Environmental Macroeconomics: A critical literature review and future empirical research directions

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ABSTRACT
In the existing literature much attention has been given to the toolbox of regulatory policy instruments at the disposal of policy makers for addressing environmental concerns. Microeconomic treatment of environmental policy considers the optimal allocation of a given scale of resource flow within the economy, but neglects the scale and composition of economic activity relative to the ecosystem that supports it. An ecological approach to macroeconomics requires the appreciation of physical constraints to economic growth. This paper presents the theoretical underpinnings and the empirical findings of the literature on the link between economic growth and environmental quality, as well as of the relationship between fiscal policy and environmental degradation, by reviewing the relevant literature. The empirical findings on both relationships are not robust and are therefore inconclusive. The paper provides conclusions and directions for future research which may assist to solve this ambiguity on the examined relationships.

Keywords: Environmental Macroeconomics; Economic growth; Natural resources; Fiscal policy

JEL Classification: Q56; Q32; Q28; E62; Q01; P28.

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1. Introduction

In the existing literature much attention has been given to the toolbox of regulatory policy instruments at the disposal of policy makers for addressing environmental concerns (Islam and Lopez, 2015). On the other hand, while the effects of several economy-wide policies such as trade policies have been extensively studied, little efforts have been devoted to the study of the impact of fiscal policy on environmental quality. This is particularly surprising in view of the immense importance of government expenditure in many economies worldwide.

The physiocratic[1] and classical schools[2] of economic thought, already during the eighteenth and nineteenth centuries, pointed out the significance of land in the production process, and highlighted the way of life of natural constraints on economic growth (Harris and Codur, 2004). Most notably, Thomas Malthus (1798, 1820) argued that humanity was trapped in a world where population growth would intensively consume natural resources and eventually cause, particularly for the lower class, misery and therefore prevent any permanent improvement of their state. Malthus suggested that two types of stabilizers may assist in holding population within sustainable limits: positive checks, which raise the death rate; and preventive checks, which lower the birth rate (Hollander, 1997). The positive checks include war, hunger and disease; the preventive checks birth control, abortion, encouragement of celibacy and postponement of marriage.

Moreover, Malthus offered no gleam of hope, since he dismissed the effectiveness of several possible solutions to put an end on this vicious cycle, such as the argument that improvements in agricultural productivity could satisfy increasing nutritional needs. It is therefore not surprising that with such ominous predictions, Economics were characterized as the *dismal science* (Heilbroner, 1953).

[1] Includes writers like A.R.J. Turgot, the Marquis de Condorcet and Francois Quesnay.
[2] Particularly in the writings of Adam Smith and David Ricardo.

Nevertheless, this inconvenient characterisation of Economics appears highly unfair, considering that macroeconomic theory was oriented, for more than a century, towards a hypothesis of continuous growth in GDP and not much attention was given to the relationship between economic growth and environmental degradation until early 1970s. It was indeed this neglection that led Brock (1973) to argue that growth theory is biased, since it does not explicitly take into account the environmental costs of economic growth. On a similar note, Daly (1990) pointed out the failure of an ''*environmental macroeconomics*'' to emerge, apart from the efforts to consider environmental factors in national accounting, which were already being developed during the 1990s. Microeconomic treatment of environmental policy considers the optimal allocation of a given scale of resource flow within the economy but neglects the scale and composition of economic activity relative to the ecosystem that supports it (Daly 1991; Heyes, 2000). An ecological approach to macroeconomics requires the appreciation of physical constraints to economic growth (Harris, 2009).

The remainder of the paper is structured as follows: Section 2 presents the theoretical underpinnings and the empirical findings of the literature on the link between economic growth and environmental quality, while Section 3 does the same for the relationship between fiscal policy and environmental degradation. Section 4 provides conclusions and directions for future research.

2. Economic growth and the environment

2.1 Theoretical framework

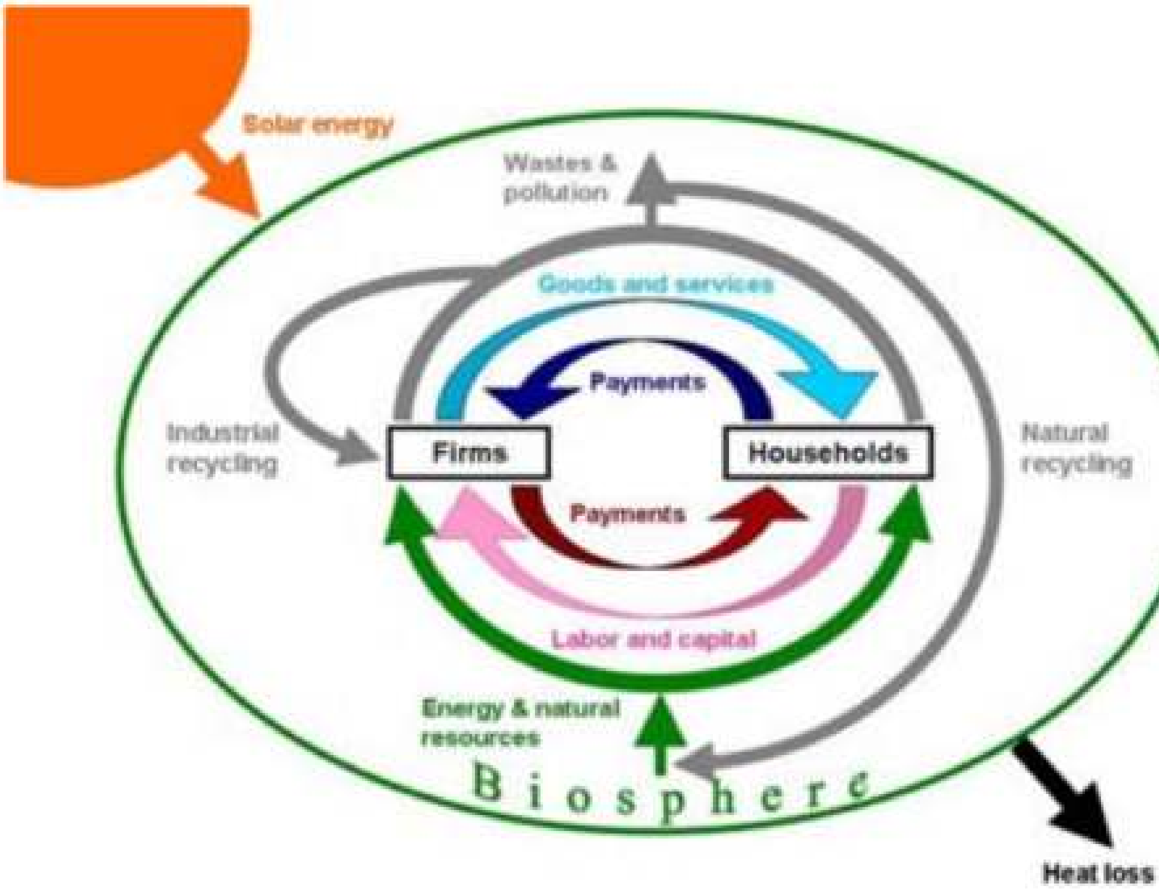
2.1.1. The circular flow model

A fundamental theoretical tool of macroeconomic theory is the circular flow model of an economic system. In its standard form, this model describes the exchange of services and goods, as well the supply and demand of factors of production between two types of economic actors, namely consumers (households) and producers (firms). However, the environment and the natural resources, which support the production process, are not considered in the standard version of this model.

According to contemporary economic theory, an economy has at least three factors that contribute to production and eventually to economic growth and welfare: human capital, physical capital and natural capital (Lopez et al., 2010). Natural capital in particular, comprises natural resources as well as environmental quality. Therefore, the standard circular flow model can be enhanced by the introduction of the biosphere as ‘‘*a provider of natural resources and also as the receptor of various undesirable outputs of the production/consumption processes, i.e. of pollution and wastes*’’ (Harris and Codur, 2004).

Following Harris and Codur (2004), we may consider the entire economic activity to be embedded in the biosphere. Related to this, Kumbhakar and Tsionas (2015) examined the environmental production process (for example, during the production of electricity) and emphasized the existence of inefficiencies in by-product technologies, which implies that more than the minimal amounts of the undesirable outputs are produced (SO_2 and NO_x emissions). Moreover, they identified the presence of technical inefficiencies which means that, given a level of inputs, less than the maximum possible level of desirable outputs is produced.

Figure 1: The augmented circular flow model



Source: Harris and Codur (2004-p.4).

Thus, a more sophisticated circular flow model should be considered. Such a model should represent the procedures and mechanisms of economic activity and its interactions with the biosphere, taking into account that certain by-products of economic activity are subsequently recycled through biological and geophysical processes. These relationships are portrayed in Figure 1.

2.1.2. Environmental pollution in growth models

During recent decades, the increasing urgency of environmental problems, both in national and global levels, provoked a growing body of research that incorporate environmental pollution factors in growth models and explicitly explores the relationships between economic growth, capital accumulation and environmental degradation. The foundation of these models is the acknowledgement of a flow of waste material as a by-product of the production process, which deteriorates the environment and possibly the factor productivity. Moreover, in these models environmental quality is positively valued by individuals.

According to Xepapadeas (2005) and assuming that the flow of emissions is related mainly to output production, the neoclassical aggregate production function for the economy can be written as:

$$Y = F\left(K_p, AL, K_\alpha\right) \quad (1)$$

where K_p is the pollution generating capital, AL represent effective labour that allows for labour augmenting technical change and K_a is the abatement capital which helps reduce pollution levels. The flow of emissions can be represented as $Z = \phi(K_\alpha)Y$ where φ depicts emissions per unit of output and $\phi'(K) < 0$, assuming existence of emissions reducing technologies.

Alternatively, the effective flow of pollution, BZ, can be incorporated in the production function in order to capture productivity effects of the environment, for example by improving the health of the labour force, as proposed by Brock (1973):

$$Y = F\left(K, AL, BZ\right) \quad (2)$$

where $\frac{\partial F}{\partial Z} > 0$. Regarding consumption, environmental quality may enter the utility function by assuming that individuals derive satisfaction from the consumption of goods as well as from the quality of the environment. Hence, the utility function for the i^{th} individual is:

$$U\left(c_i, Z\right) \quad (3)$$

and the criterion function of the government to achieve social optimization, takes the form:

$$\int_0^{\infty} e^{-\rho t} N(t) U\left(\bar{c}(t), P(t)\right) dt, \quad (4)$$

where N(t) is the population, t represents time, $\bar{c}$ is per capita consumption and ρ depicts the future utilities discount rate.

The development of the models that explore the interrelationships between economic growth and the environment is closely linked to the evolution of growth theory. As already discussed in Chapter 1, the first wave of models constituting the neoclassical growth theory, considered technical change as exogenous and the role of government policy to be limited, with no effect on the exogenously determined long-run growth rate.

On the other hand, endogenous growth theory incorporated technological progress as an endogenous factor, which allowed the determination of the growth rate endogenously in the model and eventually offered the theoretical framework for a more active and efficient role for government policy. Therefore, following the classification and analytical framework proposed by Xepapadeas (2005) the predictions and policy implications of three types of related theories are briefly presented below, namely models with fixed savings ratio and exogenous technical change, optimal growth models with exogenous technical change and finally, endogenous growth models.

- **Models with a fixed savings ratio**

These models consider that the savings ratio is fixed and no related optimization process is followed by individuals. In addition, the degradation of environmental quality does not reduce utility and is therefore not taken into account, a situation that may in some cases not deviate from reality, for instance in industrialised societies. Under these assumptions, at the steady-state environmental pollution grows at the fixed rate n + g, where n and g represent the exogenous rates of population and labour augmenting technology growth rates, respectively.

Therefore, accumulation of pollution would only cease when there is no exogenous growth, i.e. when n = g = 0 and the economy also stops growing. The introduction of emissions reducing technologies in this model is one way to sufficiently prevent the accumulation of pollution as the economy grows. In this case the level of steady-state pollution is reduced, albeit pollution in physical units still grows at an exogenous rate.

Apparently, an equilibrium steady-state level of pollution might not exist in the aforementioned basic model. This could be achieved if the flow of emissions is incorporated as an input in the production function, as in Eq. (2), and could be justified as a maximum level of emissions imposed by emission standards or by technological constraints. In this model the steady-state growth rates of the main variables in per capita terms are constant and determined exogenously, while the steady-state levels of these variables are determined by the specified level of emissions.

Moreover, due to nonlinearities, certain levels of the specified environmental standard might result in the fast accumulation of pollution which may be difficult, or even impossible, to reverse. Xepapadeas (2005) points out that such an *environmental trap* may be likely in this case, since environmental standards are not set in an optimum way based on the disutility related to environmental pollution.

- **Optimal growth models**

In these models, environmental considerations are explicitly taken into account by introducing the utility function of the representative household. However, the steady state for the competitive economy has the same characteristics as the standard Ramsey–Cass–Koopmans model without environmental pollution, with only the growth rate of consumption being lowered. This result reflects the fact that producers do not take into account the disutility from pollution, environmental degradation will continue as long as the economy grows at an exogenous rate, and that there are diminishing returns in physical capital.

On the other hand, as expected due to environmental externalities, the optimal levels of the main variables are reduced when the optimization problem of the social planner is taken into account. This result may be achieved by imposing environmental taxes or introducing abatement activities that diverge resources from capital formation or consumption. The achieved steady state levels are reduced compared to the competitive equilibrium, due to the internalization of environmental externalities by the social planner. However, also in this case, the growth rates are not affected by environmental concerns, since these rates are determined exogenously.

- **Endogenous growth models**

Endogenous growth theory defines capital in the broad sense to include human capital and therefore constant returns are achieved. Moreover, if the occurrence of diminishing returns in the abatement sector is prevented, it is possible to have sustained growth without pollution accummulation. The fundamental factor that leads to growth is the accumulation of knowledge which is considered a public good while technological progress is endogenous, and driven by investment in R&D, in expectation of future monopolistic profits. Therefore, in the framework of endogenous growth models with an environmental dimension, growth rates can be affected by government policies that internalize the negative externalities linked with pollution and positive externalities associated with the knowledge accumulation and human capital.

These policies include public expenditure in education, R&D and health, environmental taxes, maintenance of public order, as well as regulations of international trade and environmental protection. Environmental policies can be distinguished between market-based instruments and regulatory instruments. Bithas (2011) emphasized the need to combine both types of instruments to ensure sustainability, since in order to satisfy the necessary and sufficient conditions for it, the intertemporal externalities should be internalized alongside the interspatial externalities. In particular, conventional environmental policy instruments can ensure the environmental welfare of current generations and achieve allocative efficiency under existing economic and social conditions (Bithas, 2006). Nevertheless, command and control instruments, suitably designed to reflect absolute ecological targets which respect the environmental rights of future generations, could complement payment rules and provide the sufficient conditions for sustainability.

2.2. Empirical evidence

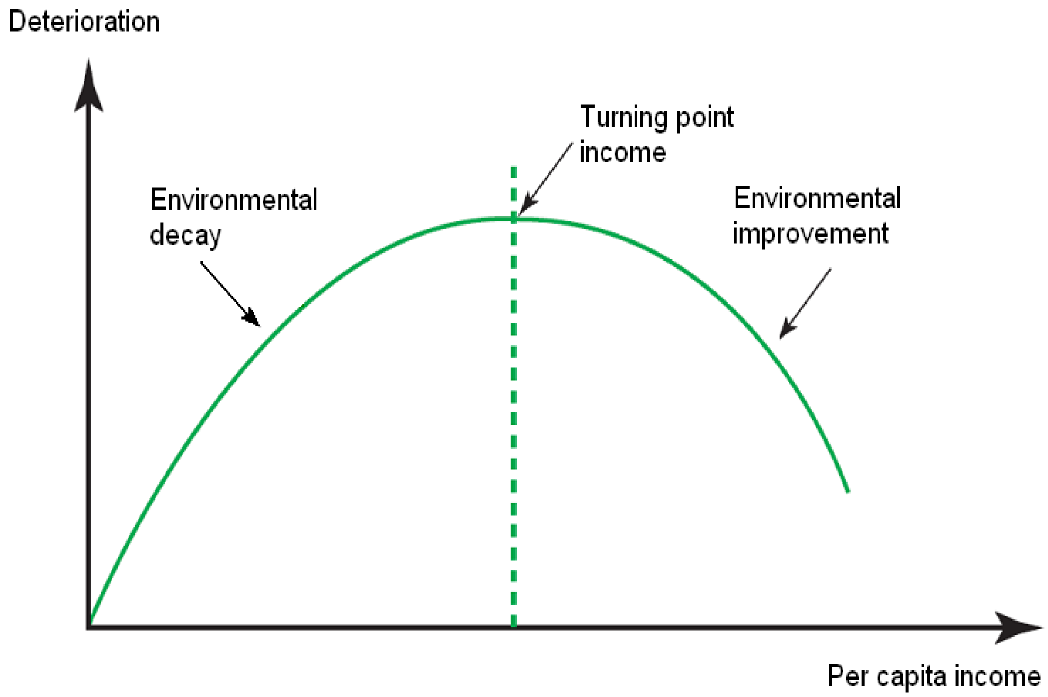
2.2.1. The Environmental Kuznets Curve

A thorough examination of the growth models sketched in the previous section suggests that, at least from a theoretical point of view, there are important interrelationships between economic growth and the environment while the exact magnitude and sign of this relationship depends on several factors. As Xepapadeas (2005) points out, growth theory provides indeterminate evidence regarding this relationship. First, if disutility from environmental degradation is not considered, environmental quality might degrade with economic growth. On the other hand, if externalities of pollution are taken into account, environmental concerns might limit growth if the productivity of capital in production and pollution abatement tends to zero as capital accumulates.

Finally, sustained growth could be associated with stable pollution in the presence of non-diminishing returns in abatement processes or output production. Nevertheless, it is important to explore which of these mechanisms are confirmed by empirical evidence. Thus, a great deal of empirical work, sought to test the relationship between per capita income and the environment, was undertaken during the 1990s and still consists an active research field of Environmental Economics.

Much of the studies that explore the relationship between economic growth and environmental degradation test the hypothesis of the existence of the Environmental Kuznets Curve (EKC). This terminology is related to the work of Kuznets (1955) who hypothesized an inverted-U shape relationship between an indicator of income inequality and the level of economic growth. The EKC hypothesis posits that during the early stages of economic development environmental degradation increases, until a threshold level of income is reached and thereafter improvements in environmental quality are achieved. This relationship is depicted in Figure 2.

Figure 2: Stylized Environmental Kuznets Curve



Source: Modified from Halkos (2013b).

2.2.2 Rationale for the existence of an EKC

According to the literature which identifies several factors that lead to the existence of the EKC, the main determinants of the growth-pollution relationship may be categorized as follows (Halkos, 2013b; Panayotou, 2003; Alstine and Neumayer, 2010; Stern, 2014):

- **Scale effect**

The expansion of production, ceteris paribus, i.e. with the mix of products produced, the mix of production inputs used, and the state of technology all held constant, increases environmental pressures and is associated with deterioration of environmental quality (Panayotou, 1993, 1997).

- **Composition effect**

During the course of economic development the output mix of the economy changes (Janicke et al., 1997; Copeland and Taylor, 2004). In particular, at the early stages of economic development as the rural sector contributes the larger percentage of GDP, environmental pollution is minimum. However, as the economy develops and the role of industries becomes more important, environmental pressures progressively increase. This pollution intensity is eventually relieved as the economy further grows and relies more on the service sector.

- **Technique effect**

The technique effect is associated with three distinct mechanisms that may reduce environmental pressures, depending on the elasticity of substitution in production (Lopez, 1994; Grossman and Krueger, 1995; de Bruyn and Opschoor, 1997; Han and Chatterjee, 1997). Firstly, it involves the modification of inputs mix employed in production, in such a way as to substitute pollution intensive factors with other which are environmentally friendlier. Moreover, as an economy grows, its capabilities in supporting R&D expenditure increase, eventually leading to improvements in the state of technology. Thereafter, these improvements lead to the introduction and diffusion of cleaner technologies, which may substitute older ones that were more pollution intensive. Finally, new technologies enhance the productivity of physical capital and therefore limit the use of pollution intensive inputs per unit of output.

- **Demand for environmental quality**

As income increases, demand for environmental quality also rises, implying that environmental quality is a normal good, i.e. its income elasticity is positive (Beckerman, 1992). In developing countries, demand for environmental quality is rather small but, as the economy grows, environmental concerns rise and demand for enhanced environmental quality shifts out. This effect is also related with the Frisch coefficient of preferences which reflects how the value of goods declines with income, in particular how the marginal utility of income declines with income (Lopez, 1994).

- **International trade**

Many studies have shown that the existence of the EKC may reflect the changing scale, composition and technique patterns that are associated with liberalized trade and economic growth (Alstine and Neumayer, 2010; Grossman et al., 1993, 1995; Heil and Selden, 2001; Suri and Chapman, 1998). According to Halkos (2013a) the environmental effect of trade liberalization may be decomposed into three distinct effects. First of all, environmental degradation may increase through the scale effect due to the increased volume of international trade (scale effect).

On the other hand, international trade is associated with implementation of stricter environmental regulations, which promote technological advances that reduce pollution levels (technique effect). Finally, the composition effect may increase pollution in developing countries by encouraging the establishment of new industries which are more pollution intensive, particularly in view of the lower environmental standards of these countries (*displacement hypothesis*[3]). Furthermore, the *pollution haven hypothesis* may explain the establishment of more pollution intensive industries in developing countries, where there are less stringent environmental regulations and there is a comparative advantage in the production of pollution-intensive goods in relation to developed countries (Dinda, 2004; Cole, 2004).

- **Population growth**

Higher income causes a reduction in the population growth rate, consequently alleviating population pressures on environmental pollution, since in general a larger population is associated with more pollutant emissions (UNDP, 1999; Zhu and Peng, 2012).

2.2.3 Empirical evidence for the existence of an EKC

The empirical analysis of the EKC has focused on whether a given measure of environmental degradation shows an inverted-U-shaped relationship with income per capita[4]. Consequently, the 'turning point' can be calculated by the level of per capita income at which the EKC peaks. Grossman and Krueger (1993) were the first to conduct an EKC study. In particular, using the Global Environmental Monitoring System[5] (GEMS) dataset for 52 cities in 32 countries in the period 1977–88, they estimated EKCs for SO_2 and suspended particles. In each regression, they employed a cubic specification of the level of PPP adjusted per capita GDP and controlled for various site-related variables and a time trend. The turning points for SO_2 and dark matter were estimated between $4,000-5,000, while the concentration of suspended particles appeared to decline even at lower income levels. During the first decade after the aforementioned work, a growing body of literature focused on empirically

[3] For example, see Tobey (1990) and Rock (1996).
[4] It should be mentioned that several studies have extended this hypothesis and explored the existence of cubic specifications of the economic growth – environment relationship. For example, see Shafik and Bandyopadhyay (1992), Zarzoso and Morancho (2003), Binder and Neumayer (2005) and Halkos (2013a). Also see Bella et al. (2014) and Yang et al. (2015) for more recent and sophisticated approaches regarding the estimation of the relationship between CO_2 emissions and economic growth.
[5] This dataset is a panel of ambient measurements from a number of locations in cities around the world.

testing the EKC hypothesis and confirmed turning points in the range of $3,000-23,000[6] (Selden and Song, 1994; Cole et al., 1997; Torras and Boyce, 1998; Kaufmann et al., 1997; List and Galett, 1999).

A recurring pattern in the literature, is that an EKC exists for pollutants with semi-local and medium-term impacts (Shafik, 1994; Arrow et al., 1995; Cole et al., 1997; Ansuategi et al., 1998; Halkos, 2003). On the other hand, for some aspects of the environment, no turning point is confirmed. These aspects include CO_2 emissions (Shafik, 1994; Holtz-Eakin and Selden, 1995), direct material flows (Seppala et al., 2001) and biodiversity loss (Asafu-Adjaye, 2003[7]). One plausible explanation of this finding is that an EKC holds for those measures of environmental pollution that have significant implications on human health and/or may not be easily externalized; these tend to improve already at low levels of income. On the other hand, those indicators that have the characteristics of global public goods and are relatively easier to externalize onto others tend to deteriorate with economic growth since they have historically not been subject to particular regulation (Alstine and Neumayer, 2010).

In a related common finding, the turning points for emissions of each pollutant are reported to be higher than that for its ambient concentrations, ceteris paribus (Selden and Song, 1994). According to Stern (2014), a plausible explanation for this finding is that in the initial stages of economic development urban and industrial development tends to concentrate more in a smaller number of cities, which also have rising population densities, while the opposite is happening during the later stages of economic growth. Therefore, it is not unlikely to observe declining pollution concentrations as income rises, even if total national emissions continue to increase (Stern *et al*., 1996). However, it should be mentioned that to find a causal relationship between environmental damage and economic activity, ambient

[6] For a comprehensive review see Stern, 2014.
[7] For contrary evidence see Perrings and Halkos (2012).

concentrations do not provide the most proper indicator of environmental impact (Halkos and Tsionas, 2001). Moreover, the use of emission indicators avoids dependence of the estimated results on geographic location characteristics and atmospheric conditions.

Despite the overwhelming presence of empirical studies on the existence of the EKC, there are a growing number of studies that have suggested that several other factors must be taken into account before drawing robust conclusions. Halkos and Tsionas (2001) argued that the EKC hypothesis may be a function of income and employed regime switching models on a cross-section of developing and developed countries, explicitly taking into account the presence of non-linearities. Their results suggested that there is an increasing relationship between two pollution indicators (CO2 and deforestation) and income.

Stern and Common (2001) pointed out that estimates of the EKC for sulphur emissions are very sensitive to the choice of sample used in the analysis. In particular, they found that SO_2 emissions per capita were a monotonic function of income per capita when they used a global sample and an inverted U-shape function of income in a sample of OECD countries only. Halkos (2003) highlighted the existence of dynamics in the examined relationships and proposed the use of dynamic econometric methods. In particular, using the same database as Stern and Common (2001), but employing a dynamic model formulation, he found much lower turning points, well within the sample levels of income, in the range of $2,805–$6,230 and confirmed existence of inverted U-shape curves. The differences in the extracted relationships between these studies, as well as the differences in the estimated turning points may be, solely, attributed to the econometric models' functional form used and the adoption of static or dynamic analysis.

Related to the aforementioned issues, if the environmental indicator used in the analysis and GDP are non-stationary, i.e. they show a common trend over time, then spurious regression results may be reported. Tests for integrated variables designed for use with panel data find that sulphur and carbon emissions and GDP per capita are integrated variables (Stern, 2014). Therefore regression estimates by using time series or panel data are reliable only if the regression exhibits co-integration, i.e. there is a long-term relationship between the models variables. Otherwise, the model must be estimated by the use of alternative approaches such as first differences or the between estimator, which first averages the data over time (Stern, 2010). According to Alstine and Neumayer (2010), only a small number of studies have addressed this potential problem properly (for example, Galeotti, Manera, and Lanza, 2006; Perman and Stern, 2003; Wagner and Müller-Fürstenberger, 2005).

Finally, several other determinants of environmental quality have been incorporated in the EKC empirical specifications, in order to avoid potential omitted variable bias that could influence the relationship between economic growth and the environment. These additional determinants comprise variables such as measures of institutional quality and political freedom (Torras and Boyce, 1998), corruption (Welsch, 2004; Cole, 2007), openness to international trade (Suri and Chapman, 1998; Cole, 2004), structure of GDP (Panayotou, 1997) and population growth (Zhu and Peng, 2012).

2.2.4 Policy implications from the EKC literature

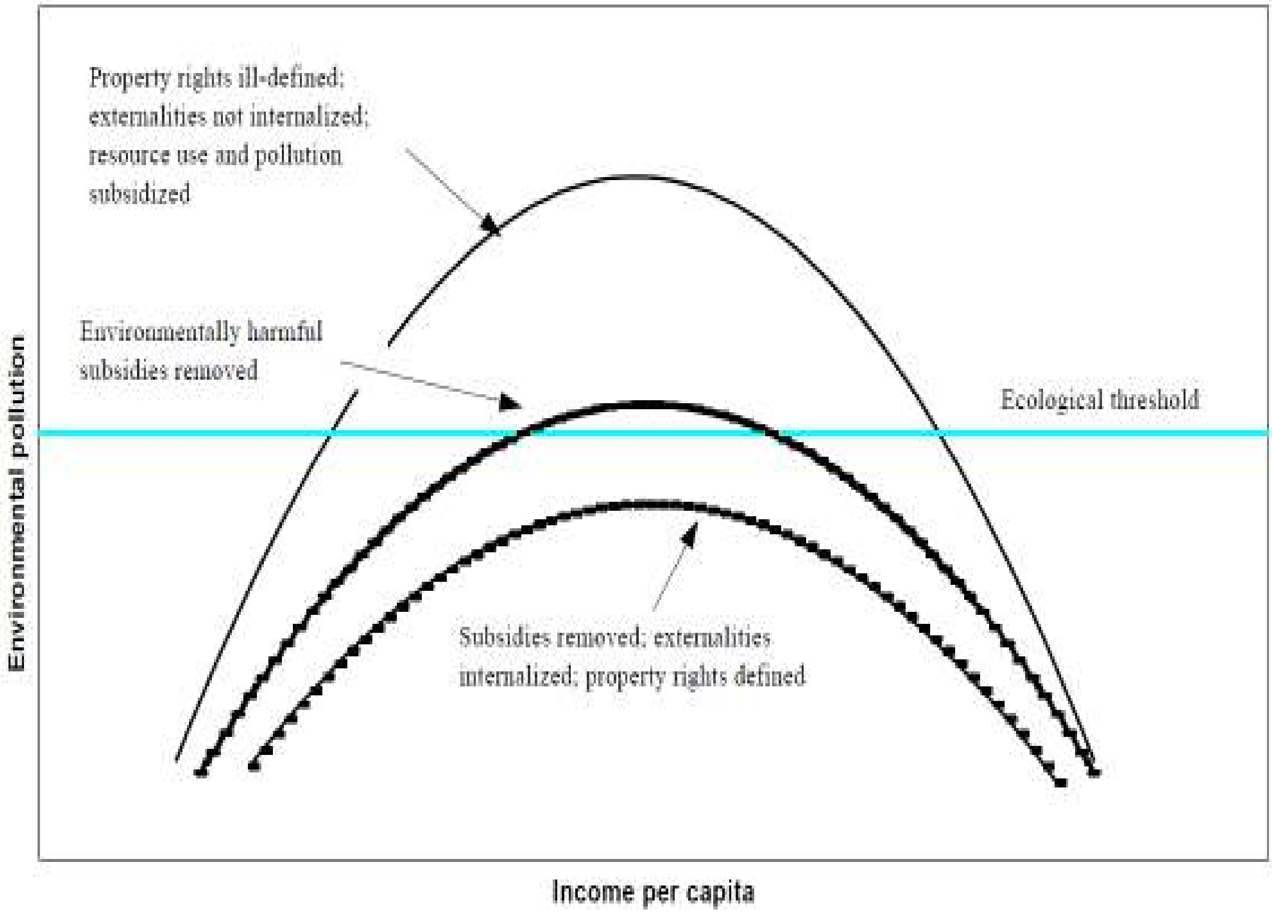
Acceptance of an EKC hypothesis implies that there is an inevitable level of environmental degradation that accompanies a country's early development stage but with a significant improvement at a later stage of this country's economic growth (Halkos, 2003). However, a fundamental issue that has to be addressed is whether the EKC relationship is quasi-automatic or policy induced (Alstine and Neumayer, 2010; Grossman et al., 1995). A part of the steepness of the inverted U-shaped relationship between economic growth and pollution could be attributed to policy distortions in the form of under-pricing of natural resources and subsidies to energy and agrochemicals, which are destructive both in terms of economic efficiency and environmental perspectives (Halkos 2013a).

Governments can flatten out their EKC by confining policy distortions that lead to market failures, reinforcing the establishment of property rights over natural resources and in general, opt to internalize environmental externalities to the sources that generate them by enforcing stricter environmental regulations (Panayotou, 1993). Regulatory institutions, normative institutions, and the beliefs and values that are imposed on, or internalized by, social actors may also determine corporate decisions' and shape corporate social responsibility through the legal requirements that are imposed on business (Skouloudis and Evangelinos, 2012).

Related to this, Jones et.al (2010, 2012) stressed the need to increase environmental education, the requirement to create social networks in order to promote information spillovers and the importance of increasing citizens' participation during the decision-making phase of environmental policy. These factors may further alleviate environmental degradation by increasing citizens' environmental awareness and willingness to pay for environmental quality improvements (Halkos and Matsiori, 2012, 2014). Figure 3 is a schematic illustration of these policy implications.

Considering developing countries, if the technique effect is emphasized through policy, then these countries may be able to ease their way through the EKC, as abatement already exist. Therefore, there is a need for technology transfer and abatement assistance to developing countries to achieve sustainability, since production methods in developed countries are relatively less pollution intensive. Finally, the finding that the EKC increases monotonically for pollutants with more global externalities highlights the need for the establishment of international environmental treaties and cooperation, which will aid the internalization of such externalities.

Figure 3: The EKC under different policy and institutional scenarios



Source: Panayotou (1997 - p. 6).

3. The role of fiscal policy

The role of government as an essential component of civilized communities, albeit in its extreme form of absolutism for the sovereign, has been pointed out by Thomas Hobbes (1651). On the other hand, Adam Smith (1776) has argued that governments should limit their tasks to fundamental functions such as protecting property rights and ensuring the rule of law and order, otherwise economic growth and welfare would be significantly deteriorated. Nevertheless, he has warned against the complete confinement of the state, since this would lead to detrimental effects and social disorder. Moreover, Adolf Wagner's law suggests that the size of government tends to increase with the level of income in order to maintain the same level of administrative and law enforcement functions, as well as to ensure the necessary provision of public goods and the alleviation of market failures[8].

Nowadays, in most countries a large part of Gross Domestic Product (GDP) is being spent through government consumption and investment. In particular, the share of government expenditure in GDP increased in most developed countries during the period 1970–1995, in an attempt to alleviate the effect of business cycles and achieve income equality. This trend reverted during the period 1995 – 2005, in order to confine increasing public debt ratios, but subsequently increased again, as several governments have followed expansionary macroeconomic policies to support and expedite the recovery of their economies in response to the economic crisis that initiated in 2008. The evolution of the size of government expenditure from 1970 to 2013, for a sample of 28 OECD countries, is depicted in Table 1. Despite renewed recent attempts to reduce government expenditure, still an average of more than 45% of GDP is spent by governments.

The economic implications of government expenditure have been shown to be significant and broad, however the empirical evidence concerning the qualitative characteristics of these relationships remain inconclusive. In particular, government spending has been shown to enhance long-run economic growth by increasing the level of human capital and Research and Development (R&D) expenditure, and by improving public infrastructure (Ram, 1986; Ghali, 1998; Dalamagas, 2000; Agenor and Neanidis, 2006). In contrast to the above, there is evidence that a greater size of government spending may be less efficient and therefore not necessarily associated with a better provision of public goods and higher levels of economic growth (Afonso and Furceri, 2010; Bergh and Karlsson, 2010).

[8] For related studies that empirically confirm this hypothesis see Rao (1989) and Martinez-Mongay (2002).

Table 1: Total public expenditure as a % of GDP (General government)

	1970	1980	1990	1995	2000	2005	2010	2013	Changes in pp 05-70	05-95	10-05	13-10
Australia	25.9	33.2	35.7	38.3	34.8	34.9	36.8	36.6	9.0	-3.4	1.9	-0.2
Austria	39.7	49.4	51.5	56.0	51.4	49.9	52.7	50.8	10.2	-6.1	2.8	-1.9
Belgium	41.0	54.7	52.2	51.9	49.0	49.8	52.3	54.5	8.8	-2.1	2.5	2.2
Canada	36.0	41.6	48.8	48.5	41.1	39.3	43.3	40.7	3.2	-9.2	4.0	-2.6
Czech Republic	..	..	..	54.0	41.7	43.6	43.0	42.0	..	-10.3	-0.6	-1,0
Denmark	..	53.6	55.9	59.5	53.9	52.8	57.1	57.1	..	-6.7	4.3	0.0
Finland	30.9	40.1	48.0	61.5	48.3	50.1	54.8	57.6	19.2	-11.4	4.7	2.8
France	39.2	45.6	49.4	54.4	51.6	53.9	56.4	57.0	14.7	-0.6	2.5	0.6
Germany	38.4	46.9	43.6	48.3	45.1	46.8	47.1	44.1	8.4	-1.5	0.3	-3.0
Greece	26.5	32.1	49.2	50.1	51.2	46.7	52.2	60.1	20.1	-3.5	5.5	7.9
Hungary	..	..	..	55.4	46.6	49.9	49.8	49.8	..	-5.5	-0.1	0.0
Iceland	31.1	35.7	41.5	42.7	42.1	43.4	49.4	44.1	12.3	0.7	6.0	-5.3
Ireland	44.8	54.6	43.1	41.3	31.6	34.1	..	39.6	-10.7	-7.1	..	..
Italy	32.5	40.8	52.9	52.5	46.1	48.2	49.9	50.9	15.8	-4.2	1.7	1.0
Japan	20.8	32.1	31.8	36.5	39.2	37.0	40.7	42.3	16.2	0.5	3.7	1.6
Korea	..	21.2	20.0	20.8	23.9	29.1	31.0	31.8	..	8.2	1.9	0.8
Luxembourg	..	..	37.7	39.7	37.6	43.2	43.8	42.6	..	3.5	0.6	-1.2
Netherlands	43.7	54.2	52.9	50.0	44.0	45.5	48.2	46.4	1.7	-4.6	2.7	-1.8
New Zealand	..	..	53.2	42.0	39.6	38.2	47.4	..	..	-3.8	9.2	..
Norway	39.1	46.1	54.0	51.5	42.7	42.8	45.0	44.0	3.7	-8.7	2.2	-1.0
Poland	..	..	..	47.7	41.0	42.7	45.9	42.2	..	-5.0	3.2	-3.7
Portugal	..	34.2	40.3	43.1	43.1	47.7	51.8	49.8	..	4.7	4.1	-2.0
Slovakia	..	..	..	47.0	51.7	37.1	42.0	41.0	..	-9.9	4.9	-1.0
Spain	23.0	33.5	42.6	44.2	39.0	38.2	45.6	44.3	15.2	-6.0	7.4	-1.3
Sweden	43.9	64.1	61.3	67.1	56.8	56.3	52.0	53.4	12.4	-10.8	-4.3	1.4
Switzerland	..	..	30.0	34.5	33.9	36.2	32.9	33.5	..	1.6	-3.3	0.6
United Kingdom	42.0	46.4	42.4	44.9	37.5	44.9	48.7	45.5	2.8	-0.1	3.8	-3.2
United States	32.3	34.3	36.3	37.3	38.3	39.3	42.9	38.5	7.0	2.0	3.6	-4.4
Minimum	20.8	21.2	20.0	20.8	23.9	29.1	31.0	31.8	8.3	8.2	1.9	0.8
Maximum	44.8	64.1	61.3	67.1	56.8	56.3	57.1	60.1	11.5	-10.8	0.8	3.0
Simple average	35.0	42.6	44.8	47.3	43.1	43.8	47.4	45.9	9.1	-3.5	2.8	-0.6

Source: Afonso and Furceri, 2010-p.10 (extended using OECD stats and own calculations)

Moreover, it is likely that the size of government expenditure and its composition are associated with key aspects of the quality of growth, such as income inequality and environmental sustainability (Lopez et al., 2010). Calbick and Gunton (2014) suggest that policy factors alone account for much of the variation in emissions among developed countries. This relationship is of great interest since, if a positive relationship between government expenditure and environmental quality can be established, it will provide reassurance to macroeconomic policy makers that a fiscal spending expansion does not induce pollution and in fact may lead to a significant alleviating effect on environmental degradation. In such a case, fiscal spending could complement the efforts to improve environmental quality, rendering environmental policy easier and more cost efficient. Despite the potentially significant implications of fiscal spending on the environment, it is surprising that this relationship had been neglected in the literature and only recently there is a burgeoning body of theoretical and empirical studies that have systematically started to explore it (Lopez et al. 2011; Halkos and Paizanos, 2013; Bernauer and Koubi, 2013; Galinato and Islam, 2014). At the same time, as we have seen in Section 2, a large body of empirical literature posits a relationship between economic growth and pollution/

Therefore, the framework for analysis in this field is related to three bodies of literature: (i) the literature linking fiscal policy to long-term growth and short-term income fluctuations; (ii) the literature on the growth-pollution relationship; and (iii) a small but growing literature on the effects of fiscal policy on the environment. Since the literature examining the fiscal policy-growth is well-established and the growth-pollution relationship has been already reviewed in Section2, this section focuses on how fiscal policy affects environmental quality.

3.1. Fiscal policy and the environment

As already mentioned, economic theory identifies three main factors which are important for production and to promote economic growth sustainability, namely, physical capital, human capital and natural capital. Physical capital accumulation leads to economic growth and eventually enhances welfare. On the other hand, accumulation of human and natural capital not only contributes to growth by boosting total factor productivity and increasing investment returns, but these forms also consist direct components of welfare (Lopez et al. 2010).

Natural capital, which comprises natural resources and environmental quality, is considered a public good, since it is characterized by significant externalities. Inadequacy to internalize such externalities due to market failures, systematically leads to overexploitation of natural capital and degradation of environmental quality. Moreover, considering human capital, there are limited incentives for the private sector and often for the public sector to invest on that, since returns of investments on education, knowledge and health require several years to materialize. This inherent gap in the optimum accumulation of human and natural capital may ultimately imperil the sustainability of long-term growth. As discussed in the previous sections, when considering public goods and in the presence of externalities, there is a significant role for government policies and intervention.

3.1.1. The effect of fiscal policy on the environment

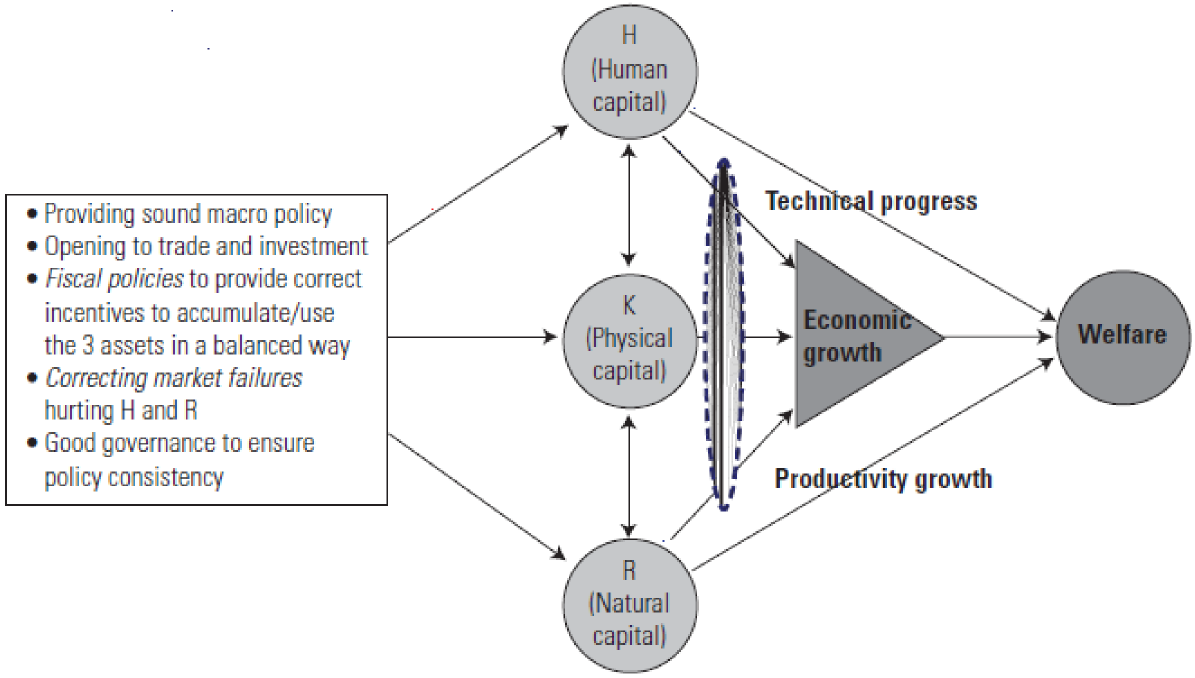
An important tool through which governments can alleviate the negative consequences of market failures and contribute to growth sustainability is the implementation of fiscal policy, especially taking into account that government expenditures often account for more than 30 percent of GDP. The mechanisms through which government expenditure and environment interact with each other were initially examined in theoretical papers by Heyes (2000), Lawn (2003) and Sim (2006).

More recently, according to Lopez et al. (2010), there are three reasons that render fiscal policy crucial in this framework. First, fiscal policy may determine the allocation of resources to human capital, physical capital and natural capital in an optimum way by creating appropriate incentives through expenditure and tax policies. Second, implementation of fiscal policy can generate macroeconomic expansions and contractions and determine intergenerational transfers through debt, social security, taxation on the use of natural resources and pollution and finally, by expenditures on mitigation and adaptation strategies. Third, there is also the possibility that fiscal policy may harm environmental quality. For example, government may succumb to lobbies and interest groups and offer subsidies and tax exemptions and thus, encourage resource extraction, depletion, and generation of emissions that contribute to the deterioration of environmental quality. This highlights the requirement for high institutional quality and political freedom that can promote good governance and help avoid bad practices.

Furthermore, five more ways through which fiscal policy can affect environmental quality may be additionally identified. First, as the size of government increases as a percentage of GDP, progressively the structure of production in the economy changes in favour of the service sector, which is less pollution intensive compared to the industrial and rural sectors. Second, government spending on public order and safety reinforces the protection of property rights which may in turn alleviate environmental externalities such as the overexploitation of natural resources and assist the enforcement of environmental regulations. Third, public spending in education and health can increase public awareness regarding the adverse effects of environmental pollution and therefore increase demand for improved environmental quality. Moreover, a greater educational level may also contribute to the control of population growth rate that can reduce environmental pressures. Moreover, if the environment is considered a luxury public good, it is likely that it will only be demanded when the demand for other public goods has been satisfied, i.e. at large levels of government size (Frederik and Lundström, 2001). Finally, investment in infrastructure, such as the public transportation system, can reduce environmental degradation by encouraging more environmental cleaner methods of production and consumer behaviour.

In addition, it is important to mention that each one of the above ways through which fiscal policy may affect environmental degradation, may also interact with economic growth and therefore can influence environmental quality indirectly through this channel. These interrelationships are depicted in Figure 4.

Figure 4: Framework for sustainable growth



Source: Lopez et al. (2010-p8, originally from Thomas et al., 2000).

3.1.2. Decomposing the effect of government expenditure on pollution

Despite the potentially significant implications of fiscal spending on environmental pollution, it is surprising that this relationship was not considered in the literature and only recently theoretical and empirical studies have systematically started to explore it. A comprehensive review of the related theoretical works and empirical evidence in the literature is presented in the respective sections of Chapters 3-5 of this dissertation.

It is important however to mention at this point, that the mechanism through which government expenditure may affect environmental degradation is expected to differ, according to the generating source of the pollutants and in particular whether they are production or consumption generated. These differences are important since they can influence the magnitude and the significance of the estimated effect of government expenditure on different indicators of pollution. The theoretical underpinnings of this relationship are hereby sketched, based on the models proposed by Lopez et al. (2011) and

Galinato and Islam (2014). Both these studies focused on the effect of the composition of government expenditure, i.e. of the share of public goods in total government expenditure, on the environment. In their research, public goods are defined broadly to include expenditures that complement rather than substitute for production in the private economy and comprise such functional categories of expenditure as spending on education, health, social security, transport, communication, public order and safety, housing and community amenities, environmental protection and finally, spending on religion and culture.

Effect on production-generated pollution

Lopez et al. (2011), using the terminology employed to decompose the effect of international trade on environmental quality, suggest four main mechanisms through which government expenditure can affect environmental pollution, as follows:

- **Scale effect**

Depending on the relationship between fiscal spending and economic growth, increased government spending may amplify or reduce environmental pressures.

- **Composition effect**

Government expenditure may favor human capital intensive instead of physical capital intensive activities which are more pollution-generating inputs, and therefore is likely to improve environmental quality by modifying the output mix of the economy.

- **Technique effect**

Government expenditure in education and health encourages the accumulation of human capital and is associated with greater labor efficiency. To the extent that human capital and physical capital are substitutes in production, it is likely that a greater provision of human capital would encourage more environmentally friendly production and therefore reduce the pollution per unit of output. Furthermore, government spending in R&D may further enhance knowledge diffusion and lead to the adoption of cleaner technologies.

- **Income effect**

Depending on the relationship between fiscal spending and economic growth, expenditures on public goods can also induce an income effect, according to which increased income raises the demand for improved environmental quality and thus more environmental regulation, which consequently may reduce pollution.

The analysis of Lopez et al. (2011) suggests that the effect of government expenditure on environmental pollution, ceteris paribus, is strictly non-positive when a) there is a larger output elasticity of public goods in the non-polluting sector compared to the polluting sector and b) the marginal utility of consumption is elastic[9]. Moreover, if both the above mentioned assumptions hold, a shift in fiscal spending from private subsidies to public goods is expected to cause a reduction in production-generated pollution.

Effect on consumption-generated pollution

Galinato and Islam (2014) recognized that the mechanism that connects consumption-generated pollution and government expenditure must consider the ways that government spending affects consumers' budget, income and prices. In particular, they suggested that government expenditure might affect consumption-generated pollution through the following two channels:

- **Scale effect[10]**

Fiscal spending on sectors like health and education increases the current and future income of households and may in turn lead to an increase of consumption pollution.

[9] The assumption that the elasticity of consumption is greater than 1 is supported by several studies. For example, see Evans (2005).
[10] It should be noted that Galinato and Islam (2014) define this effect as *income effect*; however we refrain using this definition here, in order to avoid confusion with the income effect on production-generated pollution which tends to reduce environmental pollution. For a similar approach see Islam and Lopez (2015).

- **Regulations effect**[11]

Government expenditure encourages the development of institutions and therefore the establishment and enforcement of environmental regulations which enhance environmental quality (Fullerton and Kim 2008). For example, such a regulation is the introduction of a pollution tax which changes the output price of a good.

<u>Other relevant channels</u>

Furthermore, the following two mechanisms are expected to be significant in both production- and consumption-generated pollution and interact with the effect of government expenditure on environmental quality:

- **Governance quality**

Galinato and Islam (2014) emphasize the importance of governance quality in this framework. In particular, they suggest that in democratic regimes, where it is more likely to adopt stricter environmental instruments compared to non-democratic administrations, the effect of environmental regulations has been found to dominate that of the scale effect and therefore lead to a reduction of consumption pollution. Likewise, it is expected that enhanced institutional quality may reinforce also the alleviating effect of government expenditure on production-related pollution.

- **Special interest groups**

Special interest groups that support a large government in order to gain private benefits can lead to environmental degradation, particularly if the dominant special interest groups are not promoters of environmental quality and influence the strictness of environmental regulation the government imposes (Mueller and Murrell 1986; Bernauer and Koubi, 2013; Galinato and Islam, 2014). In a related study, Bernauer and Koubi (2009) reported that labour union strength is negatively associated with air pollution, a finding that is

[11] This effect is also relevant in production-generated pollution, however its importance is expected to be greater in consumption-related pollution.

consistent with this interpretation. The greater the strength of interest groups that tend to lose from stricter environmental policies, the higher the environmental degradation is likely to be (Bernauer and Koubi, 2009). This mechanism may influence the effect of government expenditure on pollution since the existence of such groups is associated with greater government size as pointed out by Mueller and Murrell (1986) and Sobel (2001).

4. Conclusions and future research directions

The empirical literature provides controversial evidence concerning the sign of the effect of government size on pollution. In an early study, Frederik and Lundstrom (2001) suggested that greater economic freedom, in terms of lower government size, reduces CO_2 emissions when the size of government is small, but increases emissions when the initial size of government is large. In a related work, Bernauer and Koubi (2013) found that an increase in the government spending share of GDP is associated with more air pollution and this relationship is not affected by the quality of the government. In addition, several studies provide a theoretical basis for determining the effect of government expenditure on pollution, emphasizing the importance of fiscal spending composition (Lopez et al., 2011; Galinato and Islam, 2014).

In particular, these studies have shown that a reallocation of government spending composition towards social and public goods reduces pollution while increasing total government size, without changing its orientation, has a negative or non-positive effect on environmental pollution. Given this background, there is still scope for future research that explicitly examines several dimensions of this relationship that have not been sufficiently considered in previous studies.

First, as already mentioned, there is established evidence on the link between fiscal policy and growth, as well as on the relationship between growth and pollution. These relationships imply that fiscal policy, to the extent that it affects economic growth, might also indirectly influence environmental quality through this channel. However, existing research, with the exception of Halkos and Paizanos (2013), ignores this mechanism and therefore the reported results in the literature capture only part of the effect of government expenditure on pollution.

In addition, it is well documented that environmental quality is influenced by various other factors, apart from fiscal policy and economic growth, including political institutions, population, trade and investment (Grossman and Krueger, 1995; Halkos, 2013a; Bernauer and Koubi, 2009; Zhu and Peng, 2012; Cole and Elliott, 2003). Some of these characteristics may interact with government expenditure and influence its effect on environmental quality. In this regard, it is highly unlikely that the effect of government spending on pollution is independent from country specific characteristics. For example, Galinato and Islam (2014) have given credibility to the hypothesis that the magnitude of the direct effect of government expenditure on pollution depends on whether a specific country has a democratic or autocratic regime.

Furthermore, the level of economic development might also affect the magnitude of the relationship between fiscal spending and environmental degradation. Nevertheless, all but one[12] of the studies that examine the direct effect of government expenditure on environmental quality, report a unified estimate based on a world sample of countries. Since this approach may lead to omitted variable bias, future research should identify and estimate the distinct channels which may influence the direct effect of government spending on pollution.

[12] Galinato and Islam (2014).

Another interesting aspect to explore is how the effect of fiscal policy varies according to the different characteristics of the pollutants. The mechanisms through which fiscal policy affects pollution might differ according to the source of pollution, i.e. whether pollution is production- or consumption-generated (McAusland, 2008; Lopez et al., 2011; Galinato and Islam 2014). Furthermore, depending on the atmospheric life characteristics and geographical range of the effect of different pollutants, emissions externalities may range from local and immediate to those that are global and occur mostly in the future (Shafik, 1994; Cole, 2007).

However, only one study (Islam and Lopez, 2015) takes into account these important distinctions and reports estimates on both production- and consumption-generated pollutants, however all the pollutants used in that work refer to local environmental degradation. Further analysis should incorporate several indicators of environmental degradation and therefore report estimates, on each of the aforementioned categories of pollutants, which can be directly compared.

Furthermore, the empirical studies dealing with the effect of fiscal policy on the environment use reduced-form models and estimate the long-term effect of government spending. Thus, implicitly they make strong assumptions about the lack of correlation between government expenditure and other fiscal variables which are excluded from the model, assumptions that would appear unlikely to hold in general, as pointed out by Blanchard and Perotti (2002). To alleviate such concerns, future research could focus on drawing structural conclusions using Vector Autoregression methods which are solely based on minimal hypotheses about the signs of the impacts of certain shocks (Faust, 1998; Canova and de Nicolo, 1998; Uhlig, 2005; Mountford and Uhlig; 2009). This approach has the additional advantage to provide insights regarding the short-term interrelationships between fiscal policy and environmental degradation. Such analysis could also offer indications regarding the effect of a tax-cut based fiscal expansion on the environment.

Finally, the empirical analysis should employ appropriate econometric techniques in order to take into account the dynamic nature of the examined relationships. In particular, when large N and T dimensions data are employed, non-stationarity and the potential dynamic misspecification of the pollutants equations should be explicitly considered (Halkos, 2003; Christopoulos and Tsionas, 2004). Static models, which are used in the majority of the works in this literature, assume that adjustments to any shock occur instantaneously, however this could only be justified in equilibrium or if the adjustment mechanism is rapid and is highly unlikely, considering that the return to long-run equilibrium emission levels can be relatively slow (Perman and Stern, 1999).

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