Environmental Kuznets curve and domestic material consumption indicator: an European analysis

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Environmental Kuznets Curve and Domestic Material Consumption Indicator: an European Analysis

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Abstract

In our paper, we investigate the relation between per capita Domestic Material Consumption indicator (DMC) assumed as a potential environmental degradation indicator and per capita income. DMC is a physical measure developed by official statistics in recent years and derived from a Satellite Accounts System to evaluate the material dimension of human development and the environmental consequences of economic growth. While the literature has focused its attention on pollution and its measures, we consider as environmental degradation the impact of production and consumption on natural resources extracted from the global environment for the functioning of social-economic systems. In particular, we want to estimate if there exists a relationship similar to the Environmental Kuznets Curve (EKC) between per capita DMC Indicator and per capita GDP controlling for final Consumption expenditure, Openness index trade and national Research and Development expenditure by using a cross–European panel of countries over the period 2000-2010. Our results support the EKC hypothesis. However, the value of income at the turning point is high and probably there is a delink between DMC indicator and GDP as in the case of CO2 emissions and income literature.

JEL classification: Q53; Q56

Keywords: Natural Resource Use, Environmental degradation, Environmental Kuznets Curve, Domestic Material Consumption Indicator, Economy-wide Material Flows Accounts (Environmental Satellite Accounting), GDP, cross-European panel of countries.

1. Introduction

The increasing awareness about global warming, air pollution and other environmental disasters is becoming the main issue for both people and policy makers in these recent years. In fact, 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 environment, in particular natural resources, is fundamental for the prosperity and the growth of a nation. Economic growth, environmental quality and sustainable development can be pursued by managing well and using efficiently natural resources and materials.

Human activity implies the use, the consumption and the depletion of renewable and non-renewable resources. The effects of production and consumption activities on the environment could be divided into: i) *economic effects* such as increasing costs of natural resources management, issues of growth sustainability and efficiency on natural resources use; ii) *social effects*, as a consequence of the exploitation of natural resources, such as human health and equal possibility of access to public goods; and iii) *environmental effects* such as landscape changes and degradations, ecosystem threats and damages and climate change. However, the negative effect of production process on the environment can be analysed by the rate of extraction and depletion of renewable and non-renewable resource stocks, as well as by the associated environmental burden such as pollution, waste and so on (OECD 2004, 2008a).

Due to the importance of this issue, many countries have started to manage in an efficient way natural resources following sustainable development strategies or environmental plans. They have launched initiatives to promote waste prevention, sustainable material management, integrated product policies, 3R (Reduce, Re-use, Recycle) related policies, and circular economy approaches.

The economic literature has focused its attention on the understanding and the prediction of the evolution of environmental quality over time. Until now economic studies have analysed individual media (air, water, land) and pollution sources, adopting an end-of-pipe approach, while only recently environmental policy gradually evolved towards a more result-oriented approach, with greater emphasis on preventive and integrated approaches, increasing the use of cleaner technologies and the mixing of policy instruments.

The Environmental Kuznets Curve (EKC)'s analysis is the most important empirical result of the end-of-pipe approach. In other words, the EKC hypothesis, based on the relationship between per capita environmental degradation and per capita income, exhibits an inverted-U shaped curve.

The EKC relationship is based on a rather intuitive assumption. In early stages of industrialization, pollution grows rapidly because people are more interested in income and welfare than environment. In the later stage, however, when income rises and reaches a turning point, people are more keen on having a clean environment and thus they pretend stringent regulations and standards which reduce pollution. On the basis of this hypothesis, economic growth could be compatible with environmental improvements.

Since the early 1990s, several studies have tried to demonstrate the existence of the EKC hypothesis and many of them have supported the inverted-U shaped relationship while others have criticised both findings and assumptions. Several authors have underlined constraints to the statistical relationship (Stern *et al*., 1996 and Stern, 1996). Arrow *et al*. (1995) have emphasized the finding that EKCs for global pollutants with long-term costs and perhaps for some resource stocks have tended to be monotonically increasing. In particular, some authors have criticised reduced-form models when is applied for empirical analyses of the EKC.

Cole *et al*. (2001) 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. Moreover, the assumption of this reduced–form is a specific and fully parametric function. In this way they try to capture the potential non–linearity of pollution–GDP relationship. This rigidity, criticised by Grossman and Krueger (1995), Selden and Song (1994), Grossman (1994), Stern et al. (1996) and Harbaugh et al. (2002), can affect the type and the level of turning points in the empirical EKC. For this reason, estimates of the range of per capita income in which pollution indicators are expected to descend are often significantly different.

Having in mind all these critiques, our paper is close in spirit to the seminal works of Grossman and Krueger (1991, 1993 and 1995) on the EKC analysis. Differently from these papers, we adopt an environmental degradation indicator derived from official statistics of the Economy-wide Material Flow Accounting (EW-MFA) within Satellite Accounts System (EUROSTAT, 2001, 2002). This approach can: i) provide an integrated view of the material used in the production of an economy; ii) capture flows which do not enter the economy as transactions, but are relevant from an environmental point of view; iii) understand better how flows of material shift within and among countries and regions and how this can affect the global environment. This type of analysis can give an impulse in understanding the "*driving forces*" behind environmental burden. Greater insight will then help decision makers to prevent environmental issues, reduce inefficiencies in the use of materials, and improve resource productivity (OECD, 2008b).

Within the MFA and among official statistics Consumption Indicators, we have focused our attention on Domestic Material Consumption (DMC) which accounts materials required by economic systems. In particular, DMC indicator measures the total amount of material flows directly used in production and consumption processes of an economic system. For this reason this indicator can be considered as a proxy for potential environmental pressure. The assumption is that sooner or later material flows required can represent an environmental burden such as waste, emissions or scarcity of natural resources. Moreover, DMC as sustainability indicator is used both in the context of the European Union Sustainable Development Strategy (EU-SDS) and the EUROPE2020 Strategy in order to monitor resource productivity. Having in mind methodological aspects, we are aware of the limits of the DMCa highly aggregated indicator that can hide important variations within its constituent variables.

In particular, our study uses a panel data of European countries with the aim of estimating the relationship between per capita DMC Indicator and per capita GDP - controlling for Openness trade index, Research and Development expenditure and final Consumption expenditure - in a adjusted EKC model with fixed country effects. In EKC literature several authors such as 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. In particular, in Suri and Chapman (1998)' study, it has been analysed the positive relationship between per capita consumption of pollution-intensive goods with income per capita.

Environmental degradation can be affected by consumers' behaviour in a direct and indirect way. The demand of goods and services is the first impulse to produce, sell and trade them across borders (Rothman, 1998). In other words, national consumption can negatively influence the environment mainly due to production activities undertaken domestically and abroad. The production and consumption processes have several effects: natural renewable and non-renewable resources depletion, waste and emissions production and air and water pollution.

For these reasons, using a sustainability indicator as DMC, our paper intends 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, as potential environmental degradation, and the level of per capita income, our purpose is to delineate some stylized facts based on time series and cross-country comparison.

Hence, even if our empirical model is very simple as the seminal works of the EKC literature, the results should highlight important issues that merit further investigations. A first consequence of our analysis is to estimate the inverse of domestic material productivity[1]. Besides capital and labour productivity, total factor productivity can be influenced by natural material resources used. In fact the decoupling of resource use from economic growth can be useful to analyse efficiency levels of each country about natural resource management.

Our empirical results show that there exist an inverted–U shaped relationship between per capita DMC indicator and per capita GDP within the EU–27 countries and the EU–30 countries enlarged to consider three important and neighbouring countries such as Norway, Switzerland and Turkey. However in all the estimations, the value of income at the turning point is high and there could be a delink between per capita DMC indicator and per capita GDP as in the case of per capita CO2 emissions and per capita GDP (Holtz-Eakin and Selden, 1995, Roberts and Grimes, 1997, Cole et al., 1997, and Abdullah and Ansuategi, 2011).

The remaining of the paper is organized as follows. The second section provides the background literature of the relationship of environmental degradation and income. In the third section, we review Physical Measures of Environmental Impact developed in recent years by official statistics adopting a Satellite Accounts System in particular focusing on the Economy-wide Material Flows Accounting. The fourth section underlines some stylised facts about the DMC indicator in order to better understand its components and trend for EU-27 Member States and NO-EU countries in the period 2000-2010. In the fifth section we focus on the European Sustainable Development Strategy and some indicators used as tools for policies. In the sixth section we describe the empirical model used to estimate the relationship between per capita DMC and per capita GDP to verify the existence of an adjusted EKC-like curve by considering in the model some control variables: Openness trade index, total Research and Development (business and government) expenditure and final Consumption expenditure for EU-27 Member States and EU-30 countries, by including three NO-EU countries (Norway, Switzerland and Turkey). The seventh section illustrates and comments the main econometric findings, and finally, in the last section, we conclude.

[1] Domestic material productivity represents the amount of materials used to generate one unit of gross domestic product (GDP/DMC).

2. Literature Review

The relationship between economic growth and environmental degradation measured by several pollutants has been analysed by several authors (Panayotou, 1993 and 2000; Grossman and Krueger, 1991 and 1995; Selden and Song, 1994 and 1995; Lopez, 1994; Holtz-Eakin and Selden 1992 and 1995; Shafik and Bandyopadhyay, 1992; Hettige, Lucas and Wheeler, 1992, Koop, 1998; Copeland and Taylor, 2004). In their empirical studies, they have found some evidence that the level of environmental degradation and of per capita income follows an inverted-U-shaped pattern as the relationship between per capita income and income inequality described by Simon Kuznets (1955). This means that as per capita income increases, pollution also increases at first but then, after a turning point, starts declining.

In the seminal works of Grossman and Krueger (1991), Shafik and Bandyopadhyay (1992) and Panayotou (1993), the authors have reached the same conclusion. Using a cross-country analysis, it appeared that the connection between some per capita pollution indicators and per capita income can be described by an inverted-U shaped curve.

Several are the explanations for the existence of an EKC curve[2]. The most common explanation for the EKC curve is that people, with sufficiently high per capita income, give more value to the environment and natural amenities (Pezzey, 1992; Selden and Song, 1994; and Baldwin, 1995). Another important explanation is the composition effect based on the change of production structure. At the beginning of the industrialization process when the economy changes its structure from agriculture to industrial system the environmental pollution starts increasing, while the changing of the production structure from energy intensive industry to services and knowledge-based technology intensive sector has reduced the environmental burden since pollution starts falling (Grossman and Krueger, 1993).

As underlined by Brock and Taylor (2011), economic growth theory and the EKC findings 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. On the contrary, income growth can have positive effects on the environment through the composition effect.

[2] See e.g., Borghesi (1999 and 2001), Panayotou (2000), Dinda (2004), Yandle et al. (2004), He (2007) or Kijima et al. (2010), for a more detailed and comprehensive analysis of the EKC literature.

In these recent years, several authors have developed complex indicators to estimate the relationship between environmental impact or resources requirement and economic activity. A group of researchers, using the national current accounting system, has elaborated new indicators to take into consideration the environmental aspects, such as Green GDP (Hartwick, 1990), Genuine Saving (Pearce and Atkinson, 1993) and Index of Sustainable Economic Welfare (Daly and Cobb, 1989).

Another group of researchers, instead, has developed *ex–novo* indicators as measures of the physical damage of human activities on natural environment such as Net Primary Productivity (Vitousek et al., 1986), Environmental Space (Schmidt Bleek, 1992), Material Intensity per Unit Service (Schmidt Bleek, 1993), Ecological Footprint methodology (Wackernagel and Rees, 1996) and finally Total Material Requirement (Bringezu, 2001). TMR is an official statistics' indicator and belongs to a family of sustainability indicators based on a holistic approach: Domestic Material Consumption is included. These physical measures of environmental impact have been the basis for calculating the *Material Footprint* of a country (Femia, Marra Campanale and Vignani 2011). The physical indicators have been developed by international official statistics and derived from a Satellite Accounts System coherent with the core of National Accounts (Eurostat 2001 and OECD 2004). TMR and DMC related to GDP have been widely used by literature in the decoupling and resource productivity analysis. A rise in GDP per capita growth is considered positive for socioeconomic development, because of positive effects on economy and social life, but also means a more intensive exploitation of resources. In the long run an increase in resource productivity is necessary to avoid detrimental influence on climate change, on availability of energy and other resources renewable and non-renewable, on Nature and on biodiversity. Hence, sustainable development relies on promoting the decoupling of economic growth from environmental degradation, through natural resource efficiency use, "green" technologies and changes in production and consumption patterns. Decoupling occurs when the growth rate of an environmental pressure is less than GDP growth rate over a given period. 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.

In the next section, we will focus on Domestic Material Consumption Indicator. Through this measure of potential environmental degradation (DMC), we want to estimate if there exists a relationship similar to the Environmental Kuznets Curve (EKC) between DMC and GDP using a cross–European panel of countries.

3. Physical Measures of Environmental Impact: focusing on Domestic Material Consumption Indicator (DMC)

In the last fifteen years official statistics have developed some indicators considered highly significant as physical measures of potential environmental impact. Our analysis is based on one of them namely Domestic Material Consumption (DMC) base for the construction of Total Material Requirement (TMR) indicator that nowadays have gained in importance for international and national official statistics of European countries (EUROSTAT 2001). We first give a brief description of the TMR clarifying the statistical meaning of this indicator derived by the Economy-wide Material Flow Accounting (EW-MFA). Our analysis should have been based on TMR indicator for verifying the existence of an EKC curve for European countries but it has been impossible due to the lack of statistical data time series at European level over the period 2000-2010. For this reason, we decide to focus on DMC indicator because is available for a large number of countries and years.

National official statistics have gradually provided more complete information on physical flows, required for the functioning of social-economic systems. In this way, statisticians have found new indicators to better understand and measure environmental consequences of economic growth and to satisfy a growing demand for statistical information. In the past, the lack of environmental data has reduced the opportunity for studies on some specific issues related to the environment-economy interaction. In recent years national and international official statistic organizations have made a great effort in issuing data to evaluate and to analyse ecological and growth sustainability.

Consistently with this approach, a Satellite Accounting System has been constructed and adopted in the last decade and raised to the dignity of official statistics. Within this System, Material Flow Accounts (MFA) is a system of accounts specifically dedicated to measure raw resources extracted by Nature and given back to the natural environment in forms, times and palces other than those of origin. All items present in the accounts are expressed in units of weight. The accounts system described is one of the main blocks of New Handbook of Integrated Environmental and Economic Accounts SEEA (System of Environmental-Economic Accounts), that will be soon adopted as International Standard of official statistics (UNITED NATIONS, 1993, 2001). Within Material Flow Accounts (MFA), Economy-wide Material Flow Accounting (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 EU Regulation n. 691/2011. The OECD issued a 3-volumes Manual and two Council Recommendations on the matter (OECD 2004). Italy[3] has very actively contributed and contributes to these international developments through Istat, which achieved important results in the field because of an early experience. Istat[4] has started to develop EW-MFA since 2000 (Femia and Vignani 2005a, 2005b, 2006a, 2006b).

EW-MFA is the methodology for the construction of this system of accounts dedicated to natural resources and its derived indicators based on an holistic approach. This system gives synthetic information on physical exchanges of an economy and offers an overall view of the phenomena of potential environmental pressures. In this optics, the anthropic system is looked at as a living organism (composed by buildings, railways, human bodies, etc.) whose activities need flows of untouched materials extracted or harvested from natural environment (Inputs). Then they are processed in many ways (refined, mixed, burned and so on) through manufacture, use, reuse and recycling and finally accumulated in stocks or returned back to natural environment in an altered shape (Outputs). All these interactions between "*anthroposphere*" and natural environment are of a physical kind (Adriaanse et al, 1997). Measuring inputs to socio-economic functioning gives an indication of all potential "*pressures*" to natural environment. In other words, whenever a physical flow is caused by human activities a pressure on natural environment occurs. Statistical information on the size of these flows is therefore very important to evaluate long term ecological sustainability. In fact, demand of natural resources by human system is limited by the finiteness of environment. To this extent, Environmental Accounting experts' work consists in the exploitation and reduction to unity and coherence of a large set of heterogeneous, fragmentary and, in some cases, unfortunately, low-quality statistical data and metadata (Costantino, Femia and Vignani, 2008, Femia and Vignani, 2003, 2007). The EW-MFA analysis can be carried out at different levels of detail, according to the set of activities and the type of materials, included in the domain of interest. Compared to other methodologies EW-MFA offers three advantages:

[3] Italy is one of the countries that has mostly supported this initiative. Importance has been given to EW-MFA as a tool for policies so that material flows-based indicators are used in the Action Plan Strategy on sustainable development for Italy approved by CIPE in 2002.

[4] In the framework of EW-MFA, Istat compiles accounts and derived indicators on yearly basis: the time series 1980-2010 are published in www.istat.continazionali. Istat estimates the quantities of materials moved by the Italian economic system by typology by integrating many data sources.

- certainty of the basis on which the aggregation is done: all the aggregates included in the accounts are given in units of weight[5], easy to compare and use
- accounting of actual phenomena, by avoiding "*what if*" evaluations
- use of the main national accounting concepts set out in SNA93 (System of National Accounts) and SEC95 (Sistema Europeo dei Conti Nazionali e Regionali): due to MFA are satellite accounts, its physical aggregates can be put in relation to the aggregates of the core of National Accounting.

As that observed in national accounts, where a logical division of the functioning of the economy in a sequence of stages is made, in EW-MFA accounts the cycle of matter is divided into a series of steps, each illustrated by an account. The system is structured to produce aggregates in waterfall and are all linked together, as to show the relationships among various measures of resources use. On the basis of these accounts a family of sustainability indicators are derived. Material-Flow-based indicators provide an aggregate picture by describing the evolution of the demand for natural resources by a socio-economic system and how the country could contribute over time to change Global morphology and terrestrial ecosystem.

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, 2001b).

TMR is obtained by adding together the following items, all expressed in units of weight:

- *Domestic Extraction of Materials Used (DEU)*

it accounts for all materials extracted from natural environment in a country, to be incorporated into products. These materials are divided into three main typologies: biomass, fossil fuels and no-energy producing minerals

- *Imports*

it accountsfor imports of raw materials, semi-manufactured and finished products

- *Domestic Extraction of Materials Unused (DEUnused)*

it accounts for all materials flows extracted from Nature intentionally but not to be used, in fact they are not incorporated in products. These materials are removed to take other useful

[5] Water and air are excluded from accounts as they are so large that they would dominate all other material flows considered. They are included into accounts and indicators only to the extent that they are embodied in products or as *memorandum items* in overall balance.

materials and to carry out human activities. They are differentiated by origin: i.e. materials from mining and quarrying activities, harvesting of biomass and excavation activities (Greca and Vignani 2005)

- *Indirect Flows Associated to Imports (IF)*

IF associated to imports consist of quantities of materials, used and unused, removed from other countries' Nature in order to produce goods imported by a country. These materials are not actually embodied in those goods, as they have been transformed in waste and emissions during the production process carried out abroad. Taking into account IF associated to imports means making reference to the several phases of products' life-cycle that take place abroad. In this way it is possible to account waste and emissions generated abroad to produce goods and services to satisfy the final demand of a country.

Including the last two aggregates (DEUnused and IF), which account materials not actually embodied in products but removed nationally and abroad to satisfy the *domestic final demand* of a country, TMR is considered as a comprehensive measure. It indicates the total amount of natural resources, used and unused, that had to be taken from natural environment – in terms of Global Nature – to food, directly or indirectly, the functioning of a socio-economic system. According to National Accounts in monetary terms, *total available resources* of a country - given by GDP plus Imports - is the monetary aggregate that better corresponds to TMR. Therefore, the comparison between TMR and this monetary aggregate allows to evaluate the existence of *decoupling* by considering overall natural resources demand required at a global level (Femia and Vignani 2007, 2010).

As this paper intends to analyse a panel of European countries by using Environmental Kuznets Curve methodology, the lack of available data on TMR at EU level over the perido 2000-2010 forces to use another EW-MFA indicator Domestic Material Consumption (DMC) base for calculating the more relevant indicator TMR. The EU level TMR, in fact, is still under development as only a few Member States currently compiled it. The main difficulty is represented by calculating "*Indirect Flows associated to Imports*" item, that are *hidden flows* related to imports of raw materials, finished and semi-manufactured products.

DMC indicator 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 plus all physical imports minus all physical exports.

The DMC indicator is composed by two aggregates:

- *Domestic Extraction of Materials Used (DEU)*
- *Physical Trade Balance* (PTB) equal to imports less exports

This consumption-based indicator is relevant not only because it refers to the domestic use of natural resources but also because it provides an assessment of the absolute level of them allowing to distinguish between consumption driven by domestic demand and consumption driven by the export market. In environmental terms, 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, 2001a, 2001b). As accumulated materials (i.e. physical stocks) will eventually turn into emissions and wastes, the value of DMC also indicates the potential waste of a given country (Moll, Bringezu and Schütz 2003). *Resources of domestic uses* - GDP plus imports minus exports value - is the monetary aggregate that better corresponds to DMC.

A resource efficient Europe is one flagship of the Europe2020 Strategy aiming at a shift towards a resource-efficient, low carbon economy to achieve sustainable growth. The leading indicator assigned to this policy initiative is *Resource Productivity* regularly produced by Eurostat. It is calculated by the ratio of total amount of materials directly used by EU-27 economy and the value of its economic growth measured by using respectively aggregated DMC and GDP. It provides insights into whether decoupling between the use of natural resources and economic growth is taking place in the medium and long term, thus addressing a key objective of the EU Sustainable Development Strategy and the EUROPE2020 Strategy

It is important to underline that DMC and TMR are only rough proxies for measuring the overall environmental potential impact of resource use, as materials by typology have very different impacts on the environment. Further developments to depict environmental impacts of materials use are needed.

In the last year, policy makers have given an increasing importance to information on the size and the nature of material flows due to society's metabolism. In this framework EW-MFA is perceived as a very relevant decision support tool allowing overview and analysis of trends for resource use, waste production and sustainability policy. As European policy is concerned, we will underline later on how the European Union Sustainable Development Strategy (EU-SDS) based on an EU set of sustainable development indicators, uses also DMC to guide the Community policies.

In Europe EW-MFA is strongly promoted by Eurostat with the support of an *ad hoc* task force (including Italy with Istat) that in 2000 has prepared a Methodological Guide to harmonize concepts and definitions that is the main reference for compilers along with the United Nations Handbook of National Accounting Integrated Environmental and Economic Accounting 2003. In the last years also OECD has started a program for the promotion of MFA applications world-wide and the issuing of coherent and comparable accounts and indicators.

4. The European Union Sustainable Development Strategy (EU-SDS): targets and indicators.

Sustainable development is a fundamental goal of European Union and aims at improving continuously the quality of life and well-being for present and future generations, by linking economic development, protection of environment and social justice. The EU Sustainable Development Strategy (EU-SDS), launched by the European Council in Gothenburg in 2001 and renewed in June 2006, represents a single coherent strategy that defines both objectives and targets to put the EU on a *path of sustainable development*. It emphasizes how the EU will actually achieve important goals by managing and using resources efficiently, ensuring prosperity, environmental protection and social cohesion. Measuring progress towards sustainable development is an integral part of the EU-SDS and it is based on a EU set of Sustainable Development Indicators (EU-SDIs). The indicators may highlight whether the EU is moving in the right direction towards objectives and targets set out in the strategy (EUROSTAT, 2005, 2007, 2009). They are more than one hundred and have been organised within a theme-oriented framework depicting social, economic and environmental dimensions. The indicators give a clear and easily communicable statistical picture for the EU-27 countries. Eleven of them have been defined as "*headline indicators*" monitoring the overall objectives related to the key challenges of the EU-SDS (Table 1).

TABLE 1: EU- SDS: Sustainable Development Theme and related Headline Indicators

SDI Theme	Headline Indicator
Socioeconomic development	Growth of GDP per capita
Climate change and energy	Greenhouse gas emissions Consumption of renewable
Sustainable transport	Energy consumption of transport relative to GDP

Sustainable consumption and production	**Resource productivity**
Natural resources	Abundance of common birds Conservation of fish stocks
Public health	Healthy life years
Social inclusion	Risk of poverty
Demographic changes	Employment rate of older workers
Global partnership	Official development assistance
Good governance	*[No headline indicator]*

Source: EUROSTAT

They are widely used indicators with a high communicative and educational value. They are robust and available for most EU Member States, generally for a period of at least five years. The statistics covered illustrate the range of issues relevant for sustainable development, and will contribute to raising awareness of opportunities and challenges lying ahead. Impartial and objective statistical information is crucial for all decision making and provides transparency and openness. Official statistics play a fundamental role in today's society and are essential for development implementation, monitoring and evaluation of European Policy. For this reason Eurostat and all National Statistical Institutes have a leading role to play in providing data and monitoring to what extent the EU is on track to achieve the concrete goals for a sustainable development set out in the strategy.

The EU-SDS looks also at the "*sustainability of consumption and production*" and at the sub-theme *"resource use and waste"*. The headline indicator for this area of intervention is Resource Productivity and is meant to measure efficiency in the use of natural resources in an economic system. It is calculated dividing GDP by Domestic Material Consumption indicator at EU-27 level. DMC has been chosen as significant indicator to estimate *"resource use and waste"* as a consumption-based physical measure of potential environmental impact. As DMC is obtained with relative ease of calculation through basic statistics, it is calculated by a broad set of countries for the period 2000-2007.

All these considerations strengthen the reasons for our selection of DMC as relevant indicator for the purpose of our analysis. In our opinion is an appropriate measure to analyse the relationship between environment and economic activities by using the Environmental Kuznets Curve methodology, as mentioned before.

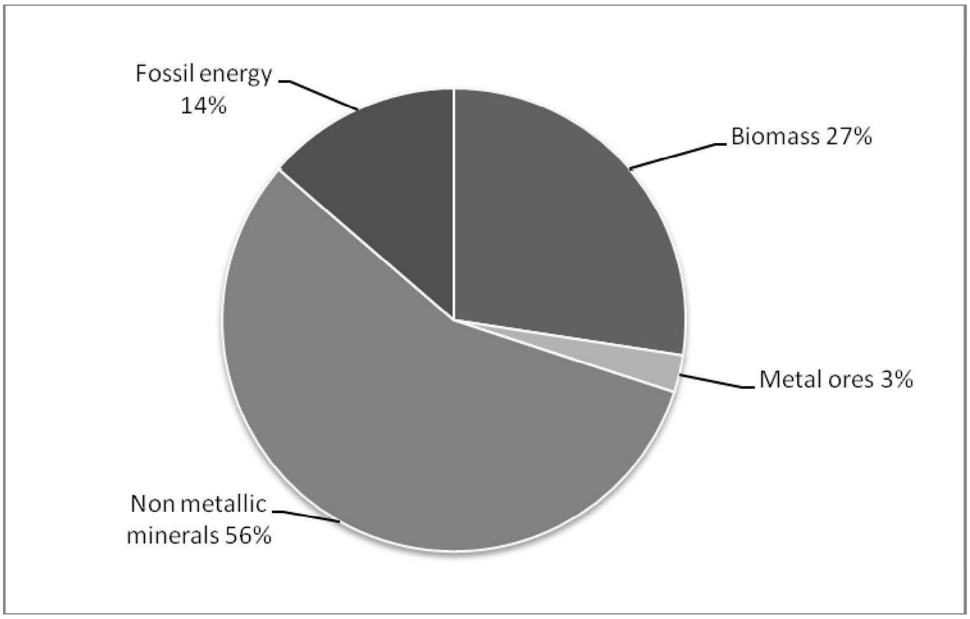
Conventional pollutants, such as carbon dioxide, are generally used in Kuznets curve type analysis by representing different negative externalities. Because of its meaning also DMC can indicate “negative externalities” determined by natural resource consumption. It can generate environmental impacts as an alteration of the original *status* of Nature and not only as a by-product effect like pollution. This type of indicator help to underline aspects of the change of the environment in which man lives due to production-consumption activities, aspects certainly related to the threats of environmental equilibrium: geological instability, desertification, loss of biodiversity and climate changes.

5. 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, its trend and its relationship with national production.

Starting from the composition analysis of Domestic Extraction Used (DEU) for EU-27 member states in the last available year 2010, Figure 1 shows total amount of materials directly used by the EU–27 countries distinguishing by the typology of natural resources. EU-27 countries’ DEU on the whole is equal to 5.937 million of tones in 2010. 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, which use much of the sand, gravel and other non-metallic minerals, can be easily seen. Biomasses harvested represent about the 27% of total (1.626 million of tonnes) while fossil energy materials (14%) and metal ores extracted (3%) are respectively almost 812 million of tonnes and 155 million of tonnes.

Figure 1: Domestic Extraction Used (DEU) by materials, EU–27, year 2010 (percentage values)

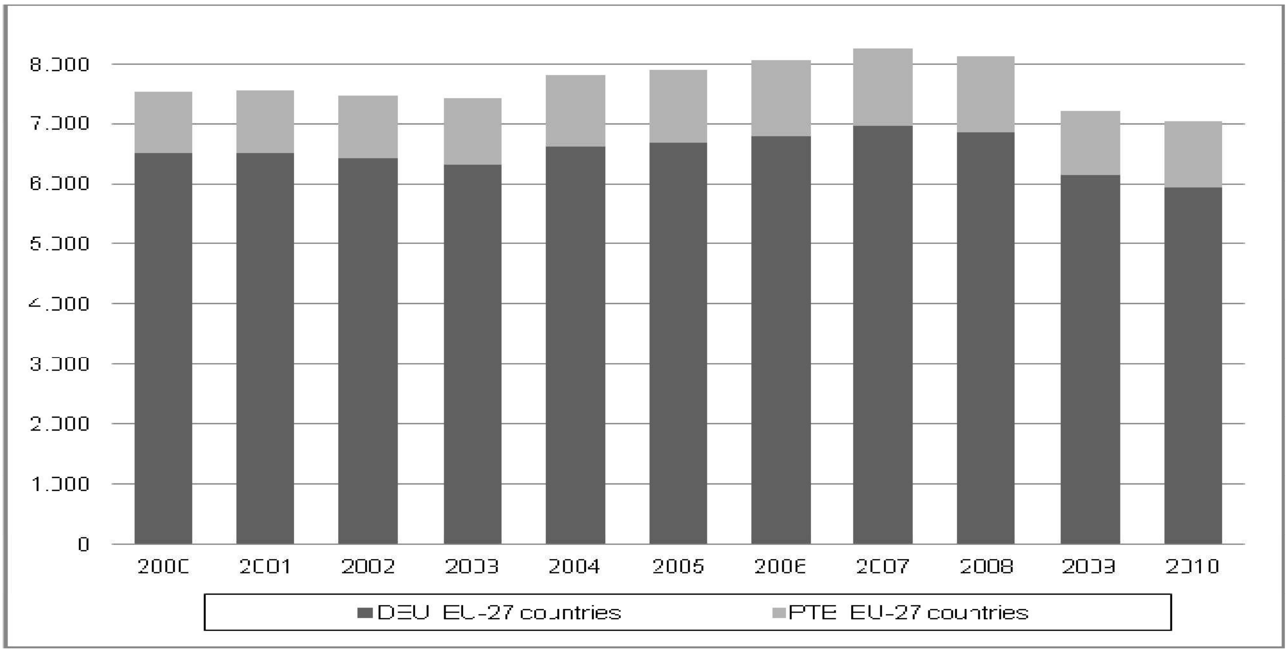


Source: EUROSTAT

As describe above, DMC is composed of two aggregates: D*omestic Extraction Used (DEU)* plus *Physical Trade Balance (PTB)* equal to imports less exports.

Analyzing the available data for EU-27 countries, 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 (Figure 2). The following charts suggest that a structural break should have taken place between 2008 and 2009 due to the financial and real crisis that is still active nowadays. This suggestion will be verified in the following econometric analysis of this paper. In fact, the sizeable decreasing of DMC and its components from 2008 onwards is a clear consequence of the persistent global economic crisis that reducing production and consumption activities has had a positive result on domestic demand of natural resources (both raw and processed) for the EU countries considered. Times series show that DEU is the first component and on average accounts for the 85% of the EU–27's DMC while the second component PTB accounts for the remainder 15%. As PTB presents a positive value in overall period observed the EU–27 can be considered as a net importer of materials to allow the functioning of "economic and social metabolism" of its countries.

Figure 2: Domestic Material Consumption (DMC) by components, EU–27, years 2000-2010 (million tonnes)



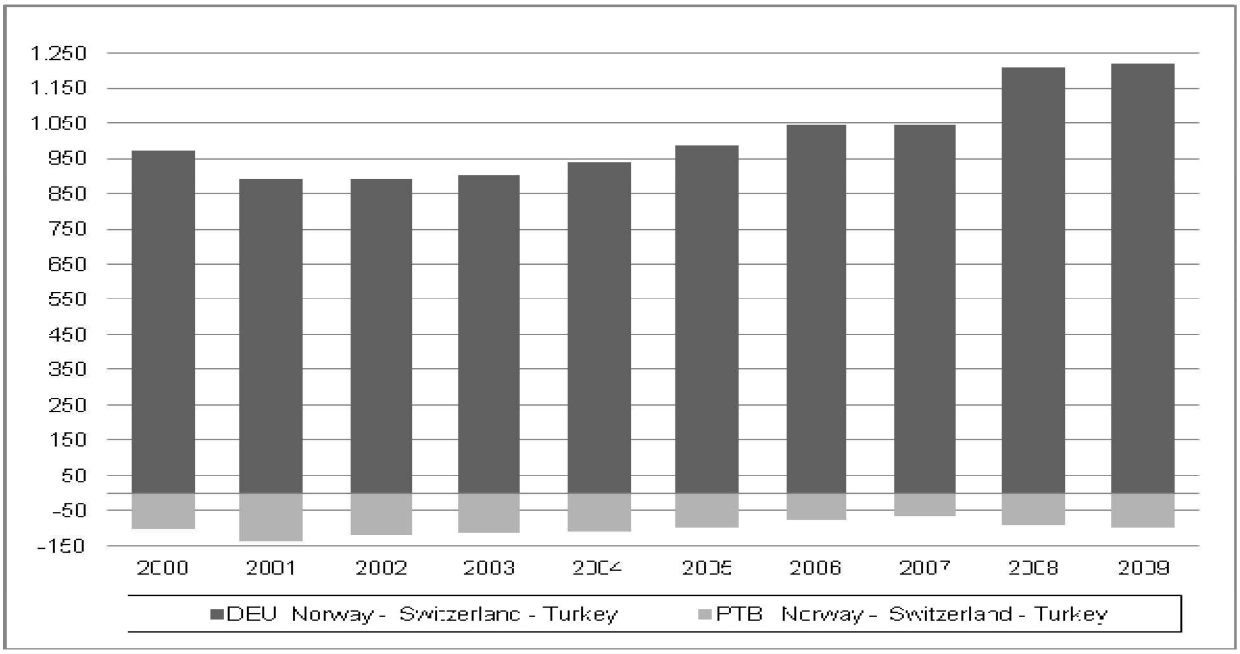
Source: data processed by EUROSTAT

Observing the trend of components, while from 2000 to 2003 DEU has decreased by 3%, then it has raised until to 2007 reaching more than 6.967 million of tonnes (+6.9% compared to 2000). In the period between 2007 and 2010 DEU has diminished by almost 14,7% strongly affected by the recessive effects of global economic crisis. As far as Physical Trade Balance is concerned, it has raised almost constantly from 2000 to 2007 of about 27%. PTB has reached the highest value of the period observed just in 2007 when foreign imports of materials have exceeded exports by 1.306 million of tonnes. Natural resources and products, needed to satisfy EU-27 countries' demand, have been replaced by foreign sources. Similarly to DEU, PTB decreases in the following period 2008-2010 placing around to 1.107 millions of tonnes. Even if DEU has shown a reduction in some countries, a decoupling between GDP growth and materials' consumption (DMC) has not taken place because EU countries have simply de-localized their pressures on foreign natural environments.

As shown below in detail, we have build our sample by drawing a panel dataset of 30 European countries: EU–27 countries and three NO–EU–27 countries such as Norway, Switzerland and Turkey. Our empirical analysis has actually been enlarged to include these further countries that in a different way are linked to the European Union and to the Commission Policy.

At the moment, these three NO-EU countries' DMC data are available in Eurostat dataset only for the period 2000-2009. Analysing the aggregate value of DMC for Norway, Switzerland and Turkey we notice immediately that the component PTB (i.e. Imports less Exports) has remained negative, meaning that these countries are net exporter of material flows with an annual average of export surplus of more than 100 million of tonnes (Figure 3).

Figure 3: Domestic Material Consumption (DMC) by components NO-EU-27 countries, years 2000-2009 (million tonnes)

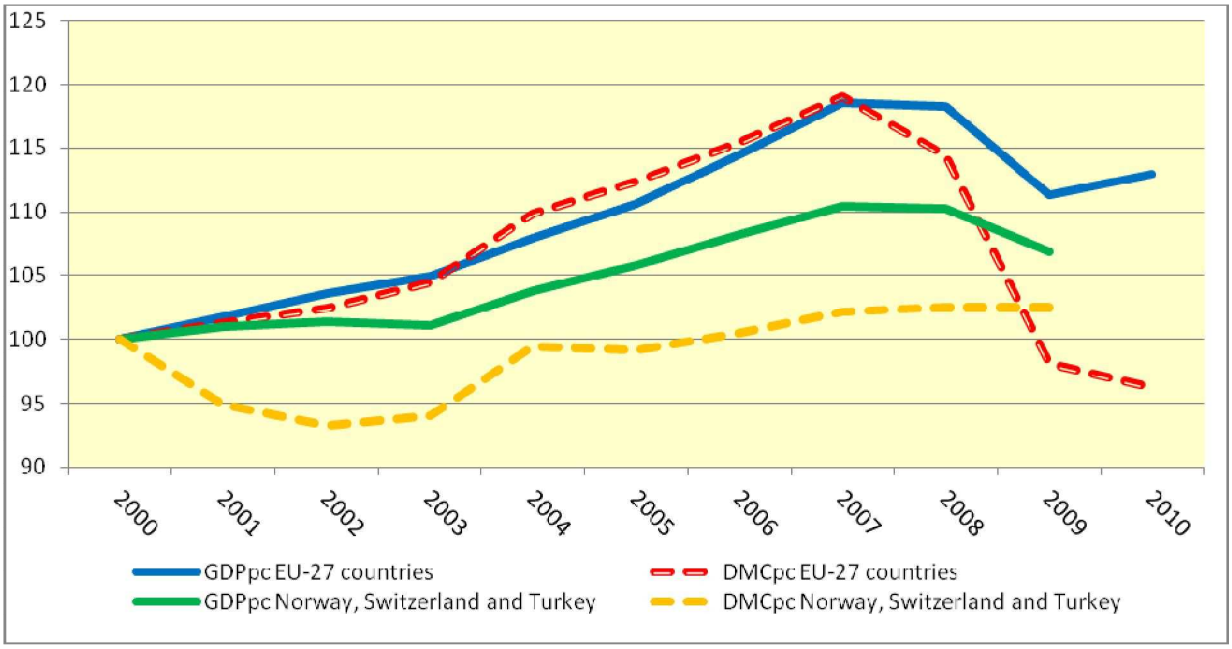


Source: data processed by EUROSTAT
Note: Eurostat dataset does not present data for Norway, Switzerland and Turkey in 2010.

The negative value of PTB component has contributed to reduce DMC in each year. However, DMC has shown a positive trend from 2000 to 2009 with an overall increase of 29%. In particular, in the last two years a DMC acceleration has occurred (+14,2%) and it has reached the highest value of the whole period considered: 1.122 million of tonnes of natural resources required by the functioning of economic systems of Norway, Switzerland and Turkey.

As far as a dynamic comparison between per capita DMC and per capita GDP of the EU-27 countries is concerned, Figure 4 shows that only from 2000 to 2003 per capita DMC seems to be relative decoupled from per capita income growth (GDPpc +5% and DMCpc 4.5%). Starting from 2003 up to 2007 GDPpc has increased more quickly than in the previous four years (+9,9%) and has been accompanied by a similar rise of DMCpc (+8,4%).

Figure 4: Per capita Domestic Material Consumption and Gross Domestic Product, years 2000-2010 (index 2000=100)



Source: data processed by EUROSTAT dataset

From 2007, the year of the economic crisis, the chart shows a structural break for the EU-27 countries in the per capita DMC series. In the following period (2007-2010) the decreasing of DMCpc and GDPpc have taken place (respectively -19% and -4,7%) a relative *decoupling* occurred. In absolute values, DMCpc, that has exceeded 20 tonnes of material flows in 2007, comes down to just over 16 tonnes in 2010 while per capita GDP changes from 17,770$ to about 16,929$[6].

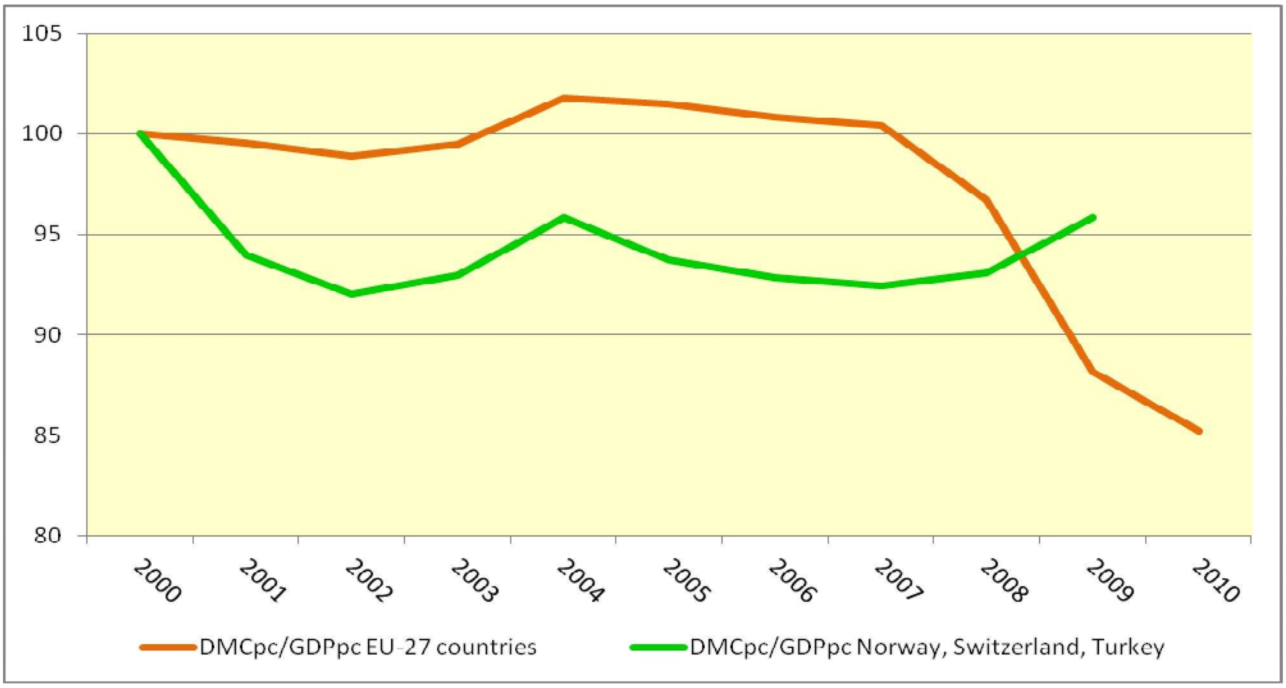
The same analysis for the three NO-EU countries has underlined a similar trend for per capita GDP. As regards DMCpc in the period 2000-2003 is evident a decoupling with respect to per capita GDP. in 3. What is interesting to highlight is that in 2001 per capita DMC has decreased (-13% over the previous year). However, starting from 2003 up to 2009 there has been a continuous increasing of DMCpc that has reached almost 20 tonnes of materials with an overall rise of 30% in the period considered.

An important measure of resource use efficiency is the Domestic Material Intensity calculated as units of resource consumed per unit of GDP. Thus, resource intensity is a measure of natural

[6] For more details on unit used see note 10

resources needed for the production, processing and disposal of a unit of good or service, or for the completion of a process or activity. It is therefore a measure of the efficiency of resource use. In other words, this indicator is the inverse of productivity indicator that is the quantity of good or service that is obtained through the expenditure of a unit of resource. This ratio (DMC/GDP) measures efficiency in natural resource use in an economic system, by pointing out the degree of resource use - measured in physical terms - on the basis of the richness produced. As resource use intensity is concerned, the NO-EU-27 countries have shown a better performance than the EU-27 countries in the period 2000-2010 (Figure 5), a good condition for a sustainable development.

Figure 5: Resource use Intensity DMC/GDP, years 2000-2010, index 2000=100



Source: data processed by EUROSTAT dataset

6. Empirical Model

In our econometric analysis, we have estimated a model called *adjusted EKC* and we have calculated the level of income at the turning point in an unbalanced panel dataset based on 30 European countries, discriminating between fixed and random effect panel estimates with proper diagnostics. Following the EKC literature[7], we have just focused and tested the existence of an inverted-U shaped relationship between economic growth and an "*environmental pressure*" indicator (DMC) controlling for Openness to international trade, Research and Development Expenditure and Final Consumption Expenditure. Our estimations have been conducted both on a cross–European panel of EU-27 countries and EU-30 including Norway, Switzerland, Turkey over the period 2000-2010. This relationship, not being monotonic, may change sign from positive to negative when a certain level of income is reached. At this turning point, socio-economic systems start to ask for more environmental quality using i.e. more efficient and "*green*" technologies. In this way, negative externalities (such as pollution, excessive exploitation of natural resources, environmental degradation, etc.) could be reduced to improve the quality of life of present and future generations and to pursue a sustainable development and growth.

In this study, we have analysed the impact of several variables on a particular environmental degradation measure: the Domestic Material Consumption Indicator (DMC). Our awareness about the limits of the basic econometric model based called unadjusted EKC curve - extensively criticised on econometric and theoretical grounds - has forced us to estimate a more complex and complete model as in Auci and Becchetti (2006). By using the adjusted EKC specification described in the following equation, we specify a possible relation between the per capita "*environmental pressure*" indicator DMC and some macro-economic variables. Thus, the EKC curve could be represented by a polynomial approximation in logarithmic terms:

$$\ln(DMC/Pop)_{it} = \alpha_i + \beta_1 \ln(GDP/Pop)_{it} + \beta_2 \ln(GDP/Pop)^2_{it} + \beta_3 \ln(CONS/Pop)_{it} + \beta_4 \ln(OPEN)_{it} + \beta_5 \ln(R\&D)_{it} + \varepsilon_{it} \quad (1)$$

where:

β_1 and β_2	are the parameters of levels and square of per capita GDP with $\beta_1>0$ and $\beta_2<0$;
DMC	is the Domestic Material Consumption Indicator
Pop	is the mid-year population
GDP	is gross domestic product
CONS	is the final consumption expenditure

[7] See among others Shafik and Bandyopadhyay (1992), Panayotou (1993), Grossman and Kreuger (1993) and Selden and Song (1994)

OPEN is the openness trade index defined as the ratio of total exports and imports to GDP

R&D is the total research and development expenditure (that comes from both business and government sector) expressed as percentage of GDP.

This specification is estimated using panel data, with *i* and *t* indicating, respectively, countries and years and with α_i intercept measuring country specific time invariant effects. From this specification the turning point of income at which per capita resource use is at its maximum level is easily derived as:

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

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

7. Empirical Results

We build our sample by drawing an unbalanced panel dataset of 30 European countries by the European Statistical Office (EUROSTAT) dataset for DMC indicator, GDP and all the other variables used in the analysis. Data are collected yearly from 2000 to 2010.

TABLE *2* reports the descriptive statistics of all the variables included into the estimation model. The descriptive statistics are reported not only for the whole data in the dataset but also distinguishing between EU–27 countries and NO–EU–27 countries such as Norway, Switzerland and Turkey. Our empirical analysis has been enlarged to include these further countries because of their economic and political relationship with European Union members.

As describe in Figure 4 the trends of GDP and DMC do not show a wide gap. However in Figure 5, the resource use intensity is decreasing. This could be interpreted as evidence in favour of the EKC hypothesis. Of course this simple descriptive analysis is not sufficient to understand the phenomenon and could be quite misleading as several factors besides GDPpc may affect DMCpc.

For example, Research and Development could lead to technological improvements and Consumption per capita or International Trade may have effects on per capita Domestic Material Consumption.

TABLE 2: Descriptive statistics of estimation variables (year 2000–2010)

	VARIABLE	MEAN	SE(MEAN)	CV	P25	P50	P75	N	IQR
OVER ALL	**DMCpc**	18.3	0.465	0.459	12.9	16.4	21.6	327	8.71
	GDPpc	19459	752	0.702	6351	16290	28764	330	22413
	EXPpc	12515	946	1.37	3805	7623	16577	330	12772
	IMPpc	11621	807	1.26	4815	7944	13707	330	8892
	CONSpc	14258	489	0.624	4847	13796	20663	330	15816
	OPEN	1.18	0.0324	0.501	0.736	1.02	1.53	330	0.798
	R&D	1.4	0.0373	0.601	0.64	1.25	1.93	508	1.29
EU27	**DMCpc**	18.34	0.47	0.44	13.564	16.685	21.554	297	7.9893
	GDPpc	18342	737.69	0.69313	6421.4	15839	27458	297	21036
	EXPpc	12413	1037	1.4396	3883.1	7418.5	14168	297	10285
	IMPpc	11694	885.69	1.3052	4887.8	7617.7	12193	297	7304.7
	CONSpc	13567	478.27	0.60755	4889.7	13173	19994	297	15105
	OPEN	1.2263	0.034605	0.48632	0.77283	1.0939	1.5794	297	0.8066
	R&D	1.417	0.039108	0.59645	0.67	1.25	1.95	467	1.28
NO EU27	**DMCpc**	18	2.1	0.64	10.2	12	35	30	25
	GDPpc	29516	3058.10	0.60	5995.10	39824.00	42259.00	33	36264.00
	EXPpc	13,424	1,561.9	0.67	1,309.3	17,894	19,430	33	18,121
	IMPpc	10960	1254.5	0.6575	1627.3	14315	16493	33	14866
	CONSpc	20482	2059.7	0.57768	4709.6	27969	28917	33	24207
	OPEN	0.72096	0.035049	0.27927	0.48893	0.76541	0.85682	33	0.36789
	R&D	1.192	0.11935	0.64116	0.49	0.85	1.66	41	1.17

Notes: the NO–EU27 are: Norway, Switzerland and Turkey; CV is coefficient of variation (sd/mean); IQR is interquartile range = p75 - p25. Variable legend: DMCpc: per capita Domestic Material Consumption (unit of tonnes); GDPpc: per capita Gross Domestic Product (unit of euro); EXPSpc: per capita Exports (unit of euro); IMPpc: per capita Imports (unit of euro); CONSpc: per capita Final Consumption expenditure (unit of euro); OPEN: openness trade index defined as the ratio of exports plus imports to GDP (unit of euro); total R&D expenditure business and government (percentage of GDP).

Indeed, technological improvements are usually considered as environmental friendly factors of economic growth and international trade is a mechanism through which richer countries relocate pollution-intensive products to developing countries. Hettige et al. (1992) observe that there is some evidence of "*industrial displacement effect*" on the dirtier industries, as a result of tightening of environmental regulations in the industrialized nations since 1970.

We estimate our adjusted EKC model choosing fixed effects panel estimation since it is the best econometric methodology to use. The Hausman tests (reported in Table 3 and Table 4) confirm 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. With the fixed effects model we control for country specific constant terms which may account for the portion of the dependent variable heterogeneity not explained by the considered regressors.

The results of our estimation model confirm the EKC literature (Table 3 and Table 4).

Table 3: Fixed effect estimates of adjusted EKC specifications (EU-27 countries)

Dependent Variable: Ln DMCpc	**EU-27**			
	model 1	**model 2**	**model 3**	**model 4**
GDPpc	3.03***	3.10***	1.83*	1.76*
	(3.16)	(3.25)	(1.75)	(1.74)
GDPpc^2	-0.15***	-0.14***	-0.08	-0.08*
	(-3.05)	(-2.91)	(-1.60)	(-1.68)
CONSpc	0.31	0.28	0.68**	0.79***
	(1.18)	(1.07)	(2.35)	(2.69)
OPEN		-0.23**	-0.24**	-0.25**
		(-2.32)	(-2.36)	(-2.45)
2-year lagged R&D			-0.19***	
			(-3.42)	
1-year lagged R&D				-0.20***
				(-3.59)
Constant	-15.56***	-16.59***	-13.21***	-13.53***
	(-4.34)	(-4.63)	(-3.46)	(-3.70)
R-sq Within	0.38	0.40	0.43	0.44
R-sq Between	0.06	0.07	0.06	0.05
R-sq Overall	0.06	0.07	0.06	0.05
F test °	55.64	43.75	38.48	40.21
F test (u_i =0)°°	125.47	120.96	106.10	113.44
Hausman χ^2 °°°	24.85	36.22	40.07	42.74
Number of obs	287	297	282	285
Turning point	31,289.77	70,182.00	57,384.82	36,881.28

*Notes: in parenthesis absolute value of t-statistics are reported; F test ° H0: joint significance of the regressors; F test °° H0. joint significance of the fixed effects. Hausman χ2 test °°° H0: random effects may be used alternatively to fixed effects; * significant at 10%; ** significant at 5%; *** significant at 1%. Variable legend: see Table 2.*

In particular, Table 3 contains the estimation results when we consider only EU-27 countries - that are more homogeneous among them - while Table 4 shows the estimation results when we consider all EU-30 countries. It seems that there exists an inverted–U shape between GDPpc and DMCpc indicator when we control for the variables described above. The coefficients' values of EKC-like specification are significant, meaning that there is an increasing pressure on the environment in terms of natural resources required when GDPpc raises. It is plainly noted that coefficients of per capita income and square per capita income are significant and the corresponding signs are correct in all estimations of the adjusted EKC specifications. As in several studies such as Cole et al. (1997), Agras and Chapman (1999), Galeotti and Lanza (1999), Heil and Selden (2001), Cole (2004) and Galeotti et al. (2006) we confirm the existence of an inverted–U shaped relationship but with quite high turning points, indicating a functional delinking of per capita DMC growth from economic growth.

Observing the robustness results, the turning points assume different values according to the model considered (from model 1 to model 4 for EU-27 and EU-30). However, in EU-27's analysis, turning points tend to be close to a reachable value when we introduce all control variables including 1-year lagged R&D variable. As far as the EU-30 countries are considered, even if the same analysis can be shown, the turning points' levels are systematically higher than the EU-27's values in each models estimated.

Table 4: Fixed effect estimates of adjusted EKC specifications (EU-30 countries)

Dependent Variable: Ln DMCpc	**EU-30**			
	model 1	**model 2**	**model 3**	**model 4**
GDPpc	3.10***	3.16***	2.13**	2.23**
	(3.52)	(3.63)	(2.17)	(2.39)
GDPpc^2	-0.15***	-0.14***	-0.09*	-0.10**
	(-3.35)	(-3.18)	(-1.92)	(-2.18)
CONSpc	0.30	0.26	0.60**	0.65**
	(1.23)	(1.07)	(2.21)	(2.40)
OPEN		-0.25**	-0.26***	-0.27***
		(-2.57)	(-2.63)	(-2.77)
2-year lagged R&D			-0.17***	
			(-3.22)	
1-year lagged R&D				-0.16***
				(-3.15)
Constant	-15.87***	-16.92***	-14.27***	-15.04***
	(-4.79)	(-5.11)	(-3.94)	(-4.35)
R-sq Within	0.40	0.41	0.45	0.45
R-sq Between	0.09	0.09	0.08	0.08
R-sq Overall	0.09	0.09	0.08	0.08
F test °	64.93	51.28	42.95	44.37
F test (u_i =0)°°	141.36	143.02	113.91	121.33
Hausman χ^2 °°°	24.91	32.21	34.36	36.89
Number of obs	327	327	302	306
Turning point	33,558.51	81,532.846	73,853.413	54,296.296

*Notes: besides EU27, the estimation includes three important countries for Europe: Norway, Switzerland and Turkey; in parenthesis absolute value of t-statistics are reported; F test ° H0: joint significance of the regressors; F test °° H0. joint significance of the fixed effects. Hausman χ2 test °°° H0: random effects may be used alternatively to fixed effects; * significant at 10%; ** significant at 5%; *** significant at 1%. Variable legend: see Table 2.*

Deepening the influence of control variables on DMC, the per capita Consumption coefficient shows a positive sign as an increasing consumption implies a raising in per capita Domestic Material Consumption because social economic systems grow requiring increasing material quantities from the environment for production and consumption activities.

The sign of the coefficient of Openness trade index is negative and significant in all estimation results. The negative relationship between DMCpc and Openness suggests that if the openness to international trade grows, per capita Domestic Material Consumption reduces. International trade has been a mechanism through which richer European countries relocate raw material-intensive products to developing countries. The *industrial displacement effect* on dirtier industries is often a result of tightening of environmental standards as set by EU's regulations in the last thirty years. Moreover, the more open an economy is the more efficient technology can be easily transferred and used from one country to another, thus leading to a lower consumption of resources within the European countries.

A negative effect on DMCpc is obtained by total Research and Development expenditure variable (the sum of business and government expenditure) as the sign of R&D coefficient is negative and significant. In the all estimations, we used lagged values of the R&D variable and in particular firstly we considered 1-year lagged variable and secondly 2-year lagged variable. This time is the minimum sufficient to consider the implementation of theoretical research results into applications regarding processes and products. R&D expenditure seems confirm these targets in reducing the quantity and/or quality of material flows used in production and consumption processes. In general, R&D expenditure has been oriented among European countries to innovate and develop new *process and product technologies* that support i) the reduction in the use of natural resources, ii) the decrease in the resource use intensity, iii) the recycling process of scrap and waste materials to generate secondary raw materials and iv) consequently lower environmental pressures.

7. Conclusions

In this paper, following the economic environmental literature we have proposed a new indicator to measure environmental burden. So far, the EKC analysis has usually been based on measures such as water and air pollution, waste and so on, adopting an end-of-pipe approach. In our analysis, instead, we analyse a consumption based-oriented approach. We investigate the negative effect of production and consumption processes of social economic systems on natural environment, through the analysis of the amount of extraction and depletion of renewable and non-renewable resources. The DMC indicator is a consumption-based physical measure of *potential environmental impact* and has been developed in the last ten years by official statistics in the European countries (EUROSTAT, OCSE) with the aim to tackle new challenges in pursuing sustainable growth and development. Measuring DMC in physical units of weight, materials directly used in production and consumption processes sooner or later could represent an environmental burden.

Over the period 2000-2010, per capita DMC has shown an increasing trend until 2007, while in the last period has changed its trend from positive to negative. EU-countries' economic growth has been based on a constant increase of natural resource use up to 2007 while due to economic and financial crises a lower demand has reduced material flow use. In addition, the resource use intensity shows a decreasing slope especially from 2007 onwards. The main implications for EU countries could be either a more efficient use of natural materials in production and consumption or a more intensity use of natural resources from abroad. In other words, EU countries could prefer to import inputs for their production and consumption or outputs including foreign natural resources as inputs.

In our paper, starting from the simple EKC specification, we have used a more complex and complete model called *adjusted EKC specification*. This model considers the relationship between per capita GDP and per capita Domestic Material Consumption indicator, controlling for final domestic Consumption expenditure, Openness to international trade, national Research and Development expenditure (both business and government) effects by using a cross–European unbalanced panel of countries, over the period 2000-2010.

The existence of an inverted U–shaped relationship between per capita income and per capita DMC indicator is confirmed. The quite high turning points, even if close to a reachable value, could mean both a functional delinking of per capita DMC growth from economic growth and a insufficient awareness by European citizens about the natural depletion of material flows determined by their consumption and production behaviours. However, we think that our results even if strong and significant, needs more deep and detail investigations.

As far as control variables are concerned, the positive relationship between per capita Consumption and per capita DMC confirms the link between growth and natural resources required for production and consumption activities. Instead the negative relationship between DMCpc and Openness to international trade suggests that European countries have relocated raw material-intensive products to developing countries. The *industrial displacement effect* on dirtier industries could be an effect of more strict standards for the environment set by EU's regulations in the last thirty years. Moreover, the more open an economy is the more materials flows could be exchanged among countries, thus European countries could reduce their own consumption of natural resources. Finally the negative relationship between DMCpc and the lagged variable of total Research and Development expenditure seems to confirm that innovations can reduce the quantity of raw materials used in production and consumption processes.

What we can sum up at the end of our empirical analysis is that European Union should both encourage more sustainable technology to reduce the use of natural resources and promote the cooperation among national agencies in monitoring and delimiting the problem of environmental burden of human activities. European policy should focus its attention more on the use of raw materials from natural resources. Since human activities and production processes may surely have several economic, social and environmental consequences, managing efficiently natural resources and raw materials could be the main determinant to improve economic growth, environmental quality, human health and sustainable development within a territory. A good policy could be to incentivize private and public sectors in using more efficient technologies to reduce the consumption of natural resources. The main consequence of this policy should be the reduction of environmental pressure on natural resources and landscapes both within and without European economies.

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APPENDIX A

Table A.1: 30 European countries chosen for our estimation

European Countries	
EU27	**NO-EU27**
Austria	Norway
Belgium	Switzerland
Bulgaria	Turkey
Cyprus	
Czech Republic	
Denmark	
Estonia	
Finland	
France	
Germany	
Greece	
Hungary	
Ireland	
Italy	
Latvia	
Lithuania	
Luxembourg	
Malta	
Netherlands	
Poland	
Portugal	
Romania	
Slovak Republic	
Slovenia	
Spain	
Sweden	
United Kingdom	