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Environmental taxes, reforms and economic growth: An empirical analysis of panel data

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Abstract

This paper explores the relationship between environmentally related taxes and the economic growth rate. The analysis also investigates whether this relationship differs between countries that have implemented environmental tax reforms (ETRs) and those that have not. Using panel data from 31 OECD countries over the period 1994-2013, the paper finds that when we allow environmentally related tax revenues to interact with an initial level of real GDP per capita, the overall revenues of these taxes are negatively associated with the economic growth rate in the short and long term. Furthermore, we show that the higher the initial level of GDP per capita, the more environmentally related tax revenues can promote the economic growth rate. The analysis also reveals that the relationship between environmentally related tax revenues and economic growth varies between countries that have a mechanism to redistribute environmentally related tax revenues and those that do not.

Keywords: Environmentally related taxes, Environmental tax reforms, Economic growth, Multiple imputations

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1. Introduction

Over the past two decades, all OECD countries have introduced environmentally related taxes to a varying extent in order to reduce pollution and greenhouse gas emissions. Also, in the early 1990s, some of them started implementing environmental tax reforms (ETRs) based on a “revenue recycling system” that shifts the tax burden from labor, personal and corporate income to environmentally harmful activities (EEA, 2005, 2011). The revenues from environmentally related taxes are used, for example, to decrease labor taxes or social security contributions, with a view to stimulating employment and promoting economic growth.

In the recent literature, the impact of environmental taxes on economic growth has been widely debated at a theoretical level. However, there is disagreement on the short- and long-term effects of environmental taxes on economic growth and little empirical evidence on this topic has been examined to date. In this paper we make an empirical contribution to the debate about the relationship between growth and environmental tax. We believe that exploring the nature of the relationship between environmentally related taxes and economic growth is an important issue, as it shows whether the use of tax as an instrument for environmental policy has any correlation with economic growth, and whether this is positive or negative. The available data on this topic is not abundant, as the OECD statistics only provide data on the revenue generated from environmentally related taxes but not on their rates. Therefore, we use this revenue as a proxy of environmentally related taxes, and our analysis focuses on the total revenue of these taxes. According to the data provided by the OECD, the overall revenue of environmentally related taxes in the OECD zone has increased from 420.754 billions US\$ in 1994 to 786.134 billion US\$ in 2013. This significant rise in revenues makes us wonder whether the nature of the relationship between environmentally related taxes and economic growth is sensitive to the level of revenue generated from these

taxes. In other words, we want to explore whether there is a non-linear relationship between these revenues and the economic growth rate. On the other hand, and during the negotiations of the Paris Agreement (2015), a dispute between developing and developed countries has emerged on the responsibility for the accumulation of carbon dioxide in the atmosphere during the nineteenth and twentieth centuries. The developing countries consider themselves not to be responsible for these emissions and argue that the measures envisaged today should not be barriers to economic growth when they are just beginning to reap its benefits. This motivated us to suppose that the nature of the relationship between environmentally related tax revenue and the economic growth rate may depend on the country's initial level of GDP per capita, justifying this as follows: according to the three-sector theory, when the level of GDP per capita increases, the share of agriculture and industry in GDP declines in favor of an increase in the share of services. This means that when the initial level of GDP per capita is low, the contribution of agriculture and industry in GDP will be high. As the inputs of the production process in these two sectors rely heavily on physical capital and raw materials, like machinery, equipment, fossil fuels and electricity, the production will lead to a high level of pollutant emissions and pollution, forming a broad tax base of environmental tax. Thus, the introduction of an environment tax in countries with a low level of GDP per capita will harm economic growth by increasing the cost of inputs of production in these two sectors. This situation may be reversed in countries that have a high level of initial GDP per capita, where the contribution of agriculture and industry in GDP declines compared to the service sector. In this case the production process depends on human capital more than physical capital and raw materials, leading to a decrease in pollutant emissions. In addition, rich countries have a high capacity for improving energy use efficiency and the productivity of physical capital in the agriculture and industry sectors, and thus reduce pollutant emissions that are the tax base of environmentally related taxes. For these reasons, the initial level of a country's development

measured by the initial level of GDP per capita can affect the nature of the relationship between environmentally related taxes and economic growth.

On the other side, and in light of the wave of environmental tax reforms that started in the early 1990s in a number of OECD countries, the majority of theoretical studies suppose that these reforms will generate a positive impact of environmental tax on economic growth (see Bovenberg and Smulders, 1995; Goulder, 1995; Bovenberg and Mooij, 1997; Fullerton and Metcalf, 1997; Bosquet, 2000; Markandya, 2005). They assume that shifting the tax burden from income, employment and investment to pollution, waste and resource depletion can achieve a ‘double dividend’, i.e. an improvement in environmental quality coupled with an economic benefit: revenues generated from environmental taxes could be used to cut distorting taxes on labor and capital and thus reduce the excess burden of the tax system, with positive consequences for employment and investment and thus for economic growth. However, there is no empirical study to date that shows whether the nature of the relationship between environmentally related taxes and economic growth differs between countries that made these reforms and those that did not.

Consequently, the main contributions of this study to the literature comprise four aspects. First, we used a new database constructed by the OECD on the revenue generated by environmentally related taxes. Second, we apply an innovative econometric approach not yet used in the existent literature, namely the correlated random effect panel data model. Third, the multiple imputation method was used in order to complete the missing data. This method has improved data quality. Finally, we empirically answered the following three questions: Are the overall environmentally related tax revenues associated with the economic growth rate in the short and long term? Is this relationship sensitive to the level of revenue generated from environmentally related taxes or to the level of other variables in the economy? Does the

relationship between overall environmentally related tax revenues and the economic growth rate differ between the countries which have implemented ETRs and those which have not?

To achieve our goal, the analysis is divided into two stages. The first stage is based on a sample of 31 OECD countries from 1994 to 2013. Then, using information collected from the academic literature, in particular Oueslati et al. (2017), and policy reports about ETRs, we divide the sample into two groups: the countries that have established ETRs over these years and those that have not. After that, we perform the same empirical analysis used in the first stage on these two samples.

The rest of the paper is organized as follows. Section 2 presents the literature review of environmental taxation and economic growth. Section 3 provides an overview of the development in GDP per capita growth rate and different environmentally related tax revenues in OECD countries over the last two decades. Section 4 describes the empirical strategy including the model and data used. In Section 5, we discuss the empirical results on a short- and long-term basis. The last section concludes the paper by summarizing the main findings.

2. Literature review

Environmental taxation could achieve the desired environmental improvement at minimum cost to society at large (Baumol and Oates, 1971). It has now become a principal approach to justify environmental taxes (Ekins and Speck, 2011). However, the debate about the effect of these taxes on economic growth is still a contentious issue among researchers to date. The existing research has used a number of different models to address this question. Bovenberg and Heijdra (1998), using an overlapping generations model and modeling the quality of the environment as a durable consumption good, found that an environmental tax increase will make future generations suffer from a smaller physical capital stock, but benefit

from a larger stock of natural capital. This result is reversed with older generations. Thereby, in the long term, economic growth will decrease due to the low physical capital that the younger generation will have to work with. Similarly, Wang et al. (2015), based on an overlapping generations model, show that pollution tax can reduce pollution but causes a distortion in the rate of return to capital and thus damages growth. In the same context, Siriwardana et al. (2011) built a computable general equilibrium (CGE) model to analyze the effects of carbon tax on the Australian economy. They found that Australia's real GDP may decline in the short term by about 0.68 percent after the introduction of a \$23 tax on carbon dioxide emissions. They explain the GDP contraction through four factors: (i) a reduction in energy consumption, which is estimated to be 2.65 percent, (ii) an increase in consumer prices (0.75 percent), (iii) a decline in real household consumption (-0.14 percent), and (iv) a reduction in export volumes (-3.00 percent).

In contrast, several papers demonstrate that environmental taxation policy may boost economic growth via a variety of channels. Lans Bovenberg and Smulders (1995), Ewijk and Wijnbergen (1995) and Lans Bovenberg and de Mooij (1997) propose that an environmental tax improves the quality of the environment, which increases the productivity of other productive inputs, and thus the total factor productivity of the economy, thereby stimulating economic growth. Based on the Uzawa–Lucas endogenous growth model extended by elastic labor supply, Hettich (1998) and Oueslati (2002) show that a higher environmental tax enhances long-term growth as follows: The increased environmental tax induces firms to raise their private abatement activities, which reduces final output net of abatement at the expense of household consumption. The reduction in private consumption in turn causes a substitution away from leisure towards time spent studying, which boosts human capital accumulation and thus growth. In addition, an environmental tax can lead to higher research intensity, as it induces a reallocation of resources towards R&D activities, which are an engine of growth

(Nakada 2004; Aloï and Tournemaine, 2011; Ambec et al., 2013). Similarly, Hart (2004, 2008) argues that environmental taxes encourage investment in emissions-saving technology and thus enhance growth. The relationship between environmental taxation and innovation have also been examined by the OECD (2010). The study confirmed that environmental taxation can and does increase innovation and the diffusion of environmental technologies. Some researchers have demonstrated that, by affecting health, pollution has a direct impact on long-term growth because it reduces the ability to learn (Gradus and Smulders, 1993; Ewijk and Wijnbergen, 1995; Vellinga, 1999; Withagen and Vellinga, 2001). They also argued that the environment does not influence the long-term accumulation of human capital if the direct impact of pollution on education is not taken into account. Contrary to this condition, Pautrel (2008) demonstrates that, when the long-run growth is driven by human capital accumulation, the effects of pollution on life expectancy may by themselves explain the influence of the environment on growth. In this case, environmental taxes can stimulate economic growth through decreasing pollution, which positively affects public health and increases life expectancy. The former will decrease the frequency of generation replacement and thus reduce the associated loss of knowledge. Therefore, this increases the aggregate human capital accumulation and the growth rate in the long term.

On the other hand, some theoretical research in this area shows contradictory effects of environmental tax levels on economic growth. For instance, with an overlapping generations model of growth and the environment, Ono (2003) demonstrates that, in the long run, environmental taxation has two opposing effects on economic growth. When the tax rate is high, the firms emit a lower flow of pollution, which leads to a higher quality of the environment bequeathed to future generations, implying a positive income effect. Thereby, the new generation can allocate a larger part of its resources toward savings (and investment) instead of pollution abatement activities, which increases the accumulation of productive

capital and then economic growth. On the other hand, a higher tax imposes a heavier burden on the firms. Therefore, the wages they pay their workers and the taxes paid to the government will decrease. This negative income effect causes a decline in savings and investment, thereby lowering the economic growth rate. In contrast, these effects are reversed with a low level environmental tax rate. In a similar context, but by using an overlapping generations model where long-run growth is driven by the accumulation of physical capital stock (AK model à la Romer, 1986), Pautrel (2009) shows that, when pollution does not affect life expectancy, the negative impact of the environmental policy on growth is limited if agents smooth their consumption over time, whereas when pollution affects life expectancy, the economic growth rate and environmental taxation describe an inverted U-shaped relationship.

Other theoretical studies suppose that the positive impact of environmental tax on economic growth can be generated not only via improving the quality of the environment but also through recycling environmental tax revenues. When the government uses these revenues to reduce the rates of distortionary taxes in the economy (such as income and labor taxes), economic growth is expected to have a positive effect from such a mechanism, through decreasing the negative effects of these taxes on labor supply, saving and investment decisions (see Bovenberg and Smulders, 1995; Goulder, 1995; Bovenberg and Mooij, 1997; Fullerton and Metcalf 1997; Markandya, 2005; Oueslati, 2014). Other scenarios of environmental tax reforms associated with a change in the structure of public spending have been proposed by Oueslati (2015). He finds that the use of environmental tax revenue to increase education spending has a greater positive impact on stimulating growth.

However, environmental tax can negatively affect economic growth in some cases, even with the existence of ETRs, through the following mechanism: A reform based on using energy tax revenues to reduce distortionary tax rates changes the relative costs of the products produced by all companies, and in particular by energy-intensive companies. This change

comes from increasing the costs of fossil fuels and decreasing the costs of labor and/or capital. Therefore, the net effect of these changes may be positive or negative according to the structure of labor, capital and fossil fuel consumption in the company. For instance, in energy-intensive companies that consume large amounts of energy while having a small labor stock, the compensation they receive via the reduction in labor tax or social security contributions may not fully match the additional energy costs. In this case, an environmental tax will increase the cost of production and thus harm economic growth, even with ETRs (Andersen et al., 2007). Goulder (1995) also suggests that the positive effect on GDP costs of using energy tax revenues to finance cuts in income taxes cannot be taken for granted, but depends on the level of pre-existing tax rates that are replaced by energy taxation. In the same context, Ekins et al. (2012) explore the implications – for Europe and the rest of the world – of a large-scale ETR in Europe designed to achieve the EU’s 2020 greenhouse gas reduction targets, i.e. cutting GHG emissions by 20% over the period 1990–2020 (or 30 % in the context of global cooperation). In order to investigate whether ETR could deliver these targets, they used two well-known macro-econometric models: E3ME and GINFORS. The results show that an ETR that meets the emissions target by imposing a tax on material inputs and recycling all the revenues through a reduction in employers’ social security contributions and income taxes would raise employment, lower resource consumption and have a small negative impact on GDP. This is driven by a reduction in labor costs, higher household incomes resulting from lower income taxes and higher employment rates, increasing the price of various products according to their direct and indirect carbon content and thus reducing price competitiveness on export markets. However, in other scenarios for the same model, when 10% of environmental tax revenues are spent on eco-innovation measures and the remaining 90% on recycling through a reduction in employers’ social security contributions and income taxes, the loss of international competitiveness is expected to be offset by gains in the international

trade sector through increasing the exports of renewable technologies (EEA, 2011). Consequently, the existence of ETR mechanisms can affect the economy through five channels: international trade, employment, human capital, investment and innovation.

Although numerous arguments have been provided regarding the effects of environmental tax on economic growth, the suggested results are often contradictory, and empirical evidence to support them is scarce. To the best of our knowledge, there is only one published econometric study about this topic, which is by Abdullah and Morley (2014). This paper evaluates the causal relationship between environmental taxes and economic growth, using the standard Granger non-causality approach. They find some evidence of a short- and long-run causal effect from economic growth to environmental taxes; nevertheless, there is little evidence of long-run causality in the other direction. These results show an ambiguous relationship between environmental tax and economic growth. It should also be noted that Abdullah and Morley (2014) do not distinguish between countries that have implemented environmental tax reforms and those that have not. Consequently, rather than studying the causal relationship, we investigate the nature of the relationship between environmentally related taxes and economic growth in the short and long term, including a large set of explicative variables of economic growth. In addition, part of our analysis will be concentrated on investigating whether the nature of this relationship differs between the countries that have implemented ETRs and those that have not. Furthermore, in order to complete our unbalanced dataset, we implement a multiple imputation method using an Expectation Maximization Bootstrapped algorithm.

3. Evolution of GDP per capita growth rate and different environmentally related taxes in OECD countries

Figure 1 demonstrates how the average GDP per capita growth rate in 31 OECD countries has evolved since 1994. The mean GDP per capita growth rate shows a rising trend from 1994 to 2000, reaching 4.18 % in 2000, from which it declined from 2001 to 2003 and then stabilized at 1.8% in 2003. After that we can see an increase to 3.57% in 2007, falling sharply in 2008 to stabilize at -4.57% in 2009, due to the latest world financial crisis in the U.S.A. After its recovery in 2010, it decreased again to -0.17% in 2012. In 2013 it increased to 0.38%. From these evolutions, we note that there are many fluctuations in the average of the GDP per capita growth rate in OECD countries during the period of study.

<insert Figure 1 here>

Figure 2 shows the evolution of the OECD average share of overall environmentally related tax revenues in GDP over the period of study (1994–2013). Based on the OECD categorization of taxed economic activities, the figure also presents the evolution of seven categories of environmentally related taxes: *Energy; motor vehicles and transport; ozone-depleting substances; water and wastewater; waste management; mining and quarrying*, and *other environmentally related taxes*. Overall, the share of environmentally related tax revenues in GDP shows many fluctuations during the period of study. From the figure the following observations may be made: (i) environmentally related tax revenues as a share of GDP show a rising trend over the period 1994–1999, increasing from 2.41% in 1994 to 2.61% in 1999. This rise in the aggregated measure comes mainly from the rise in the *energy, motor vehicle and transport, water and wastewater, waste management* and *other environmentally related tax* revenues share in GDP. In contrast, revenues from *ozone-depleting substances* and *mining and quarrying taxes* have decreased as a share of GDP in this period. (ii) During 2000–2001, environmentally related tax revenues as a share of GDP decrease to 2.55% in 2001. (iii)

Then they increased from 2.58% in 2002 to 2.62% in 2005. (iv) During the period from 2006 to 2008, they decreased sharply from 2.52% in 2006 until 2.38% in 2008. This comes mainly from the decrease in the *energy, motor vehicle and transport, water and wastewater, waste management and other environmentally related taxes*. (iiv) In 2009-2010, environmentally related tax revenues as a share of GDP increase from 2.40% in 2009 to 2.47% in 2010. (iiiv) During 2011-2013 they show a decreasing trend, falling from 2.45% in 2011 to 2.44% in 2013.

According to the OECD (2006), there are about 375 environmentally related taxes in the OECD countries. The evolution of these taxes has shown that the majority of revenue received comes from energy taxes and motor vehicle and transport taxes, whereas the rest constitute a small proportion of total environmentally related tax revenues.

<insert Figure 2 here>

4. Empirical strategy: Model and data

4.1 Empirical economic growth model

In order to explore the nature of the relationship between aggregate environmentally related tax revenues and the economic growth rate, we built a complete empirical growth model that controls the main drivers of economic growth according to the empirical and theoretical literature. The specification of this model is based on the Correlated Random Effects (CRE) approach developed by Wooldridge (2010). The CRE method is able to address the problem of endogeneity caused by the correlation between model variables and unobserved effects of time-invariant variables. It considers endogeneity as an unobserved heterogeneity problem without imposing any strict conditions or requiring any instruments (Bache et al., 2013). This method, as shown by Wooldridge (2010), is a reasonable way to

deal with endogeneity and lagged effects within a small N dataset. It also has the advantage of allowing the estimation of time and country trends. The explanatory variables in this approach are separated into three principal categories, as follows:

$$gr_{it} = \phi\lambda_t + \theta Z_i + \delta W_{it} + \eta_i + \varepsilon_{it} \quad (1)$$

where gr_{it} indicates the annual percentage growth rate of GDP per capita in country i and year t , λ_t is a vector of time dummy variables for years, Z_i is a set of time-constant observed variables; W_{it} represents a vector of control variables changing across countries and over time; η_i is the unobserved effects (heterogeneity) and ε_{it} indicates an error term. The (CRE) approach combines the fixed effects model, which assumes that there is a correlation between η_i and independent variables, with the random effects model, which supposes that the correlation between η_i and independent variables does not exist. In particular, the (CRE) approach models the relationship between $\{\eta_i\}$ and $\{W_{it}\}$, allowing arbitrary correlation between them as follows¹:

$$\eta_i = \Psi + \gamma\bar{W}_i + a_i \quad (2)$$

where Ψ is a constant, $\bar{W}_i = T^{-1} \sum_{t=1}^T W_{it}$, a_i is a time-constant component and $\text{Cov}(a_i, \bar{W}_i) = 0$. By replacing (2) in (1), the CRE estimating equation becomes:

$$gr_{it} = \phi\lambda_t + \theta Z_i + \delta W_{it} + \Psi + \gamma\bar{W}_i + a_i + \varepsilon_{it} \quad (3)$$

¹ In order to model the relationship between η_i and W_{it} , Wooldridge (2010) used the following hypothesis: as η_i is constant across time, it can be correlated by a simple linear relationship with the average values of W_{it} across time.

The similarity between equation (3) and the equation of random effects model (RE) emerges from the hypothesis that a_i is uncorrelated with (W_{it}) , whereas equation (3) looks like the fixed effects model (FE) through including the time-constant variables (Z_i) . Many advantages can be achieved by using the CRE model. Firstly, an international non-linear time trend in economic growth could be controlled by the term λ_t . This term takes into account international variations in economic growth that cannot be explained with the explanatory variables, but could, however, be correlated to them. For example, the 2001 and 2008 worldwide economic crises that affected growth may be partly estimated by these time dummies for years. Secondly, whereas the fixed effects model cannot estimate the effect of time-constant variables, the CRE model has the ability to measure their impact through the term (Z_i) . Thirdly, the CRE regression is robust towards heteroscedasticity and serial correlation in $\{\varepsilon_{it}\}$. This robustness comes from a “*cluster*” option used in the command that estimates the CRE equation in Stata software. This option produces consistent standard errors for linear panel models if the residuals are correlated within the cluster (Hoechle et al., 2007). Finally, the (CRE) approach is based on a simple test in order to choose between the random effects or correlated random effects estimator. The estimations will be the usual random effects estimates if $\gamma = 0$. The *Variable Addition Test (VAT)* is used to test this hypothesis and examines whether the averages of the explanatory variables changing across time are jointly equal to zero.

Consequently, the generic model that investigates the relationship between aggregate environmentally related tax revenues as a share of GDP and economic growth rate, in the short term, can be described as follows:

$$gr_{it} = \Psi + \beta_0 ETRT_{it} + \theta Z_i + \delta W_{it} + \gamma \bar{W}_i + \phi \lambda_t + a_i + \varepsilon_{it} \quad (4)$$

where $ETRT_{it}$ denotes the share of environmentally related tax revenue in GDP. In order to explore this relationship in the long term, we re-estimate equation 4 with the lagged values of all explanatory variables for five periods, each period being one year. To examine whether this association depends on the level of revenue generated from environmentally related taxes itself or on its interaction with the initial level of GDP per capita, we allow ETRT to interact with itself and with $\ln Y_0$. The first interaction term means that the revenue generated from environmentally related taxes is multiplied by itself (the square of revenue). This term allows us to know whether there is a non-linear relationship between these revenues and the economic growth rate. Therefore, the equation that answers the second question is as follows:

$$gr_{it} = \Psi + \beta_0 ETRT_{it} + \beta_1 (ETRT_{it} \times ETRT_{it}) + \beta_2 (ETRT_{it} \times \ln y_0) + \theta Z_i + \delta W_{it} + \gamma \bar{W}_i + \phi \lambda_t + a_i + \varepsilon_{it} \quad (5)$$

Then we re-estimate equation 5 with the lagged values of all explanatory variables for five periods, each period being one year, in order to answer the second question on the long term. This method allows us to know whether the revenue generated from these taxes over the last years are correlated with the economic growth rate in the current year. Moreover, this paper also aims to investigate whether the relation between environmentally related tax revenues and economic growth differs between countries that have established environmental tax reforms (ETRs) and those that have not. For this purpose, information about the implementation of ETRs in OECD countries in the examined period is collected through a literature review. We then use this information to build two groups of countries: those that have implemented ETRs, and those that have not. After that, we apply the same empirical approach used in equation (4) on the two groups, with the intention of identifying possible

differences in the relationships between environmentally related taxes and economic growth rates both in the short and long term.

4.2 Data

Panel data was chosen to study the nature of the relation between environmentally related tax revenues and economic growth for two reasons: firstly, the available data about environmental taxation, which according to OECD statistics ranges from 1994 to 2013, is not long enough for using time-series econometrics. Employing panel data will allow us to cover more observations and thus raise the statistical power and inference of the model. Secondly, Temple (1999) and Baltagi (2001) argue that panel estimators are the most appropriate choices for growth regression.

The sample used is annual data covering the period 1994-2013 for 31 OECD countries, namely Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Luxembourg, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom, which are considered for this panel analysis. Because data concerning productive expenditure variables for Chile, Mexico and the US are missing completely, we excluded these countries from our sample. The selection of the period was constrained by the availability of data on environmental tax revenues that have been newly introduced in most OECD countries and other explanatory variables.² The data was extracted from various sources: (i) Government Finance Statistics (GFS) published by the International Monetary Fund (IMF); (ii) World Development Indicators (WDI) published by the World Bank; (iii) The Organization for Economic Co-

² The environmental tax revenues data provided by OECD statistics cover the period 1994-2014. But as the data on human capital is available only until 2013, we decided to restrict our study from 1994 to 2013.

operation and Development (OECD). Data on human capital stock are from the Laboratory of Applied Economics in Development (LAED) at the University of Toulon (France). Online Appendix A includes a summary of the variables and data sources.

The dependent variable and the explanatory variables

The dependent variable is the economic growth rate, measured as the annual percentage growth rate of GDP per capita based on purchasing power parity (PPP) at constant 2005 U.S. dollars. As far as the control variables are concerned, we considered a broad set typically used in the empirical and theoretical growth literature. We classified them into five categories, as follows:

- *Environmental taxes*

According to Pigou (1920), *the optimal environmental tax* is one that equals between the marginal private benefit of emissions in production and the marginal social damage of emissions, while the international organizations define environmental tax as “a tax whose tax base is a physical unit (or a proxy of it) that has a proven specific negative impact on the environment” (United Nations et al., 2003).

The measure of environmental tax revenue in this paper is based on the United Nations definition, which is accepted by the main international organizations, such as the OECD and the Statistical Office of the European Union (Eurostat). The environmental tax revenue data, which is provided by OECD statistics, is comprised of taxes on *energy products* such as fossil fuels, electricity and transport fuel (petrol and diesel). This includes all CO₂-related taxes. Environmental tax revenue data also encompasses *motor vehicle and transport* taxes, which refer to one-off import or sales taxes on transport equipment, recurrent taxes on ownership, registration or road use of motor vehicles and other transport-related taxes (excluding transport fuel taxes). Recently, in 2016, new data concerning four categories of environmental

tax revenues were added to the OECD statistics. They are: (i) *ozone-depleting substances taxes*, such as chlorofluorocarbons (CFCs) and carbon tetrachloride; (ii) *water and wastewater taxes*, like taxes on water extraction, piped water, wastewater treatment; (iii) *waste management taxes*, for example, taxes on the final disposal of solid waste, on packaging (e.g. plastic bags); and (v) *mining and quarrying taxes*, which include mining royalties and excavation taxes (e.g. sand and gravel). The rest of environmentally related tax revenues that are not included elsewhere, e.g. hunting and fishing taxes, SO_x and NO_x emission taxes were classified into the category *other taxes*. In this study, we used the total revenue of all environmentally related taxes as a proportion of GDP, extracted from OECD statistics, to investigate the relationship between environmental taxes and the economic growth rate. This variable is coded as (ETRT).

- *Conditioning variables*

Three variables, usually used in the growth regressions literature as conditioning variables³, were selected to be included in this group of control variables: (i) the initial level of real GDP per capita measured by the natural logarithm of GDP per capita for each country in the year 1994. It is coded as $\ln y_{i0}$. The growth rate of real GDP per capita is related to the initial level of real GDP per capita in the standard growth model of Barro and Sala-i-Martin (2004). They predict that a country with a low level of initial income per capita relative to its own steady-state will tend to grow at a faster rate than a country that is already close to its long-run potential level of steady-state. As this variable is constant over time, it has been included in the category Z_i of equation (4). (ii) Total labor force growth rate (*TLF*). The population structure could influence economic growth through its impact on some determinants of growth such as investment and savings rate. (iii) Gross fixed capital formation as a percent of GDP was used to account for investment in physical capital. It is coded as (k).

³ The conditioning variables are the variables used in the Barro-type regressions (Kneller et al., 1999).

- *Human capital*

Human capital refers to “the knowledge, skills, competences and attributes embodied in individuals that facilitate the creation of personal, social and economic well-being” (OECD, 2001). On the connection between human capital and growth, endogenous growth models predict that human capital could affect growth through two distinct channels. On the one hand, human capital might accelerate growth through the externalities that originate from an educated labor force, which enhances the productivity of both labor and physical capital (Lucas Jr., 1988). On the other hand, human capital might affect growth mainly via innovation (Romer, 1986, 1990; Aghion and Howitt, 1992).

In an empirical growth application like those by Baldacci et al. (2008) and Chi (2008), changes in the stock of human capital and the initial level of human capital are usually used to capture the effect of human capital on growth. Consequently, we used the natural logarithm of the initial level of human capital ($\ln H_{t-1}$) and the annual change in human capital ($changeH$) to estimate the impact of human capital on the economic growth rate. We used the human skill index, published by (LAED) as a measure of human capital. Literacy rate, enrolment in tertiary education and mean years of schooling of adults were used to construct this index. As the data is annual, we are able to include the annual change of human capital in the model, whereas this possibility is not available with the data of Barro and Lee (2013), which was constructed for a 5-year age group.

- *Fiscal variables*

With regard to the relation between (non-environmental) fiscal policy and growth, three variables have been selected to capture the impact of this policy: productive expenditure (exp), distortionary taxation (tax), and fiscal balance ($Balance$). The productive expenditure is

defined as the sum of general government⁴ spending on education, health, public order and safety, housing and defense, all of which are measured relative to GDP. Following Kneller et al. (1999), Adam and Bevan (2005), Teles and Cesar Mussolini (2014) and Alcántar-Toledo and Venieris (2014), these elements are considered as productive expenditure, because they are used in order to form physical and human capital and thus stimulate growth. Other government spending on social protection, economic services, recreation and culture as well as “unclassified” spending, was not included in the specification, because these categories of expenditure are considered growth neutral (Barro, 1990; Kneller et al., 1999; Teles and Cesar Mussolini, 2014). We mainly took the data of productive expenditure from the OECD statistics and completed it with the Government Finance Statistics (GFS). The distortionary taxation was calculated as the sum of the taxes on income, profit and capital gains, payroll and workforce, as well as social security contributions as a percent of GDP. We consider these three measures of taxes as the main distortionary forms of taxation, because the revenue of environmentally related taxes, in most countries that have established environmental tax reform, has been used to reduce one or more of these three distortionary taxes. The presence of distortionary taxes in the model is very important when we study the effect of environmental taxation on the economy, because this reflects the level of pre-existing tax distortions (Bovenberg and de Mooij, 1994; Metcalf, 2000). As the non-distortionary taxation⁵ (tax on domestic goods and services) is assumed to have negligible growth effects (Barro, 1990; Kneller et al., 1999), we didn’t include it in the model.

⁴ “General government consists of central government, state government, local government and social security funds” (OECD, 2013, p.62).

⁵ Our division of taxes into distortionary and non-distortionary taxes has been inspired by Barro (1990), who suggests that the effects of taxes on economic growth depend on whether a tax is distortionary or non-distortionary. Distortionary tax is defined as a tax that has an impact on the saving/investment decisions of agents and hence distorts the steady-state rate of growth, whereas non-distortionary tax does not affect saving/investment decisions and thus has no effect on the growth rate.

The fiscal balance (surplus/deficit) “also referred to as net lending (+) or net borrowing (-) of general government, is calculated as total general government revenues minus total general government expenditure. Revenues encompass social contributions, taxes other than social contributions, and grants and other revenues. Expenditure comprises intermediate consumption, compensation of employees, subsidies, social benefits, other current expenditure (including interest spending), capital transfers and other capital expenditure” (OECD, 2013, p. 62).

- *Macroeconomic control variables*

Based on the literature of macroeconomic theory, we have chosen the inflation rate and goods trade openness as macro control variables. The Inflation rate (INF) is measured by the annual percentage change in the Consumer Price Index. This variable is considered a proxy of macroeconomic stability. It is expected to have a negative relationship with the economic growth rate. Openness to international trade of goods (OPENG) is defined as exports plus imports of goods in percentage of GDP. It is a measure of the extent to which a country is linked to the rest of the world. In general, trade liberalization promotes economic performance and is expected to be positively related to the economic growth rate.

As we indicated in Section 4.1, the expression W_{it} represents a vector of control variables varying across countries and over time. Therefore all the explanatory variables mentioned above (except $\ln y_{i0}$) are included in the category W_{it} , and their averages in the category \bar{W} , of equation (4). After identifying the variables used in this study and collecting their data, we used a multiple imputation procedure to treat missing data. Appendices B and C provide the details about this procedure. Table 1 shows the descriptive statistics of the variables before and after the multiple imputation process.

<insert Table 1 here>

As already mentioned, information about the implementation of a “revenue recycling system” was collected through a literature review. The reviewed literature includes articles published in academic journals, books and policy reports. The “revenue recycling system” shows three types of ETRs in which the revenues from environmental taxes were used to reduce those on labor or capital, financing renewable energy investment projects or other environmental protection initiatives. A full list of the identified ETRs and a summary of some of their characteristics are presented in Online Appendix I. For each reform, the appendix provides the main sources of environmentally related tax revenue and the primary channels via which these revenues were recycled. In addition, it also shows when ETRs were introduced and the references from which relevant information was collected.

To check the robustness of the model used in this study, first, using the QIC program, we verified whether certain or all of the four categories of control explanatory variables⁶ should be included in the CRE model. Online Appendix D shows this program. Secondly, in Online Appendix E, we studied the correlation matrix of variables and employed the Variance Inflation Factor (VIF) test to verify the absence of multicollinearity. Finally, in Online Appendix F, panel unit root tests were used to demonstrate that the time series of the economic growth rate (gr) and environmentally related tax revenues (ETRT) are stationary. Online Appendices B, C, D, E, and F present supplementary material. We found that all four categories of control explanatory variables should be included in the CRE model, that there is no multicollinearity, and that the time series of the economic growth rate and environmentally related tax revenues are stationary.

⁶ The four categories of explanatory variables are the variables that we have collected, in addition to environmental tax, as determinants of economic growth.

5. Results and discussion

Are the overall environmentally related tax revenues associated with the economic growth rate in the short and long term?

Following the *Variable Addition Test (VAT)* for equation 4 in the short and long term, (please see Online Appendix G for details of the tests), we reject the null hypothesis in the short and long term, therefore $\gamma \neq 0$. Thus, all the models have correlated random effects estimates.

First, the estimation results provide information about the appropriate multiple imputation models. We can use the number of Largest FMI (Fraction of Missing Information), displayed in the last row of Table 2 to see if the specified number of imputations is sufficient for the analysis. The rule is that " $M \geq 100 \times FMI$ provides an adequate level of reproducibility of MI analysis" (Stata Corp, 2013, p.48). In our study, the largest FMI is 0.16 for equation 4 in the short term, and 0.15, 0.08, 0.14, 0.19, and 0.15, respectively, for equation 4 in the long term. The number of imputations, 100, exceeds the required number of imputations: $16 (= 100 \times 0.16)$, $15 (= 100 \times 0.15)$, $8 (= 100 \times 0.08)$, $14 (= 100 \times 0.14)$, $19 (= 100 \times 0.19)$, $15 (= 100 \times 0.15)$. Therefore, $M = 100$ is sufficient for the analysis. Concerning the results associated with the analysis models, the estimation results of equation (4) are reported in Table 2. Column (1) includes the results in the short term, whereas columns (2) to (6) show the results in the long term for five lagged periods, each period being one year. The estimation results reveal that there is no statistically significant relationship between the overall share of environmentally related tax revenues in GDP and the economic growth rate in the short and long term. This result may be explained by discussing the following question: *Is this relationship sensitive to the level of revenue generated from environmentally related taxes or to the level of other variables in the economy?* Table 3 reports the estimation results of equation (5), which contains two interaction terms. The first

is between ETRT and itself, the second is between ETRT and $\ln Y_0$. The results reveal that when we allow these interactions to happen, the relationship between ETRT and gr becomes significant and negative in the short and long term.⁷ However, the results show that the first interaction term is statically insignificant, whereas the second is significant. We conclude that the effect of environmentally related taxes on the economic growth rate is not sensitive to the level of revenues achieved but to the initial level of the country's wealth. The results also show that the interaction term between ETRT and $\ln Y_0$ has a positive sign, indicating that the increase in environmentally related tax revenues leads to an increase in the economic growth rate as the initial level of a country's GDP per capita rises. This finding makes us wonder about the marginal effects of ETRT on the economic growth rate for countries with different levels of initial GDP per capita. To answer this question, we calculate the average marginal effects⁸ of ETRT at different quantiles of $\ln Y_0$. Table 4 shows the results of this calculation. We find that the marginal effects of ETRT differ greatly between $\ln Y_0$ levels. When the country has a low level of initial GDP per capita ($\ln Y_0 = 8.8634$), the average marginal effects of ETRT⁹ on the economic growth rate are negative in the short and long term. With the increasing level of $\ln Y_0$, the negative average marginal effects of ETRT decrease and these effects become positive when the country has a high level of initial GDP per capita ($\ln Y_0 = 10.7634$) in the short and long term.

⁷ In order to know whether the significance of ETRT comes from its interaction with itself or with $\ln Y_0$, we estimated equation (5) excluding the term (ETRT# $\ln Y_0$). We found that the coefficient of ETRT becomes insignificant. This means that the significance of ETRT comes from its interaction with $\ln Y_0$. The results of this estimation are available upon request.

⁸ For more information about the average marginal effects at specific values of explanatory variables, see Williams (2012)

⁹ As the coefficient of the interaction term (ETRT#ETRT) is not significant, we exclude it from equation 5 when we calculate the average marginal effects of ETRT. This allows us to calculate the marginal effect of ETRT on the economic growth rate taking into consideration only its interaction with $\ln Y_0$. In this case, $\frac{\partial gr}{\partial ETRT} = \hat{\beta}_0 + \hat{\beta}_2 \times \ln Y_0$.

<insert Tables 2 and 3 here>

These results allow us to propose a rule concerning the relationship between the initial level of GDP per capita, environmental taxation and the economic growth rate, which is: the higher the initial level of GDP per capita, the more environmentally related tax revenues can promote the economic growth rate. This rule could be justified through two factors: First, by assuming that environmentally related taxes lead to higher prices. However, with a higher level of GDP per capita, people have more discretionary income after paying for basic necessities and therefore have more ability and amenability to pay higher prices in return for a better environmental quality. Second, economic development leads to a shift from farming to manufacturing, which creates greater environmental degradation. However, increased productivity and rising real GDP per capita leads to a third shift from industry to the service sector. The service sector usually uses human capital more than physical capital. Consequently, introducing an environmental tax in countries whose economy depends on the services sector more than on manufacturing and farming¹⁰ could reinforce economic growth due to three elements: (i) improving the productivity of human capital, which is the main engine of growth in these countries, by improving people's health and their ability to learn through reducing pollution (Gradus and Smulders, 1993, 1996; Ewijk and Wijnbergen, 1995; Oueslati, 2002; Pautrel, 2008, 2009; Aloi and Tournemaine, 2011). (ii) Improving the quality of the environment, due to reducing pollution, may reinforce tourism, which is a principal component of the services sector. (iii) Rich countries have the ability to reduce the negative effect of environmental taxation on physical capital through improved technology and higher productivity.

¹⁰ See Online Appendix H.

<insert Table 4 here>

With respect to control variables and in order to know which equation we should use to interpret the findings, we ran the QIC program for equations 4 and 5. The best fitting model is the one that has the smallest value of the average of *QIC* (Cui, 2007). Table 5 reports the descriptive statistics of the QIC values.

<insert Table 5 here>

The best equation to interpret the results is equation 5, which has the smallest value of the mean of QIC (269654.8). We will first focus on the results obtained in the short term and then continue to discuss those concerning the long term.

In the short term, the estimation results broadly confirm our expectations about the relationship between the control variables and the economic growth rate. The analysis reveals that real gross fixed capital formation (% of GDP), annual change in human capital, and openness to international trade of goods are positively associated with the economic growth rate. In contrast, the productive expenditure and inflation rate are inversely related to the economic growth rate. The total labor force growth rate, the natural logarithm of the initial value of a country's GDP per capita, the natural logarithm of the initial level of human capital, distortionary taxation as well as fiscal balance do not seem to have a statistically significant relationship to the economic growth rate.

In the long term, the results from columns (2) to (6) indicate that $\ln Y_0$ and k have a negative association with the economic growth rate. In column (4), TLF appears to be negatively associated with the economic growth rate. This could be due to the very stable

nature of the labor force across the OECD countries relative to that in developing economies. We can clearly see that in the table with the descriptive statistics, where (on average) the annual growth rate of the total labor force is 0.009 percent, and its minimum value is -0.04, whereas the maximum value is only 0.1. Other results from columns (2) and (6) indicate that the variable that has the largest magnitude of positive relationship with the growth rate is *ChangeH*. An increase of annual change in human capital by 0.01 point is associated with a 21.764 percent increase in the economic growth rate when *lags* = 1, and with 20.098 percent increase when *lags* = 5. This can be explained by the dominance of the services sector, which mainly uses human capital, on the total output of developed countries. We can see this in Online Appendix H. Beginning in 1995, the value added in the services sector represents, on average, more than 60% of GDP in our sample of OECD countries. The productive expenditure appears to be negatively associated with the economic growth rate in column (6). This can be explained by two factors: inefficient use of money (Alesina et al., 2002) and/or “resource displacement” (Ramey, 2011). Government expenditure leads to the use of capital and/or labor and thus those resources are no longer available for private sector uses. The *tax* variable representing distortionary taxes is generally insignificant in this study. This tax variable is used as a control variable; therefore we have not fully commented on the magnitude of the coefficient. Interestingly, recent research did not find the same canonical results as Kneller et al. (1999) of a negative impact of (distortionary) taxes on economic growth for OECD countries. A recent paper by Durusu-Ciftci et al. (2018) shows that only consumption tax has a (small) statistically significant negative effect. Arin et al. (2017) also find no effect of distortionary taxes or other expenditures on economic growth using the same database. An explanation proposed by Durusu-Ciftci et al. (2018) is the hysteresis effect of taxation on income. Our model doesn’t allow us to take into account this heterogeneous effect. An extension with a more flexible econometric model (quantile regression or a finite

mixture model) may be worthwhile for future studies. The coefficient associated with *Balance* is negatively correlated with the growth rate when *lags* = 4 and 5. This could be due to the high level of deficit, which reaches -32.30 percent of GDP in some OECD countries (please see the descriptive statistics of the variables in Table 2). Finally, the coefficient of *INF* is negatively correlated with the economic growth rate during the five periods of lagged values for explanatory variables, whereas *OPENG* has a positive association with the economic growth rate only when *lags* = 1.

Does the relationship between overall environmentally related tax revenues and the economic growth rate differ between the countries that have implemented ETRs and those that have not?

Tables 6 and 7 show the results in the short and long term of equation 4 when it is estimated on two samples; a sample containing the 12 countries which have established “revenue recycling system” in the examined period and a sample including the other 19 countries. We refer to Oueslati et al. (2017), who provide some evidence on environmental tax reforms and the existence of differences between countries. Appendix I in the supplementary material shows how the reform has been implemented in countries that have applied it. For each reform, the Appendix provides the main sources of environmentally related tax revenue and the primary channels via which these revenues were recycled. In addition, it also shows when ETRs were introduced and the references from which relevant information was collected. The estimation results reveal notable differences between the two groups of countries. The association between environmentally related tax revenues and the economic growth rate, in the short and long term, is statistically insignificant in the countries that have not implemented ETRs, whereas this association is statistically significant and

negative in the countries that have implemented ETRs.¹¹ These results do not lend themselves as evidence of a negative effect of a “revenue recycling system” on the relationship between the economic growth rate and environmentally related tax revenues. They only show that there is a significant difference in this relationship between countries that have implemented ETRs and those that have not.

<insert Tables 6 and 7 here>

We think that the changes in distortionary taxes structure, energy efficiency improvements, and environmental protection projects due to the use of environmentally related tax revenues may have given a more important role to the ETRT effect on economic growth in the countries that have implemented ETR compared to those that have not.

6. Conclusions

In this paper we have provided empirical evidence on the macroeconomic relationship between environmentally related tax revenues and the economic growth rate in the short and long term. The analysis also investigates whether this relationship differs between countries that have implemented environmental tax reforms and those that have not. In order to complete an unbalanced dataset of 31 OECD countries from 1994 to 2013, we implemented a multiple imputation method with an Expectation Maximization Bootstrapped algorithm. In addition, information about the implementation of ETRs in the examined period is collected through a review of policy literature. The Correlated Random Effects (CRE) panel data model developed by Wooldridge (2010) was employed to estimate the effects. The empirical results

¹¹ In the long term, the association between environmentally related tax revenues and the economic growth rate is statistically significant and negative when the number of lagged period equals one, three and four.

reveal that there is no statistically significant relationship between the overall share of environmentally related tax revenues in GDP and the economic growth rate in the short and long term. However, when we allow ETRT to interact with $\ln Y_0$, this relationship becomes significant and negative, reflecting the importance of a country's development level in determining the nature of this relationship. Furthermore, we found that the higher the initial level of GDP per capita, the more environmentally related tax revenues can promote the economic growth rate. We believe that these results could be insightful to policymakers. Governments seeking to introduce environmentally related taxes or planning to increase these taxes in order to curb emissions should take into consideration the initial level of GDP per capita in order to promote the economic growth rate. More precisely, introducing environmentally related taxes in countries having a low level of initial GDP per capita (poor countries) will damage the economic growth rate, while these taxes could promote the economic growth rate when the initial level of GDP per capita is high (rich countries). Consequently, this finding validates the argument made by developing countries that using the tax as an instrument of environmental policy may constitute a barrier to economic growth when they are just beginning to reap its benefits. In this case, rich countries can provide financial and technological assistance to developing countries to help them reduce the negative effects of these taxes on their economies. Our results also reveal that the relationship between environmentally related tax revenues and the economic growth rate varies if there is a mechanism to redistribute the revenues generated from these taxes. In countries where such mechanisms are present, the association between environmentally related tax revenues and the economic growth rate is statistically significant and negative in the short and long term. Conversely, no significant association is identified between these variables when such mechanisms are absent.

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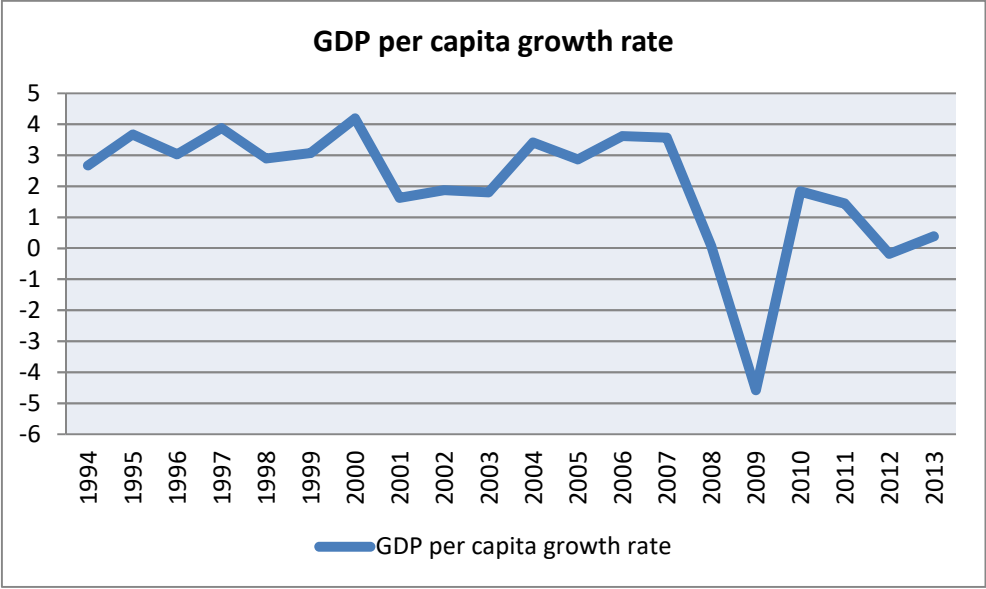
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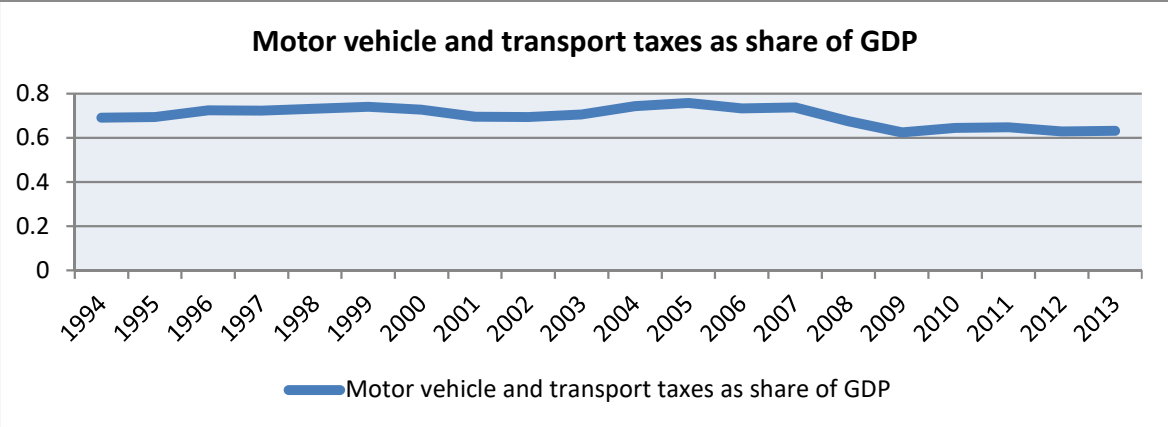
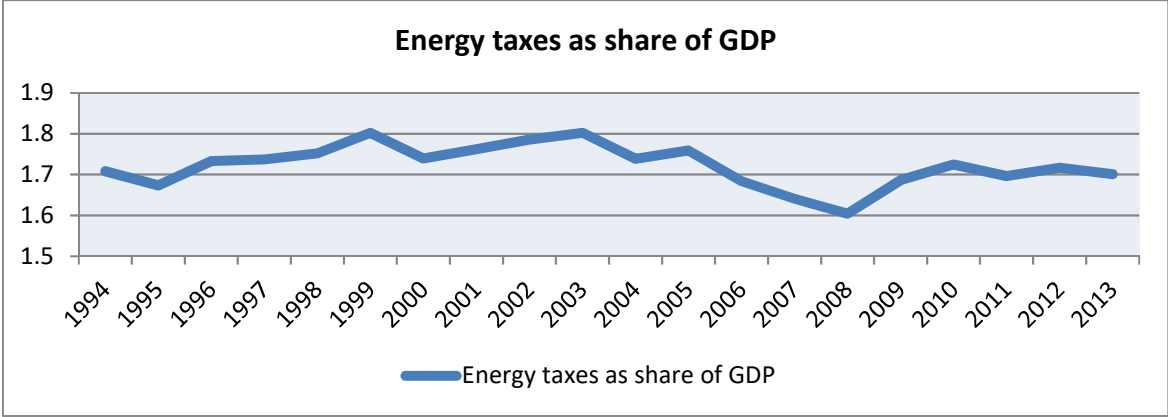
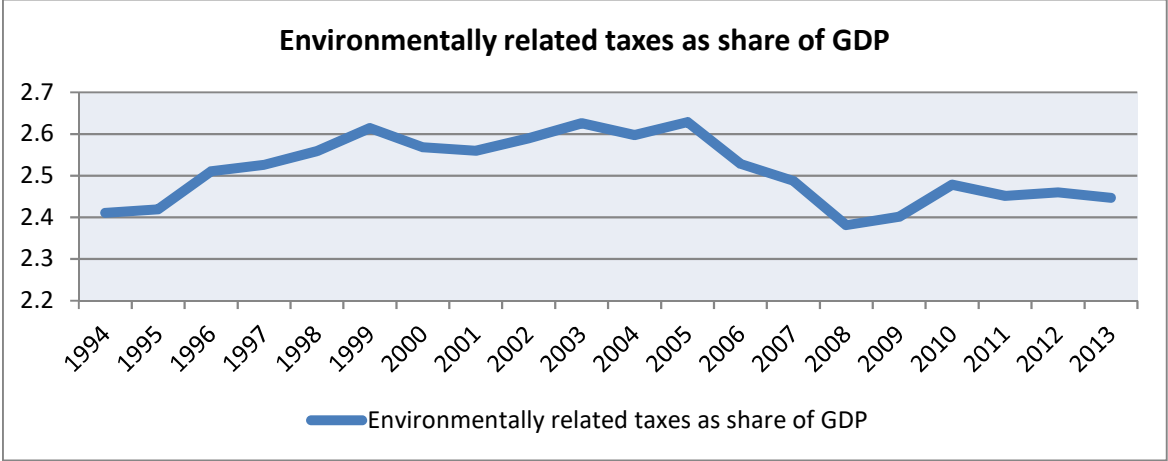
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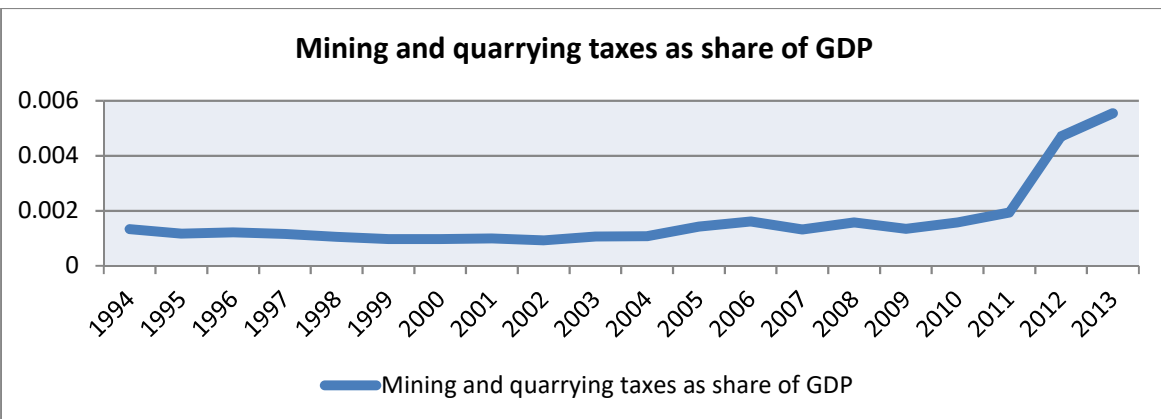
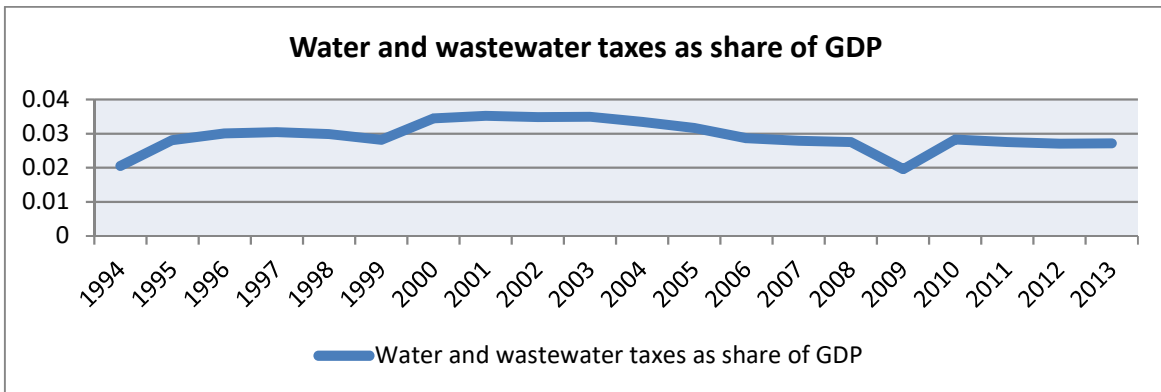
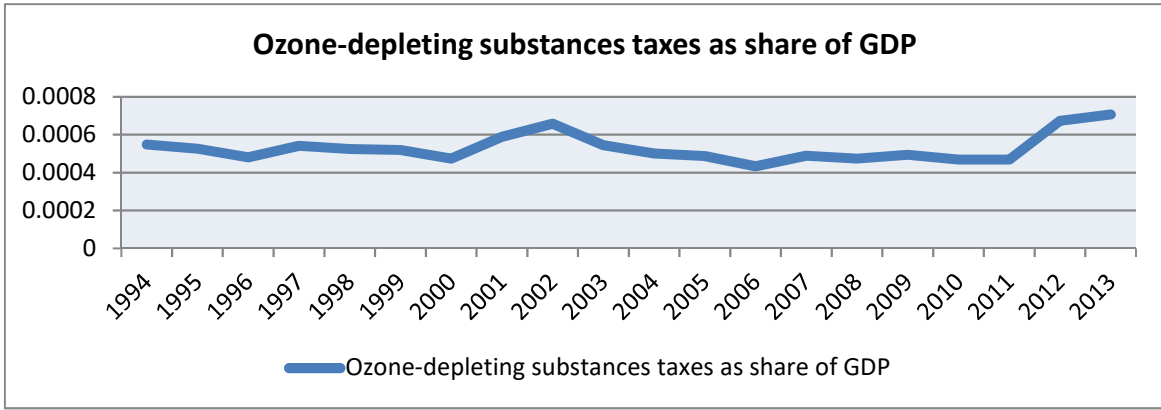
Figure 1. Evolution of GDP per capita growth rate over time 1994–2013, OECD average (31 countries)

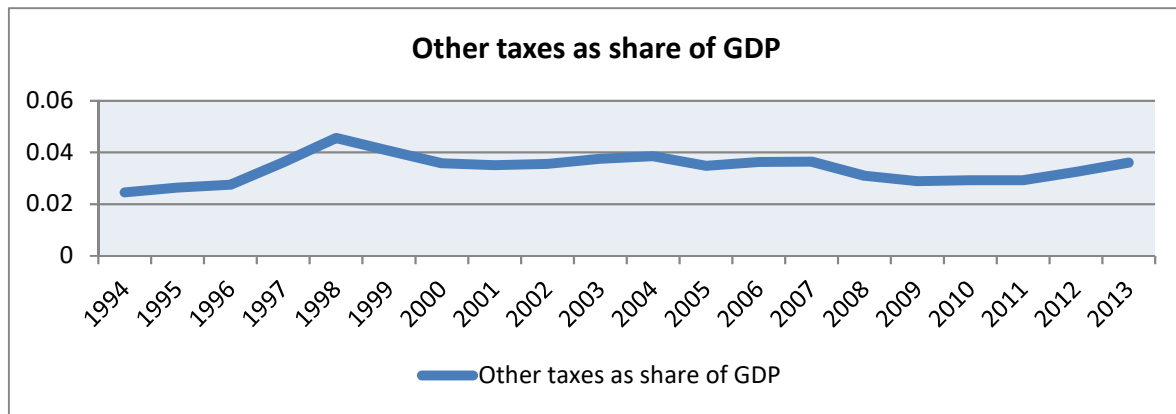


Source: Authors' calculations based on data from the World Bank database.

Figure 2. Evolution of different environmentally related taxes in the years between 1994 and 2013, OECD average (31 countries)







Source: Authors' calculations based on data from the OECD database on *Instruments used for Environmental Policy and Natural Resources Management*.

Table 1. Descriptive statistics

Variable	Before MI				After MI			
	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max
gr	2.0656	3.1079	-14.5730	18.6211	2.0650	3.1046	-14.5730	18.6211
ETRT	2.5123	0.7398	0.2673	5.3856	2.5123	0.7392	0.26739	5.3856
lnY0	9.9078	0.7269	8.4973	10.9642	9.9078	0.7263	8.4973	10.9642
k	22.741	3.9980	11.7114	37.1010	22.7556	4.0034	11.7114	38.6839
TLF	0.0093	0.0145	-0.0432	.120029	0.0093	0.0145	-0.0432	0.1200
lnHt1	-0.172261	0.080529	-0.4613222	-0.050980	-0.172261	0.080465	-0.4613222	-0.0509803
changeH	0.0047135	0.011161	-0.0155676	0.093833	.0047135	0.011152	-0.0155676	0.093833
exp	15.2256	2.6214	7.9412	24.0129	15.0619	2.6647	3.1398	24.3408
tax	21.6628	5.2969	6.78	34.969	21.6524	5.2800	6.78	34.969
Balance	-2.0096	4.5860	-32.3045	18.6959	-2.1325	4.6208	-32.3045	18.6959
INF	4.52710	9.6895	-4.4799	106.2627	4.5271	9.6818	-4.4799	106.2627
OPENG	67.6072	35.106	13.8653	181.4052	67.9994	35.2850	12.1120	181.4052

Table 2. Regressions of equation (4), in the short and long term

Dependent variable: Annual percentage growth rate of GDP per capita.

Variables	In the short term	In the long term				
	(1)	(2)	(3)	(4)	(5)	(6)
		Lags=1	Lags=2	Lags=3	Lags=4	Lags=5
ETRT	-0.125 (0.378)	-0.0178 (0.324)	-0.031 (0.345)	0.114 (0.485)	-0.133 (0.415)	0.0411 (0.539)
lnY0	0.084 (0.191)	0.057 (0.201)	0.089 (0.195)	0.206 (0.206)	0.273 (0.190)	0.294 (0.062)
k	0.181*** (0.072)	0.043 (0.067)	-0.137 (0.090)	-0.141* (0.076)	-0.182** (0.078)	-0.169** (0.062)
TLF	-1.733 (12.423)	3.579 (11.977)	-14.368 (9.873)	-18.072* (9.295)	-6.517 (11.0422)	-22.572 (14.685)
lnHt-1	6.557 (5.542)	-2.661 (8.072)	-1.936 (7.752)	-0.523 (8.156)	0.867 (8.131)	-0.728 (10.567)
ChangeH	31.347*** (10.156)	21.826*** (7.938)	-6.638 (15.679)	11.015 (10.109)	-18.391 (19.983)	20.219* (20.219)
exp	-0.244** (0.103)	-0.154* (0.094)	-0.065 (0.108)	-0.072 (0.126)	-0.133 (0.113)	-0.179** (0.092)
tax	-0.0171 (0.082)	0.080 (0.087)	0.023 (0.094)	0.0153 (0.100)	0.007 (0.094)	-0.028 (0.087)
Balance	0.070 (0.045)	0.032 (0.046)	0.0733 (0.049)	0.0004 (0.040)	-0.082* (0.050)	-0.125** (0.060)
INF	-0.077*** (0.017)	-0.039*** (0.013)	-0.036*** (0.013)	-0.043*** (0.0163)	-0.055*** (0.017)	-0.031 (0.022)
OPENG	0.037** (0.017)	0.029** (0.015)	0.003 (0.018)	0.003 (0.016)	0.005 (0.012)	0.003 (0.016)
Observations	620	562	521	481	444	402
Number of countries	31	31	31	31	31	31
Number of imputations	100	100	100	100	100	100
Largest FMI	0.16	0.15	0.08	0.14	0.19	0.15

Notes: *, **, and *** indicate significance levels at 10, 5 and 1%, respectively, based on the two-tailed test.

Standard error estimates are in parentheses. The dummy variables of time (λ_t), the averages of the variables that change across the time (\bar{W}_i) and a constant are included but not reported.

Table 3. Regressions of equation (5), in the short and long term

Dependent variable: Annual percentage growth rate of GDP per capita.

Variables	In the short term	In the long term				
	(1)	(2)	(3)	(4)	(5)	(6)
		Lags=1	Lags=2	Lags=3	Lags=4	Lags=5
ETRT	-5.550* (3.033)	-6.588*** (2.447)	-4.859** (2.271)	-4.047* (2.482)	-4.543 (2.980)	-5.913** (2.937)
ETRT#ETRT	-0.151 (0.165)	-0.087 (0.119)	-0.029 (0.128)	-0.108 (0.129)	-0.190 (0.143)	-0.266 (0.147)
lnY0	-1.356 (0.327)	-1.612** (0.673)	-1.120* (0.628)	-0.934 (0.695)	-1.029 (0.803)	-1.442* (0.841)
ETRT#lnY0	0.601* (0.327)	0.682*** (0.246)	0.483** (0.238)	0.453 (0.287)	0.530 (0.341)	0.701** (0.335)
k	0.176*** (0.069)	0.037 (0.070)	-0.142 (0.094)	-0.149* (0.079)	-0.183* (0.078)	-0.165** (0.061)
TLF	1.486 (12.788)	7.512 (11.110)	-10.957 (8.467)	-14.298* (8.781)	-3.144 (12.012)	-19.033 (14.513)
lnHt-1	7.099 (5.836)	-1.781 (8.340)	-1.615 (8.024)	-0.855 (8.553)	0.790 (8.298)	-1.523 (10.937)
ChangeH	31.791*** (10.166)	21.764*** (8.135)	-7.055 (15.766)	10.074 (9.668)	-18.565 (20.042)	20.098* (11.146)
exp	-0.248** (0.103)	-0.150 (0.096)	-0.061 (0.111)	-0.069 (0.130)	-0.141 (0.113)	-0.193* (0.095)
tax	-0.011 (0.092)	0.0425 (0.094)	-0.003 (0.092)	-0.008 (0.096)	-0.018 (0.091)	-0.050 (0.080)
Balance	0.063 (0.047)	0.023 (0.048)	0.064 (0.050)	-0.011 (0.039)	-0.091* (0.0480)	-0.142** (0.058)
INF	-0.079*** (0.017)	-0.042*** (0.012)	-0.038*** (0.015)	-0.046** (0.0167)	-0.053*** (0.018)	-0.036* (0.022)
OPENG	0.039** (0.016)	0.031* (0.015)	0.0041 (0.018)	0.004 (0.0171)	0.007 (0.012)	0.006 (0.015)
Observations	620	562	521	479	444	402
Number of countries	31	31	31	31	31	31
Number of imputations	100	100	100	100	100	100
Largest FMI	0.14	0.16	0.08	0.13	0.24	0.14

Notes: *, ** and *** indicate significance levels at 10, 5 and 1%, respectively, based on the two-tailed test.

Standard error estimates are in parentheses. The dummy variables of time (λ_t), the averages of the variables that change across the time (\bar{W}_i), and a constant are included but not reported.

Table 4. The average marginal effects of ETRT at different quantiles of lnY0 in the short and long term

		Short term	Long term				
			Lags=1	Lags=2	Lags=3	Lags=4	Lags=5
Quantile	lnY0 value	dgr\ d(ETRT)	dgr\ d(ETRT)	dgr\ d(ETRT)	dgr\ d(ETRT)	dgr\ d(ETRT)	dgr\ d(ETRT)
P(10)	8.863364	-1.0384	-0.8072	-0.4288	-0.7462	-1.1719	-0.9164
P(25)	9.339503	-0.7216	-0.5055	-0.2610	-0.4769	-0.7926	-0.5897
P(50)	10.18427	-0.1597	0.0298	0.0367	0.0008	-0.2834	-0.1511
P(75)	10.38708	-0.02489	0.1583	0.1082	0.1154	-0.1470	-0.0336
P(90)	10.76395	0.2257	0.3971	0.2411	0.3285	0.1064	0.18470

Source: Authors' calculations

Table 5. Descriptive statistics of the values of QIC for equations (4) and (5)

Variable	Obs	Mean	Std. Dev.	Min	Max
QICeq4	100	274738.8	472.8156	274213.1	277011.7
QICeq5	100	269654.8	522.4045	269000.1	271837.2

Source: Authors' calculations

Table 6. Regression results of equation (4) in the short term for countries that have implemented ETRs and those that have not

Dependent variable: Annual percentage growth rate of GDP per capita

Variables	Countries without revenue recycling	Countries with revenue recycling
ETRT	0.105 (0.383)	-1.862* (0.995)
lnY0	-0.090 (0.305)	5.553*** (2.064)
k	0.172*** (0.083)	0.201 (0.147)
TLF	-3.110 (15.557)	15.514 (17.409)
lnHt-1	2.987 (10.096)	11.010* (6.334)
ChangeH	34.798** (15.310)	17.979 (14.721)
exp	-0.179 (0.201)	-0.3087*** (0.081)
tax	0.008 (0.134)	0.012 (0.160)
Balance	0.118** (0.060)	-0.0485 (0.0961)
INF	-0.077*** (0.021)	-0.136*** (0.0437)
OPENG	0.023 (0.019)	0.088** (0.0466)
Observations	380	240
Number of countries	19	12
Number of imputations	100	100
Largest FMI	0.46	0.42

Notes: *, ** and *** indicate significance levels at 10, 5 and 1%, respectively, based on the two-tailed test. Standard error estimates are in parentheses. The dummy variables of time (λ_t), the averages of the variables that change across the time (\bar{W}_i), and a constant are included but not reported.

Table 7. Regression results of equation (4) in the long term for countries that have implemented ETRs and those that have not

Dependent variable: Annual percentage growth rate of GDP per capita

Variables	Countries without revenue recycling					Countries with revenue recycling				
	Lags=1	Lags=2	Lags=3	Lags=4	Lags=5	Lags=1	Lags=2	Lags=3	Lags=4	Lags=5
ETRT	0.191 (0.369)	0.166 (0.477)	0.464 (0.744)	0.236 (0.631)	0.028 (0.631)	-1.651** (0.822)	-1.111 (0.714)	-1.106* (0.690)	-1.210** (0.607)	-0.967 (0.906)
lnY0	-0.141 (0.076)	-0.198 (0.293)	-0.124 (0.270)	-0.023 (0.267)	0.162 (0.288)	7.309 (7.160)	7.814 (16.070)	-17.942*** (5.104)	-16.010 (17.072)	4.634** (1.882)
k	0.144** (0.056)	-0.040 (0.087)	-0.136 (0.099)	-0.216 (0.117)	-0.184* (0.100)	-0.210 (0.132)	-0.370** (0.174)	-0.206* (0.127)	-0.053 (0.117)	-0.020 (0.095)
TLF	5.855 (14.042)	-7.923 (11.558)	-14.358 (11.319)	-12.144 (12.416)	-20.786 (18.840)	-3.334 (11.445)	-32.016** (14.115)	-39.030** (18.421)	12.413 (20.894)	-19.743 (22.060)
lnHt-1	-15.963 (13.821)	-8.012 (13.784)	-2.730 (15.250)	0.610 (14.150)	-0.058 (15.876)	6.193 (8.373)	5.733 (9.636)	8.425 (9.077)	5.526 (10.969)	2.192 (13.561)
ChangeH	11.823 (11.836)	-23.591 (29.204)	10.697 (15.898)	-20.816 (32.146)	21.536 (18.430)	18.196 (14.607)	2.042 (10.341)	20.116 (22.019)	-1.351 (33.300)	22.398** (10.312)
exp	-0.125 (0.268)	-0.119 (0.256)	-0.057 (0.285)	-0.130 (0.254)	-0.197 (0.288)	-0.238*** (0.067)	-0.1645** (0.078)	-0.166 (0.104)	-0.118 (0.114)	-0.147*** (0.054)
tax	0.120 (0.143)	-0.013 (0.133)	-0.078 (0.131)	-0.040 (0.149)	-0.063 (0.108)	-0.053 (0.247)	0.051 (0.086)	0.161 (0.142)	0.197* (0.115)	0.029 (0.182)
Balance	0.009 (0.058)	0.056 (0.056)	-0.002 (0.052)	-0.0491 (0.083)	-0.137 (0.092)	0.015 (0.157)	-0.028 (0.087)	-0.066** (0.029)	-0.207*** (0.085)	-0.232* (0.138)
INF	-0.049*** (0.018)	-0.046* (0.024)	-0.037* (0.026)	-0.046** (0.025)	-0.049* (0.027)	-0.070*** (0.027)	-0.039 (0.042)	-0.168 (0.101)	-0.080*** (0.032)	-0.138* (0.045)
OPENG	0.034 (0.024)	0.009 (0.025)	0.007 (0.021)	0.007 (0.016)	-0.003 (0.012)	0.037*** (0.007)	-0.005 (0.023)	-0.010 (0.024)	0.008 (0.018)	0.045 (0.042)
Observations	344	318	292	269	243	215	203	187	175	159
Number of countries	19	19	19	19	19	12	12	12	12	12
Number of imputations	100	100	100	100	100	100	100	100	100	100
Largest FMI	0.14	0.15	0.21	0.25	0.18	0.68	0.59	0.68	0.40	0.52

Notes: *, ** and *** indicate significance levels at 10, 5 and 1%, respectively, based on the two-tailed test. Standard error estimates are in parentheses. The dummy variables of time (λ_t), the averages of the variables that change across time (\bar{W}_i), and a constant are included but not reported.