a continuous increasing of DMCpc that reaches almost 20 tonnes of materials, with an overall rise of 30% in the period considered.

4. EMPIRICAL MODEL AND RESULTS

In our econometric analysis, we estimate a reduced form model, which, following Auci and Becchetti (2006), we call the *unadjusted EKC-like* curve. As in the previous analysis, we estimate the simple relationship between an environmental indicator DMC and GDP. Drawing an unbalanced panel dataset of 30 European countries by the European Statistical Office (EUROSTAT) dataset, whose data are collected yearly from 2000 to 2011, we compare both the EU27 countries with respect to the 30 European countries and the west European countries with respect to the east European countries, using fixed and random effect panel models with proper diagnostics.

The simple EKC curve is represented by a polynomial approximation in logarithmic terms:

$$\ln(E/P)_{it} = \alpha_i + \gamma_t + \beta_1 \ln(GDP/P)_{it} + \beta_2 (\ln(GDP/P))^2_{it} + \varepsilon_{it}$$
$$\text{with } \beta_1 > 0 \quad \text{and } \beta_2 < 0 \qquad (1)$$

where *E* stands for domestic material consumption indicator, *P* represents total population and *GDP* is gross domestic production. The subscripted indices *i* and *t* indicate, respectively, countries and years while with α_i and γ_t-intercepts we can measure, respectively, country specific time invariant effects and time effects.

From this specification the turning point of income at which per capita resource use is at its maximum level is easily derived as:

$$GDP_{max} = \exp(-\beta_1 / (2\beta_2)) \quad (2)$$

where β_1 and β_2 are the parameters of levels and square of per capita GDP in Equation (1).

We are aware that this simple specification has been extensively criticised on econometric and theoretical grounds, but our aim is to verify if this new indicator shows a relation akin to the EKC curve. However, to improve our simple empirical analysis, we conduct a sensitivity analysis.

Table 1 reports descriptive statistics of all variables included into the estimation model. Descriptive statistics are reported not only for the whole data in the dataset but also distinguishing between EU27 countries and NO–EU27 countries such as Norway, Switzerland and Turkey and between western and eastern European countries.

Table 1: Descriptive statistics of estimation variables - 2000–2011

	Variable	Mean	SE(Mean)	CV	P25	P50	P75	N	IQR
OVER ALL	DMCpc	18.20	0.44	0.45	12.70	16.50	21.60	355	8.91
	GDPpc	19,541	721	0.70	6,427	16,290	28,974	360	22,547
NO–EU27#	DMCpc	18.03	2.07	0.64	10.90	12.01	34.78	31	23.87
	GDPpc	29,646	2,925	0.59	6,014	40,239	42,645	36	36,630
EU27	DMCpc	18.25	0.44	0.43	13.53	16.77	21.59	324	8.06
	GDPpc	18,418	707	0.69	6,459	15,823	27,690	324	21,231
WEST	DMCpc	19.56	0.67	0.50	12.50	17.45	23.60	212	11.10
	GDPpc	28,110	741	0.39	21,427	27,402	32,952	216	11,525
EAST	DMCpc	16.26	0.41	0.30	13.17	16.03	19.03	143	5.86
	GDPpc	6,689	315	0.57	4,492	6,008	7,131	144	2,639

Notes: # the NO–EU27 are 3 countries: Norway, Switzerland and Turkey; CV means coefficient of variation (sd/mean); IQR means inter-quartile range = p75 - p25. Variable legend: DMCpc: per capita Domestic Material Consumption (million tonnes per capita); GDPpc: unit of euro, chain-linked volumes, reference year 2000 (at 2000 exchange rates).

We estimate our *unadjusted EKC-like* model compared to the linear specification using fixed effects panel technique both all 30 countries versus EU-27 countries and western versus eastern European countries. With this model we can control only for country specific constant terms which may account for the portion of the dependent variable heterogeneity not explained by the considered regressors and the time effects. The Hausman test confirms, in all cases, the absence of orthogonality between the set of regressors and residuals suggesting that the model should be estimated with fixed and not with random effects.

The results of our estimation model, as reported in Table 2, do not confirm the existence of an *EKC-like* curve because the turning points are very high. While coefficients of income are significant and signs are correct, the coefficients of square income have the right sign but are not significant apart from the last estimation in the last column of Table 2. The values of the coefficients of GDP are not so high (between 1.36 and 1.77), the only exception being the estimates of western and eastern European countries in the *unadjusted EKC-like* case (more than 3.5).

Moreover, we control for time effects as well introducing time dummies in the econometric estimates. Our findings show that time effects are always negative but they are significant only for 2003 and from 2005 up to 2011 in both specifications. This result confirms the structural break observed in Figure 2, where since 2007 EU-27 countries have recorded a change in their trends because of the sharp decrease of DMCpc.

The need of a government intervention by European countries on the environmental pressure by human activities is confirmed by our results. Even if Cole et al. (1997), Agras and Chapman (1999), Galeotti and Lanza (1999), Heil and Selden (2001), Cole (2004) and Galeotti et al. (2006) find an inverted–U shaped relationship and turning points so high that a de-linking of CO_2 emissions from economic growth is present, our analysis is in line with the recent analysis of Mazzanti and Musolesi (2013b) that using a more sophisticated empirical model confirms a positive monotonic the carbon-income relationship in most economically advanced countries.

The role of policy makers in managing natural resources and human activities with an impact on the environment is becoming more relevant. European countries have to both encourage more sustainable use of resources and integrate the work of national agencies in managing the environmental burden of human activity.

Table 2: Fixed effects estimates of linear and unadjusted *EKC-like* specifications - 27 countries vs. 30 countries and West countries vs. East countries

Dep. Variable: Ln (DMCpc)	Linear estimation		Unadjusted *EKC-like* estimation		Linear estimation		Unadjusted *EKC-like* estimation	
	27 countries	30 countries	27 countries	30 countries	Western countries	Eastern countries	Western countries	Eastern countries
lnGDPpc	1.36***	1.39***	1.62**	1.50**	1.77***	1.44***	3.61	3.47***
	(15.49)	(16.61)	(2.06)	(1.98)	(6.6)	(8.76)	(1.03)	(2.83)
lnGDPpc^2			-0.02	-0.01			-0.09	-0.13*
			(-0.34)	(-0.15)			(-0.53)	(-1.67)
Cons	-10.03***	-10.32***	-11.06***	-10.77***	-14.99***	-9.57***	-24.27	-17.68***
	(-12.16)	(-13.12)	(-3.48)	(-3.54)	(-5.54)	(-6.92)	(-1.36)	(-3.51)
d_2001	-0.02	-0.03	-0.02	-0.03	-0.04	-0.02	-0.04	-0.02
	(-0.79)	(-1.02)	(-0.77)	(-1.00)	(-1.09)	(-0.50)	(-1.08)	(-0.45)
d_2002	-0.04	-0.05*	-0.04	-0.05**	-0.06*	-0.05	-0.06*	-0.04
	(-1.40)	(-1.75)	(-1.35)	(-1.71)	(-1.72)	(-1.03)	(-1.71)	(-0.91)
d_2003	-0.06*	-0.06**	-0.06*	-0.06**	-0.08**	-0.07	-0.08**	-0.06
	(-1.95)	(-2.36)	(-1.87)	(-2.30)	(-2.35)	(-1.31)	(-2.34)	(-1.11)
d_2004	-0.04	-0.05*	-0.03	-0.05	-0.06*	-0.07	-0.06*	-0.05
	(-1.23)	(-1.71)	(-1.10)	(-1.60)	(-1.71)	(-1.24)	(-1.68)	(-0.93)
d_2005	-0.07**	-0.07**	-0.06*	-0.07**	-0.09**	-0.1*	-0.09**	-0.08
	(-2.10)	(-2.53)	(-1.86)	(-2.31)	(-2.39)	(-1.65)	(-2.35)	(-1.24)
d_2006	-0.11***	-0.12***	-0.11***	-0.12***	-0.14***	-0.16**	-0.14***	-0.13
	(-3.42)	(-3.83)	(-2.95)	(-3.36)	(-3.24)	(-2.35)	(-3.17)	(-1.79)
d_2007	-0.15***	-0.15***	-0.14***	-0.15***	-0.19***	-0.20**	-0.19***	-0.15
	(-4.20)	(-4.71)	(-3.46)	(-3.94)	(-3.96)	(-2.53)	(-3.87)	(-1.83)
d_2008	-0.18***	-0.19***	-0.18***	-0.18***	-0.24***	-0.19**	-0.24***	-0.14
	(-5.07)	(-5.61)	(-4.25)	(-4.74)	(-5.23)	(-2.36)	(-5.15)	(-1.65)
d_2009	-0.23***	-0.22***	-0.22***	-0.22***	-0.24***	-0.26***	-0.24***	-0.22***
	(-6.91)	(-7.31)	(-6.34)	(-6.74)	(-6.20)	(-3.63)	(-6.16)	(-3.04)
d_2010	-0.27***	-0.27***	-0.27***	-0.27***	-0.30***	-0.29***	-0.30***	-0.25***
	(-8.10)	(-8.45)	(-7.30)	(-7.61)	(-7.22)	(-3.89)	(-7.15)	(-3.23)
d_2011	-0.28***	-0.28***	-0.27***	-0.28***	-0.31***	-0.32***	-0.31***	-0.27***
	(-7.96)	(-8.59)	(-7.08)	(-7.69)	(-7.30)	(-3.93)	(-7.21)	(-3.22)
R-sq Within	0.5598	0.56	0.56	0.56	0.4178	0.6755	0.4187	0.683
R-sq Between	0.0937	0.12	0.0921	0.12	0.2733	0.1916	0.2777	0.1606
R-sq Overall	0.0968	0.12	0.0957	0.12	0.2658	0.1971	0.2702	0.1805
F test ++	30.2***	33.56***	27.8***	30.88***	10.88***	20.64***	10.03***	19.56***
F test (u_i *=0)* +++	180.54***	194.21***	172***	186.93***	239.98***	59.34***	228.51***	48.96***
Hausman Test ++++	89.37***	109.10***	58.37***	69.91***	11.8***	41.85***	9.44**	44.98***
Number of obs	324	355	324	355	212	143	212	143
Turning point			8.24E+21	9.49E+45			3.88E+08	8.85E+05

*Notes: # besides EU27, the estimation includes 3 countries: Norway, Switzerland and Turkey; in parenthesis t-statistics are reported; * significant at 10%; ** significant at 5%; *** significant at 1%;++ H_0: joint significance of the regressors; +++ H_0: joint significance of the fixed effects; ++++ H_0: the two estimates do not differ in coefficients systematically. Variable legend: see Table 1.*

Furthermore, to understand the environmental impact and costs of resource use throughout the entire life cycle of materials and products that embody them, there could be useful to deepen the analysis of MFA data and in particular of the material flows among countries. Some additional econometric information could be suitable to summarize some implications for policy makers. Having in mind that different empirical models can influence the way the burden is shared among countries, the linear and the *unadjusted EKC-like* estimations have the implication of considering that the admissible level of pressure for each country should be conditional to their level of economic development. In other words, at the lower levels of income the marginal cost of reducing the environmental pressure should be higher than at the high levels of income.

However, using the fixed effect estimator, we are assuming that some unobserved heterogeneity across individuals, fixed over time, can influence the DMCpc. In Figure 3, we report the country fixed effect values in terms of predicted values for *unadjusted EKC-like* estimations in 2010. In the first graph, based on the 30 country estimation, the western European countries are under the zero line, meaning that their effective domestic potential pressure on the environment is less than the estimated level, while the vice versa is true for the eastern European countries. The first kind of countries seems to use less their natural resources, even if they present differences once you deepen the analysis focusing only on the western countries (see the second graph). Several undefined reasons could be at the basis of this choice and certainly they could be linked to the countries' government structure and its policy.

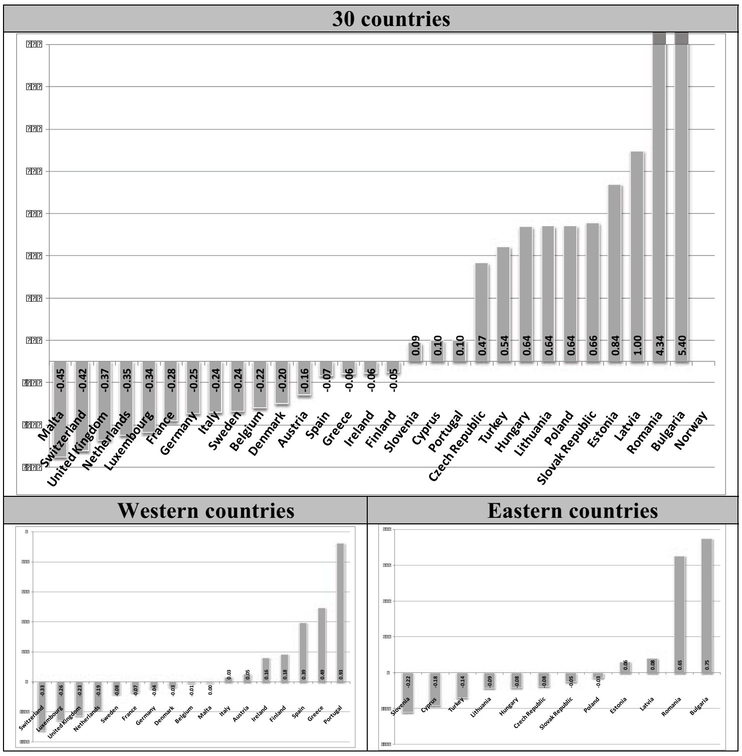

Figure 3: Fixed effects to predicted value ratios of domestic environmental potential pressure based on unadjusted *EKC-like* estimations – 2010

Among the worst countries in the pressure of natural resources, we can find Romania and Bulgaria and this is confirmed even in the third graph where the sample is restricted to only the eastern European countries. The choice of these two countries has been to boost economic growth on the detriment of natural resources this because they consider too costly reducing the environmental pressure of human activities and they give less value to the environment and natural amenities. In other words, for these countries reducing the economic, social and environmental negative effects of production and consumption activities is not desirable in terms of benefits and costs.

The fixed effect analysis could turn out to be stringent for the assumption of a unique coefficient of independent variables. No parameter variation across countries is permitted. To estimate if the heterogeneity of countries is beyond the fixed effect we report in Table 3 the test of parameter constancy based on the random-coefficients model. With this estimator the parameter vector is treated as a realization (in each panel) of a stochastic process. The results do not support the assumption of parameter constancy for all the specifications and sub-samples. However, we could not report the evidence on a country basis due to data constraints even if Mazzanti and Musolesi (2013b) show how countries differ more on carbon-time relation than the carbon-income relation.

Table 3: Test of parameter constancy

	Linear estimation		**Unadjusted *EKC-like* estimation**		**Linear estimation**		**Unadjusted *EKC-like* estimation**	
	27 countries	**30 countries**	**27 countries**	**30 countries**	**Western countries**	**Eastern countries**	**Western countries**	**Eastern countries**
chi2	6242.42	16202.45	1070.55	1531.14	14434.51	1486.31	139.89	1241.2
Prob > chi2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

5. SENSITIVITY ANALYSIS

The limitation of our dataset does not prevent us from improving our empirical analysis through a sensitivity analysis. First we conduct a linear regression with panel-corrected standard error. The model assumption is that the disturbances are assumed to be either heteroskedastic across panels or heteroskedastic and contemporaneously correlated across panels. The disturbances may also be assumed to be autocorrelated within panel, and the autocorrelation parameter may be constant across panels or different for each panel. This empirical model is used as a simple equation when all 30 countries are considered and is adapted to a multiple equation, fixed-effect, panel-data equations when the sample is divided in western and eastern countries. Secondly, due to the fact that past decisions could have an impact on current choices, we estimate a dynamic panel-data model based on the bias-correction of least-squares dummy variable (LSDV) with a small number of observations and strictly exogenous covariates.

In Table 4, the error term not only is assumed heteroskedastic and contemporaneously correlated across panels but also follow a AR(1) process. The estimate of the autocorrelation parameter is quite high (the range is between 0.41 and 0.95), meaning that the autocorrelation is present in this sample. As regards the coefficients, we observe that the significance is very high – in all estimations is at 1% – and the signs are as expected. In particular, these results turn the situation around because in this model the unadjusted *EKC-like* curve is present both for EU-27 countries and 30 countries. However, the test for a structural difference between the two specifications does not reject the null hypothesis so the addition of the 3 countries (Norway, Turkey and Switzerland) to the 27 members of European Union does not imply any differences unlike in the case of linear estimations where the test rejects the H_0.

When we estimate multiple equation, fixed-effect, panel-data equations, subdividing the sample between western and eastern countries as in Table 5, we find again that structural difference test does not reject the null hypothesis in the case of unadjusted *EKC-like* while the opposite occur in the linear case. As regards the existence of the EKC curve, the western countries do not show an inverted U-shaped curve, the vice versa is verified in the eastern country case.

Finally, to consider the influence of past decisions on the current behaviour we use the bias-corrected least-squares dummy variable (LSDV) estimators for the standard autoregressive panel-data model using the bias approximations in Bruno (2005). The outcomes, Table 6, confirm the high influence of the lagged per capita DMC variable in all the specifications while the squared per capita GDP coefficients of EKC estimations are not significant apart for the EU27 specification.

The puzzle results of our sensitivity analysis are in line with the empirical EKC literature that underlines how the results are sensitive to the sample of countries chosen and to the time period considered (Grossman and Krueger, 1995; Hill and Magnani, 2002) or to the methodology used (Borghesi, 2001). As regards the methodology, our analysis, as the majority of empirical studies, is based on a reduced-form model estimated using a parametric function which does not account for heterogeneity of time related factors (Mazzanti and Musolesi, 2013b).

Even if some authors have departed from this stringent methodology and have estimated the environment-income relationship using non-parametric technique (Azomahou et al. 2006, Azomahou and Mishra, 2008, and Millimet et al., 2003), semiparametric methods (Bertinelli and Strobl, 2005) or spline interpolation (Schmalensee et al., 1998), there is not a unique and definite result. Our opinion can be summarized by Vollebergh et al. (2009), who underline how this state of the art has left both researchers and policy makers with the idea that econometric techniques are not able to explain the real long run relationship between economic growth and the environment.

Table 4: Linear and unadjusted *EKC-like* regressions with panel-corrected standard errors - 27 countries vs. 30 countries

Dep. Variable: Ln(DMCpc)	Linear regression with panel-corrected standard errors			
	Linear estimation		Unadjusted *EKC-like* estimation	
	27 countries	30 countries	27 countries	30 countries
cons	3.07***	-10.74***	-17.44***	-14.32***
	(172.07)	(-14.93)	(-8.22)	(-3.94)
lngdppc	0.12	1.36***	3.00***	2.19**
	(0.47)	(19.51)	(6.12)	(2.27)
lngdppc2			-0.10***	-0.05
			(-3.41)	(-0.77)
d_2001	0.02**	-0.02***	-0.02***	-0.02*
	(2.50)	(-3.19)	(-2.61)	(-1.91)
d_2002	0.03***	-0.04***	-0.04***	-0.04***
	(3.50)	(-3.92)	(-3.39)	(-2.67)
d_2003	0.05***	-0.05***	-0.05***	-0.05***
	(5.04)	(-4.14)	(-3.70)	(-2.89)
d_2004	0.12***	-0.04**	-0.03*	-0.03
	(10.22)	(-2.38)	(-1.74)	(-1.19)
d_2005	0.14***	-0.06***	-0.04**	-0.05*
	(11.28)	(-3.27)	(-2.50)	(-1.91)
d_2006	0.16***	-0.09***	-0.07***	-0.09***
	(12.35)	(-4.72)	(-3.87)	(-2.79)
d_2007	0.19***	-0.12***	-0.10***	-0.12***
	(14.57)	(-5.66)	(-4.71)	(-3.04)
d_2008	0.17***	-0.16***	-0.13***	-0.15***
	(12.80)	(-7.03)	(-6.29)	(-3.92)
d_2009	0.04***	-0.19***	-0.17***	-0.19***
	(3.35)	(-9.51)	(-9.39)	(-6.70)
d_2010	0.03**	-0.23***	-0.21***	-0.23***
	(2.33)	(-10.72)	(-10.79)	(-7.28)
d_2011	0.06***	-0.23***	-0.21***	-0.23***
	(4.71)	(-10.76)	(-11.17)	(-6.99)
turning point			6.34E+06	1.82E+10
rhos	0.41	0.95	0.64	0.48
	(0.78)	(0.32)	(0.69)	(0.58)
Wald chi2	8.32E+09***	1.65E+06***	1.50E+06	5.76E+06
Wald test on eu27coefficients vs. eu30 coefficients				
chi2(13)	8.00E+05***			
Prob > chi2	0.00			
chi2(14)			7.51	
Prob > chi2			0.9133	

*Notes: Prais-Winsten regression, where panels are correlated and standard errors are corrected for heteroskedasticity and contemporaneous correlation across panels; a panel-specific AR(1) autocorrelation structure is hypothesized; in parenthesis t-statistics are reported; * significant at 10%; ** significant at 5%; *** significant at 1%.*

Table 5: Linear and unadjusted *EKC-like* fixed-effect panel-data systems with panel-corrected standard errors – western countries vs. eastern countries

Dep. Variable: Ln (DMCpc)	Linear estimation		Unadjusted *EKC-like* estimation	
	Western countries	**Eastern countries**	**Western countries**	**Eastern countries**
cons	-1.76	-9.65***	22.65	-26.03***
	(-1.46)	(-8.79)	(1.01)	(-3.80)
lngdppc	0.48***	1.62***	-4.45	5.64***
	(4.10)	(11.08)	(-0.98)	(3.29)
lngdppc2			0.25	-0.25**
			(1.09)	(-2.27)
d_2001	-0.01	-0.02***	-0.02	-0.02**
	(1.05)	(-2.89)	(-1.24)	(-2.46)
d_2002	-0.02	-0.06***	-0.03*	-0.05***
	(1.49)	(-3.78)	(-1.75)	(-2.84)
d_2003	-0.03*	-0.08***	-0.04**	-0.07**
	(1.86)	(-3.61)	(-2.11)	(-2.50)
d_2004	0.02	-0.09***	0.01	-0.07*
	(-0.86)	(-2.84)	(0.34)	(-1.70)
d_2005	0.01	-0.13***	0.001	-0.10*
	(0.72)	(-3.16)	(0.03)	(-1.78)
d_2006	0.01	-0.20***	-0.01	-0.15**
	(0.59)	(-3.88)	(-0.23)	(-2.13)
d_2007	0.01	-0.25***	-0.02	-0.18**
	(0.34)	(-4.05)	(-0.52)	(-2.10)
d_2008	-0.05**	-0.25***	-0.07**	-0.17*
	(-2.48)	(-3.68	(-2.45)	(-1.87)
d_2009	-0.10***	-0.29***	-0.11***	-0.24***
	(-5.32)	(-5.10)	(-4.79)	(-3.20)
d_2010	-0.12***	-0.34***	-0.14***	-0.28***
	(-6.45)	(-5.44)	(-5.38)	(-3.39)
d_2011	-0.12***	-0.35***	-0.14***	-0.28***
	(-6.62)	(-5.37)	(-5.15)	(-3.25)
turning point			7525.82	94864.33
rhos	0.17		0.18	
	(-0.59)		(0.74)	
Wald chi2	2828.36***		2922.77***	
Wald test on west coefficients vs. east coefficients				
chi2(13)	1.09E+03***			
Prob > chi2	0.00			
chi2(14)			331.36	
Prob > chi2			0.9133	

*Notes: Multiple equation, fixed-effect panel-data equations specified as seemingly unrelated regressions are based on Prais-Winsten regression, where panels are correlated and standard errors are corrected for heteroskedasticity and contemporaneous correlation across panels; a panel-specific AR(1) autocorrelation structure is hypothesized; in parenthesis t-statistics are reported; * significant at 10%; ** significant at 5%; *** significant at 1%.*

Table 6: Linear and unadjusted *EKC-like* regressions with dynamic panel-data models – 27countries vs. 30 countries and western countries vs. eastern countries

Dep. Var.:	Linear estimation		Unadjusted *EKC-like* estimation		Linear estimation		Unadjusted *EKC-like* estimation	
Ln (DMCpc)	27 countries	30 countries	27 countries	30 countries	Western countries	Eastern countries	Western countries	Eastern countries
L1_lndm cpc	0.67***	0.67***	0.68***	0.67***	1.00***	0.62***	1.02***	0.65***
	(10.12)	(11.16)	(10.31)	(10.56)	(11.60)	(6.70)	(11.83)	(6.47)
lngdppc	0.47***	0.52***	-0.91	-0.87	0.53**	0.72***	-2.39	-0.54
	(3.66)	(4.79)	(-1.31)	(-0.93)	(2.12)	(3.51)	(-0.64)	(-0.46)
lngdppc2			0.08**	0.08			0.14	0.08
			(2.05)	(1.56)			(0.78)	(1.11)
d_2001	0.08**	0.09***	0.11***	0.11***	0.03	-0.01	0.06	-0.01
	(2.36)	(2.96)	(3.02)	(3.75)	(0.67)	(-0.31)	(1.41)	(-0.32)
d_2002	0.08**	0.09***	0.11***	0.11***	0.03	-0.02	0.06*	-0.02
	(2.41)	(3.24)	(3.21)	(3.97)	(0.93)	(-0.41)	(1.78)	(-0.45)
d_2003	0.07***	0.08***	0.10***	0.10***	0.02	-0.01	0.05	-0.02
	(2.68)	(2.72)	(3.27)	(3.36)	(0.62)	(-0.25)	(1.54)	(-0.35)
d_2004	0.11***	0.12***	0.13***	0.13***	0.08**	-0.05	0.11***	-0.06
	(4.10)	(4.91)	(4.68)	(5.58)	(2.09)	(-1.08)	(3.10)	(-1.26)
d_2005	0.07**	0.08***	0.08***	0.08***	0.01	-0.10*	0.04	-0.11*
	(2.25)	(3.25)	(2.74)	(3.57)	(0.42)	(-1.65)	(1.35)	(-1.86)
d_2006	0.05*	0.05**	0.05**	0.05**	-0.003	-0.11	0.03	-0.13*
	(1.81)	(2.16)	(2.11)	(2.10)	(-0.08)	(-1.48)	(0.75)	(-1.75)
d_2007	0.04	0.05*	0.04	0.04	-0.02	-0.12*	0.01	-0.14**
	(1.64)	(1.93)	(1.63)	(1.43)	(-0.67)	(-1.71)	(0.20)	(-2.03)
d_2009	-0.09***	0.004	-0.07**	-0.004	-0.08**	-0.27***	-0.05	-0.29***
	(-2.93)	(0.17)	(-2.53)	(-0.18)	(-2.22)	(-4.36)	(-1.49)	(-4.66)
d_2010	-0.03	-0.07***	-0.02	-0.07***	-0.07**	-0.17**	-0.04	-0.18***
	(-0.94)	(-2.85)	(-0.54)	(-2.66)	(-2.46)	(-2.43)	(-1.35)	(-2.63)
d_2011	-0.0004	-0.02	0.01	-0.01	-0.03	-0.17**	0.03	-0.18**
	(-0.02)	(-0.63)	(0.33)	(-0.56)	(-0.98)	(-2.28)	(0.97)	(-2.50)
Turning point			232.34	170.99			4092.88	36.81

*Note: Bias-correction of least-squares dummy variable (LSDV) in dynamic panel-data models with a small N and strictly exogenous covariates; in parenthesis t-statistics are reported; * significant at 10%; ** significant at 5%; *** significant at 1%.*

6. CONCLUSIONS

The economic literature on environmental pollution, adopting an end-of-pipe approach, has focused mainly on damage measures regarding water and air pollution and land waste. In our analysis, instead, we assume a more result-oriented approach, putting much more emphasis on preventive and integrated models. We investigate the negative effect of production and consumption process on the environment through the analysis of the rate of extraction and depletion of renewable and non-renewable resource stocks, measured by DMC and considered as a good proxy for potential environmental pressure. The underlined assumption is that sooner or later material flows required can represent an environmental burden.

Even if our empirical model is based on the comparison of *linear* and—*unadjusted EKC-like* hypothesis, the results should highlight important issues that merit further investigations. However, as first result, we do not confirm the existence of an inverted U–shaped relationship between per capita income and per capita resource use indicator. These outcomes are confirmed in all estimations (EU-27, EU-30 and western and eastern European countries). The high level of turning points could imply the need of a government intervention in each European country to reduce the environmental pressure by human activities.

A limit of this empirical result, though, is related to the model we have tested. A further development of this work could be to consider an *adjusted EKC-like* relationship in which other variables are considered as control variables. To overcome some methodological limitations, we performed some sensitivity analyses. All the results confirm the previous estimations.

A brief and straightforward conclusion is that European countries have to both encourage more sustainable use of resources and integrate the work of national agencies in managing the environmental burden of human activity. Until now it is impossible to widen our conclusions because of the limits of our analysis. So far, the main important result has been the in-existence of a EKC path for this indicator of potential environmental degradation. However, we have to underline that this result, even if strong and significant, needs more detailed investigations.

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