ΠΑΝΕΠΙΣΤΗΜΙΟ ΠΕΙΡΑΙΩΣ

UNIVERSITY OF PIRAEUS

Environmental Taxation

An empirical investigation of the relation of CO_2 emissions and environmental tax revenues in selected EU countries

Rempoutsika
Paraskevi

Supervisor: Athanasios Dagoumas

MSc in Energy: Strategy, Law and Economics

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Το έργο που εκπονήθηκε και παρουσιάζεται στην υποβαλλόμενη διπλωματική εργασία είναι αποκλειστικά ατομικό δικό μου. Όποιες πληροφορίες και υλικό που περιέχονται έχουν αντληθεί από άλλες πηγές, έχουν καταλλήλως αναφερθεί στην παρούσα διπλωματική εργασία. Επιπλέον τελώ εν γνώσει ότι σε περίπτωση διαπίστωσης ότι δεν συντρέχουν όσα βεβαιώνονται από μέρους μου, μου αφαιρείται ανά πάσα στιγμή αμέσως ο τίτλος.

November 2019

Athens, Greece

Abstract

Climate change is a critical issue of our days. In an effort to tackle climate change, Europe has set ambitious targets and policy designs. A significant aspect of EU's strategy for the mitigation of climate change is the implementation of environmental taxation and environmental tax reforms, in order to correct externalities and to influence a change of economic agents' behaviors towards polluting products and activities. Green taxes have a dual purpose, to protect the environment and social welfare and to raise revenues for the governments, as any tax. Under this prism, environmental tax reform could be enforced in a revenue-neutral scheme, where the increase of taxes levied on polluting activities or on excessive resource use could offset the reduction in income, labor taxes and social contributions.

In the first part of this thesis, the emphasis is given in the theory of environmental taxation and ETR, as well as the current status of environmental tax revenue in Europe.

The second part comprises of a statistical analysis of CO_2 emissions and environmental tax revenues in terms of GDP, of six EU countries. Then, an econometric approach follows, testing the causal relation between the two variables.

Keywords: environmental taxation, environmental tax reform, externalities, environmental tax revenues, CO_2 emissions

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The movement to address climate change is about something deeper than justice, it's about solidarity. Human solidarity."

—Bill McKibben

Abbreviations

CAT: Carbon added tax

EEA: European Economic Area

EFR: Environmental fiscal reform

EFTA: European free trade association

ESA: European system of accounts

ETR: Environmental tax reform

EU ETS: European Union's emissions trading system

EU: European Union

GHG: Greenhouse gases

GTR: Green tax reform

MAC: Marginal abatement cost

MBI: Market-based instruments

SDG: Sustainable Development Goal

TSC: Total taxes and social contributions

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1. Introduction

1.1. The concept of Sustainable Development

The first definition of Sustainable Development was introduced by the Brundland Report of the World Commission on Environment and Development in 1987, named Our Common Future. According to this report, Sustainable Development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs *(World Comission on Environment and Development, 1987*). The Brundland Report aimed at raising attention to the harmful effects of human activity and the severe impacts the patterns of production and development would cause, if were continued in the same way.

The global community is nowadays aware of the threat climate change imposes on our present and future, yet this consciousness didn't come the easy way. This long journey involved landmark decisions and agreements taken by the global key players. Although many of them didn't include legally binding measures, these agreements where the keystones in shaping global climate policy in order to tackle climate change.

The first international treaty that still is referred to as the most successful example of international cooperation, was the Montreal Protocol on substances that deplete the Ozone layer. The protocol was agreed in 1987 and it was finally ratified universally. As a result of the unanimous adoption of the treaty and its effective application, the ozone layer has started recovering.

The Montreal Protocol was followed by the Rio Declaration released by the United Nations Conference on Environment and Development, held in 1992. This declaration signed in the so-called "Earth Summit", set some principles concerning the achievement of sustainable development but, since it did not include legally binding provisions, it produced little tangible results. The most important feature of this declaration, for this thesis, is the reference to the Polluter-pays-principle in article 16, which has a fundamental role in international environmental law and taxation.

In 1998 the Kyoto Protocol under the United Nations Framework Convention on Climate Change was signed, which acknowledged the occurrence of global warming and committed its parties to implement measures to reduce greenhouse gases' emissions. Many countries withdrew from the agreement or did not intend to implement the measures requested.

In September 2015, the countries participating in the historic UN Summit adopted the 2030 Agenda for Sustainable Development and the 17 Sustainable Development Goals. The Agenda sets specific goals and actions to be taken in order to tackle climate change and the degradation of the environment, to eradicate poverty, to assure and promote peace. As it is mentioned in the document, "there can be no sustainable development without peace and no peace without sustainable development" (*United Nations, 2015).* The 17 SDGs focus on three aspects of Sustainable Development: the environmental, the economic and the social one.

Figure 1

Source: United Nations

The most important agreement ever made was the Paris Agreement under the UNFCCC, adopted in 2016 by 195 countries at the Paris Climate Conference (COP21). It is the first global climate deal with legally binding targets and measures. The parties agreed on holding the increase in the global average temperature to well below 2 °C above preindustrial levels and pursuing efforts to limit the temperature increase to 1.5 °C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change *(United Nations Framework Convention on Climate Change, 2016)*.

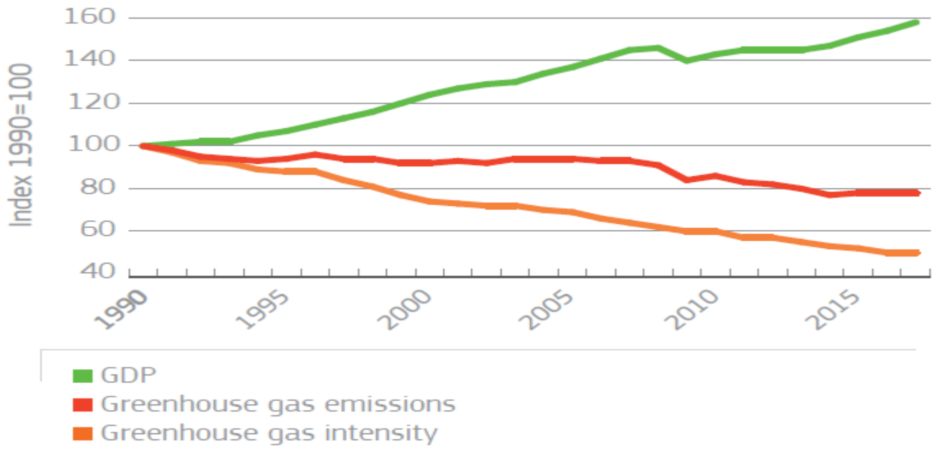
All these universal efforts and agreements put the protection of the environment and sustainable development in the center of the global attention, as the only way for the human legacy to be passed down to the next generations.

1.2. Europe's path for a sustainable future (2030)

In September 2015, when Europe signed the 2030 Agenda for Sustainable Development and the 17 SDG's, it fully committed itself to the implementation of the Agenda and is now a global key player in the fight against climate change. Europe is totally aware of the concept of sustainability and the three dimensions it comprises of- environmental, economic and social. Exiting the global financial crisis and its implications to European economies, the European Union aims in stimulating job creation through structural reforms, reducing inequalities, improving the life of the citizens and the human health, tackling waste and environmental degradation by setting high standards and adopting specific policies. Some of the sustainable policies the EU has adopted are the new European Consensus on Development, the Strategic Engagement for Gender Equality, the Circular Economy package, the Energy Union and the Bioeconomy Strategy. It is also worth mentioning the proposal of the Juncker Commission for a target of 25% of climate related expenses in EU's budget.

The EU has begun the transition to a low-carbon, climate-neutral, resource-efficient and biodiverse economy in full compliance with the United Nations 2030 Agenda and the 17 SDGs (*European Commission, 2019*). Europe is the living example that green policies and low-carbon transition can coincide with economic development, as it is shown in the following diagram. What is more, the EU promotes a set of instruments and policies in order for the low-carbon transition to succeed and the sustainable change to become a reality, such as promotion of research, innovation,

Figure 2



Source: European Commission, European Environment Agency continuous training and education, sustainable and green finance, environmental taxation.

1.3. The role of Environmental Taxation in Sustainable development and the Sustainable Development Goals

Generally, taxation has a major role in achieving sustainable development and 10 out of the 17 SDG's. More specifically, taxation in linked to sustainable development in four ways, which accordingly correspond to certain SDG's. First of all, taxes are the most important revenue for governments, which make use of their revenues to provide services to citizens and support the SDG's through the implementation of sustainable policies. As it has been proved, a minimum of 15% of GDP should be collected in taxes, in order for a government to be able to deliver basic services to its citizens (*Gaspar et al., 2016*). Taxation can influence and change people's behavior towards more environmentally friendly services and products and also impacts on economic growth, through the distribution of the tax burden among taxpayers. The last element that connects taxes and sustainable development is the trust to the governments generated by a fair tax system, which ensures social stability and therefore development of the society. Figure 3 demonstrates the relationship between certain SDG's and taxation.

Figure 3

Source: Report of the Conference of the Platform for Collaboration on Tax

As far as it concerns environmental taxation, its application can be linked to several SDG's and contribute in being achieved. To begin with, environmental taxation could change the behavior of citizens towards non environmentally friendly products and services. The integration and effective pricing of externalities can raise the price of harmful for the environment services and products while at the same time promote and increase the demand for sustainable products. Carbon tax can raise for example the demand for green energy, further taxing the diesel and gasoline cars can promote the use of electric cars. Through such measures, environmental taxation contributes in achieving certain goals such as Goal 7 (Affordable and Clean Energy), Goal 12 (Responsible Consumption and Production) and Goal 13 (Climate Action). At the same time environmental tax reforms, which will further be analyzed in the following chapter, and the subsequent swift of tax burden from labor to environmental factors, that are less distorting to growth, could stimulate job creation and growth (Goal 8-Decent Work and Economic Growth).

It is worth mentioning that according to an Eurobarometer survey, almost all European citizens agree that the polluter and not the citizens should bear the burden of repairing the damage they have caused to societies and the environment (*TNS political & social at the request of the European Commission,, 2017*). This is the basic principle of environmental taxation- the polluter-pays principle.

2. Environmental Taxation and Environmental Tax Reform

Environmental policy is high on the European political agenda due to the commitment of the EU to environmental protection and the achievement of sustainable development. The EU has set ambitious goals with regard to reducing GHG emissions, tackling climate change, protecting biodiversity, increasing the renewable energy in its energy mix and promoting sustainable production and consumption.

Economic instruments, or market-based instruments are a very important part of the European environmental policy and are intensively used for the achievement of its objectives, as advocated in the Europe 2020 strategy, the 6th and 7th Environmental Action Programme, the renewed Sustainable Development Strategy and the Reflection paper[1]. In the latter, the Commission highlights that EU tax systems and pricing should be designed to reflect real costs, address our main social and environmental issues and trigger behavioral change throughout the economy *(European Commission, 2019)*. Furthermore, the Commission calls for stricter implementation of the polluter-pays-principle and further internalization of externalities through tax systems. The main MBIs widely used are fees and charges, tradable permits and quotas, subsidies and environmental taxes. The benefits of environmental taxes are the discouragement of environmentally harmful behavior or activities, thus the reduction of pollution, and the reduction of resource use and exploitation.

Another issue which receives great attention in the European policy agenda is environmental tax reform, also called “green tax” reform. This tax-shifting program aims in increasing the revenues from environmental taxes and reducing revenues from labor taxes and social contributions. This, revenue-neutral tax shifting policy stems from the existence of studies, which have proved that environmental taxes create less distortions than taxes levied on labor and the income of corporations.

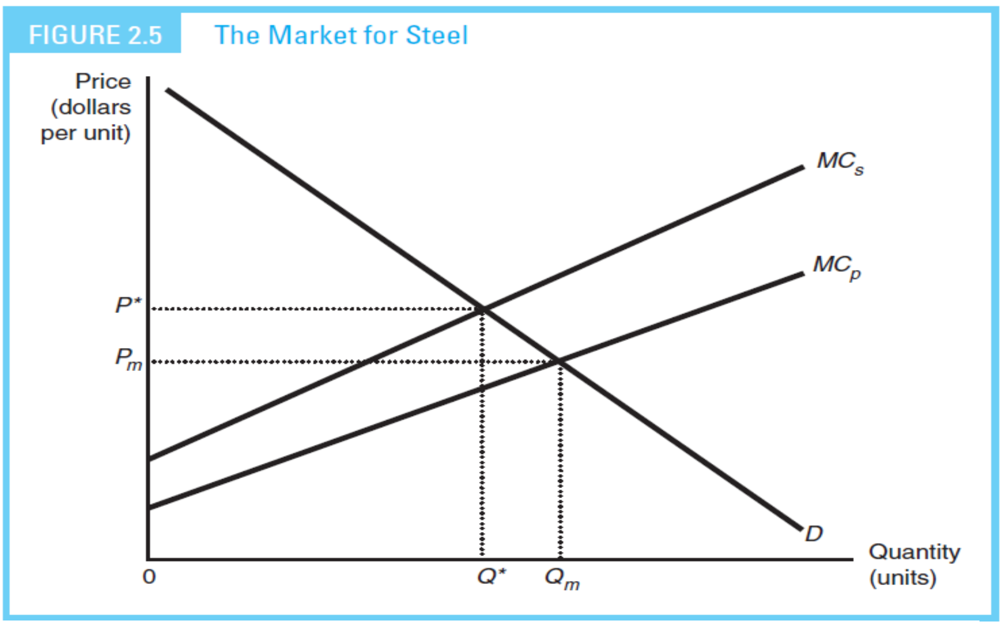
[1] European Commission, 2019. Reflection paper-Towards a Sustainable Europe by 2030, Brussels

2.1. The concept of externalities

Environmental taxes are introduced in order for the market failures caused by externalities to be corrected. An *externality* exists whenever the welfare of some agent, either a film or household, depends not only on his or hers activities, but also on activities under the control of some other agent *(Tietenberg & Lewis, 2012*). Externalities can be both negative and positive. A negative externality is a cost that one economic agent imposes on another without considering when making production or consumption decisions (OECD, 2001). Resource use and environmental pollution create externalities for the society and future generations. The environment is considered as a public good and as a result, the resources are overexploited. This is referred to the literature as "the Tragedy of the Commons". Due to the absence of property rights for the resources, the economic agents overexploit them and use them without taking into account the damage they cause to society. An example of an environmental externality is the air pollution caused by a coal-fired power plant. The pollution of the air damages the environment but also is harmful for the health of the citizens.

Market mechanisms do not reflect these external costs in the prices of goods and services, since conventional markets do not take the environmental damage into consideration. From an economic perspective, the producer of a harmful commodity considers as cost only the cost of producing the product as the Private Marginal Cost (MC_p) , while the society considers as Social Marginal Cost (MC_s) both the cost of

Figure 4



Source: Adapted from Environmental and Natural Resource Economics producing the product and the cost of pollution. This situation is depicted in Figure 4. We can conclude that the price of the good is lower and the quantity supplied is higher than it should be, in relation to the MC_s function.

This market failure further aggravates the situation. Since the prices of commodities causing pollution externalities do not internalize these costs, the prices are low, the output of the commodities are large, the pollution produced is large and no incentives are given for reduction of the pollution. This vicious cycle can be corrected by environmental taxation, which aims in internalizing these external costs in the prices of goods and services. When this internalization occurs and externality-generating goods' and services' prices reflect their true costs, the market reallocates the resources and the ensures the production of the good in an efficient quantity. This type of taxes that aim to correct market failures are called *Pigouvian Taxes*.

2.2. Pigouvian Taxation and Ramsey rule

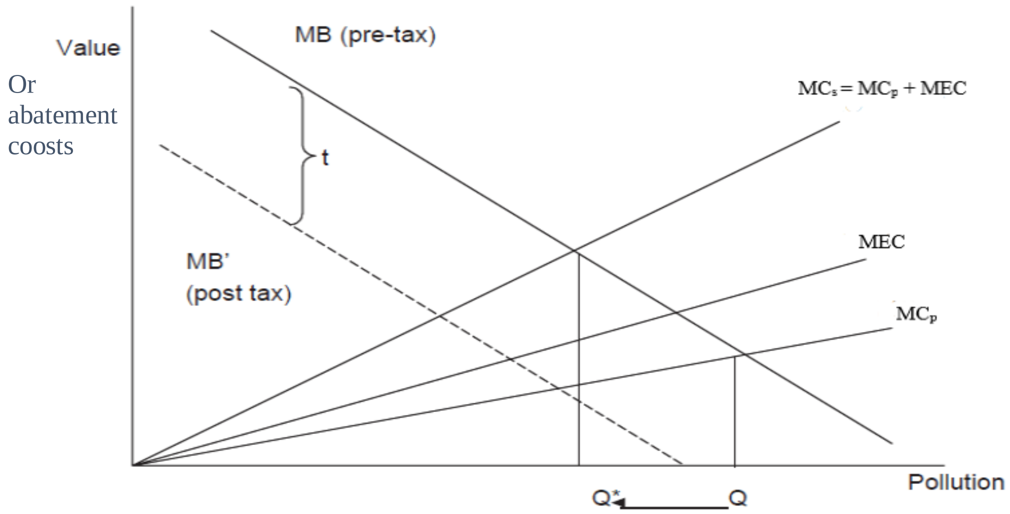
The basic idea behind the environmental taxes is credited to A. C. Pigou, who introduced back in 1920, the concept of corrective taxation. His idea is now considered as fundamental for environmental economics and public finance. Although he did not refer to environmental taxation, Pigou discussed the concept of externalities, both negative and positive, and the difference between social and private marginal costs. For negative externalities he proposed a tax system, which would correct the market failure and for positive externalities, he proposed the use of subsidies.

In the following figure, a simplified economic model demonstrates the deviations between private and social marginal costs and how corrective taxation functions. Corrective taxation drives pollution to a reduced, efficient level in which the marginal benefit from emitting an additional unit of pollution (in terms of abatement costs) equals the marginal social costs, generated due to this activity (OECD, 2001). In a conventional market without environmental taxes, the pollution produced is in the point Q, where MB equals MC_p.[2] The optimal Pigouvian tax, as mentioned before is the difference between MC_s and MC_p (the vertical distance between those functions, which equals to MEC at Q*. The tax moves the MB curve to MB' and as a result MC_p equals MB' at point Q*. This function of corrective taxes refers to the Polluter-Pays

[2] The downward slope of the MB function represents that the higher the pollution produced, the lower the abatement costs per unit of pollution.

Principle. According to this principle, the polluter pays and reimburses the society, for the pollution generated in the form of a tax. Therefore, Pigouvian taxes achieve the internalization of external costs into private costs and subsequently the prices of the externality-generating products.

Figure 5



Source: Environmentally related taxes in OECD countries, OECD

Taxes have a distributional role to the economy and society. Under this prism, lump-sum taxes[3] are not suitable, since they are not proportional to one's earning capacities (e.g. skills). Thus, taxes should be based on other variables such as income, wealth, consumption. However, these taxes create distortions to the economy. They create a deviation between the marginal rate of substitution in preferences and the marginal rate of transformation of production (Stiglitz, 2015). Sellers and buyers observe different prices, due to the deviation between pre and post-tax prices. The distortion of prices means that they do not reflect true costs and benefits. The distortion is caused by the fact that people substitute away from heavily taxed commodities. Therefore, they choose goods and services with lower taxation. The revenues lost from this substitution are called *deadweight loss*. This is a problem Optimal Tax Theory tries to correct or ameliorate.

Given the distortional character of taxes, Frank Ramsey (1927) proved that taxes should be set at a rate that will reduce the consumption of goods fairly, or

[3] Lump-sum taxes: A tax, the amount of which is not affected by behavioral variables of economic agents (work, income, consumption). These taxes are ideal and unavailable due to lack of information and other constraints.

equiproportionaly. What is now referred to as *Ramsey rule* is the result of his research that showed tax rates should be set inversely proportional to the elasticity of demand of a commodity. This is interpreted as follows: the more inelastic the demand the higher the tax rate and vice versa, the more elastic the demand the lower the tax rate. This minimizes the deadweight, as commodities with inelastic demand are more difficult to be substituted.

In an attempt to combine optimal tax theory and environmental externalities, Sandmo suggested that the final tax level should indeed be an average (weighted by the marginal cost of public funds) of the good's inverse price elasticity and the social benefits of reducing pollution associated to the good (Sandmo, 2011).

2.3. Definition of environmental taxes

The Regulation (EU) No 691/2011 provides the definition of environmental taxes. ***A tax whose tax base is a physical unit (or a proxy of a physical unit) of something that has a proven, specific negative impact on the environment, and which is identified in ESA as a tax***.

Thus, an environmental tax is imposed on activities and products that have a negative effect on the environment, are externality-generating, resulting in "correcting" prices which do not include the damage to the environment and society. Furthermore, the definition lays emphasis on the tax base, which is the most suitable basis for identifying if a tax is an environmental one, whether it is introduced for raising revenues for the state or for restricting a polluting activity or product by increasing its price. Although it is logical to assume that environmental taxes are those that the revenues produced are destined for financing environmental activities, this is only a subset of environmental taxes. This category is the taxes "earmarked" for environmental purposes. The definition of those taxes refers mainly to the use of the revenues and not on the tax base. For that reason, "earmarked" taxes could be imposed on tax bases different from those introduced on the definition of environmental taxes. Technically, "earmarked" taxes are environmental taxes whose revenues are dedicated to financing environmental activities. A case of an earmarked environmental tax is the French tax on air pollution ("taxe parafiscale sur la pollution atmosphérique", la TPPA), in force from 1985 to 1999. The revenues generated were earmarked for subsidies to abatement investments or for research and development (*Millock, et al., 2004*).

2.4. Environmental tax bases and main categories of environmental taxes

In 1997 Eurostat, the European Comission's Directorate General Environment, and Directorate General Taxation and Customs Union, the OECD and the IEA agreed and released a list, which was updated in 2011 and 2012, of environmental tax bases. The taxes imposed on the bases demostrated in the above list are environmental taxes.

Energy (including fuel for transport)

Energy products for transport purposes

• Unleaded petrol
• Leaded petrol
• Diesel
• Other energy products for transport purposes (e.g. LPG, natural gas, kerosene or fuel oil)

Energy products for stationary purposes

• Light fuel oil
• Heavy fuel oil
• Natural gas
• Coal
• Coke
• Biofuels
• Electricity consumption and production
• District heat consumption and production
• Other energy products for stationary use

Greenhouse gases

• carbon content of fuels
• emissions of greenhouse gases (including proceeds from emission permits recorded as taxes
in the national accounts)

Transport (excluding fuel for transport)

• Motor vehicles import or sale (one off taxes)
• Registration or use of motor vehicles, recurrent (e.g. yearly taxes)
• Road use (e.g. motorway taxes)
• Congestion charges and city tolls (if taxes in national accounts)
• Other means of transport (ships, airplanes, railways, etc.)
• Flights and flight tickets
• Vehicle insurance (excludes general insurance taxes)

Pollution

Measured or estimated emissions to air

• Measured or estimated NOx emissions
• Measured or estimated SOx emissions
• Other measured or estimated emissions to air (excluding CO2)

Ozone depleting substances (e.g. CFCs or halons)

Measured or estimated effluents to water

• Measured or estimated effluents of oxidizable matter (BOD, COD)
• Other measured or estimated effluents to water
• Effluent collection and treatment, fixed annual taxes

Non-point sources of water pollution

• Pesticides (based on e.g. chemical content, price or volume)
• Artificial fertilizers (based on e.g. phosphorus or nitrogen content or price)
• Manure

Waste management

• Collection, treatment or disposal
• Individual products (e.g. packaging, beverage containers, batteries, tyres, lubricants)

Noise (e.g. aircraft take-off and landings)

Resources

• Water abstraction
• Harvesting of biological resources (e.g. timber, hunted and fished species)
• Extraction of raw materials (e.g. minerals, oil and gas)
• Landscape changes and cutting of trees

Source: Eurostat (2013)

Respectively, taxes are categorized in Energy taxes (including fuel for transport), which include CO2 taxes, Transport taxes (excludong fuel for transport), Pollution taxes and Resource taxes.

Energy taxes

The category of Energy taxes includes taxes on energy products used for transport and for stationary purposes. The most significant products for transport in terms of revenue generarion are diesel and petrol, since they are used the most in all means of transport. The category includes products such as electricity, natural gas, biofules and renewable energy forms. One of the most important taxes in terms of pollution abatement is the CO2 tax, which refers to the CO2 content of fuels or energy products. All taxes levied on GHG emissions are included in this category, along with revenues from auctioned emission permits, as EU ETS system, which are treated by the national accounts as such. According to Gago et al. (2013), evidence show a high concetration of energy tax revenues in a few energy products. It is important to mention that car fuel taxes constitute around 50% of diesel and petrol final prices in many countries of the EU.

At this point, it is of high significance to explain where this extensive use of energy taxation stems from. Energy goods are characterized by a low elasticity of demand. As a result an increase in energy taxation and subsequently in prices of energy products little disturbs energy demand and the stability of revenues for the government. However, there are income distributional problems created by the implementation of energy taxation, as energy products are necessary goods and the result of those taxes on prices are disproportionatelly laid on lower income citizens.

Transport taxes

Transport taxes include most of the taxes levied on the ownership and use of vehicles and generally on the means of transport. These taxes can be one time taxes or yearly taxes. At this point, it is worth metioning that even taxes levied on more environmentally friendly means of transport, for example electric cars, are part of this category. Also congestion charges or city tolls, if treated as tax revenues, are included in this category. It depends on the country or even the city how it applies the charge. Another tax which is included in this category is the tax on the CO2 emissions of a vehicle. This tax is not an energy tax, because its tax base is not the CO2 content of the fuel consumed, but technical characteristics of the vehicle, such as the average CO2 emissions per 100km, vehicle weight or the power of the engine. This tax exists in some countries.

Pollution taxes

This category comprise of taxes on emissions of NOx or SOx to air or water, on waste management, noise, pollution of land and water by fertilisers.

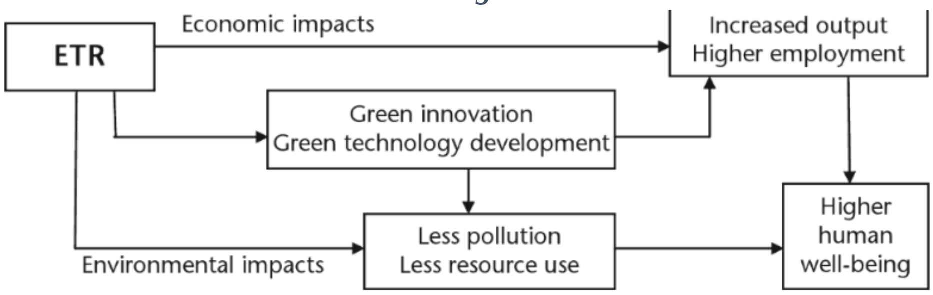
Resource taxes

This category contains taxes associated with the use and the extraction of natural resources, like minerals, hydrocarbons and water. In general, this category includes taxes on activities that cause the degradation of the environment.

2.5. The concept of Environmental Tax Reform

The concept of environmental tax reform (ETR) as it is defined by the EEA is ***a reform of the national tax system where there is a shift of the burden of taxes from conventional taxes, such as labor, to environmentally damaging activities, such as resource or pollution*** (*EEA, 2005*). This tax reform is also referred to as green tax reform (GTR) or environmental fiscal reform (EFR). ETR is the result of political initiative in some European countries, which started in the 1990s. The ETR is not the introduction of more taxes, but refers to the introduction of revenue-generating economics instruments such as taxes or tradable emission permits, levied on pollution and resource use and the subsequent reduction in other distortionary taxes, so that the final result of the reform is zero in terms of revenue increase. Thus, this policy is characterized as revenue-neutral. The purpose and the desirable effect of GTR is the protection of the environment and the limitation of its degradation, the reduction of resource use, the development of innovative production technologies and the amelioration of energy efficiency. On the other hand, the reform is expected to decrease taxes on labor and social contributions and boost employment. According to Ekins and

Figure 6



Source: Ekins and Speck (2011)

Speck (2011), ETR is considered to improve social welfare, as demonstrated in Figure 7.

There are three options for the GTR to be implemented: the removal of subsidies, the restructuring of existing environmental taxes and the introduction of new environmental taxes (OECD, 2001).

Subsidies or special tax reliefs given by governments to specific industries or sectors, distort the function of green taxes. For that reason, many European countries have reduced energy subsidies. As a result, the limitation of coal subsidies has induced reduction in its production in the UK, Belgium and Portugal. There are often cases that a substitution effect takes place from harmful to more environmentally friendly fuels. However, the phenomenon observed in many EU countries is that, still, diesel is taxed at a lower rate than petrol, besides the fact that the CO2 content of diesel is higher than that of petrol.

The restructuring of existing green taxes refers to their modification in order to fully internalize the externalities generated. A practical example is the so-called differentiation of fuel taxes, already in effect in many EU-EFTA countries such as Denmark, Sweden, Norway, UK. This policy aims in a better reflection of fuel prices in accordance to their CO2 content or the concentration of other substances (e.g. Sulphur content). The results are visible, as it is observed that consumers avoid using the most harmful fuels.

Finally, the policy could aim in introducing new environmental taxes in areas where there is lack or that are under regulation policies. One example is the carbon added tax (CAT) that would be levied on the addition of carbon in each phase of the productive process, in resemblance to VAT (Laurent & Le Cacheaux, 2010).

2.6. The double dividend issue

The term “double dividend” refers to the two positive outcomes produced by the implementation of an ETR. The first “dividend” or benefit is the impact of environmental taxation on the environment. Taxes on pollution or resources reduce pollution, contribute in less resource use, promote more energy efficient methods of production and technology and raise awareness among citizens. On the other hand, environmental taxes, if used in a neutral revenue-shifting way can be used to cut other distortionary taxes (income taxes, labor taxes), thus produce benefits in employment and a more efficient economy.[4] This is the so-called "revenue-recycling effect".

Nevertheless, the literature on double dividend, has not achieved to ensure its realization. What is more, there are evidence that environmental taxation causes a negative welfare effect, referred to as "tax interaction effect".[5] Environmental taxes increase prices of goods and activities that pollute the environment. As a result, they reduce real wages and the supply of labor. This welfare cost, according to Parry and Oates (1998), might be quite important even if the decline in labor supply is small. Another component of the "tax interaction effect", as described by Parry et al. (1999), is the necessity for the increase of taxation of other factors of production, in order for the revenues and the government spending (increased due to increased prices) to remain at the same level. Due to the replacement of a portion of labor taxes, which are broad base taxes, with green taxes, which are more of a narrow base, a *deadweight loss* occurs. Therefore, whether a double-dividend follows an ETR depends on the relative size of the two effects, revenue-recycling and tax interaction.

2.6.1 Studies on double dividend

There are many macroeconomic surveys, which use models to evaluate the impacts of environmental taxation in employment and GDP. A survey conducted by Majocchi (1996) demonstrates that many models that combine a carbon-energy tax with reductions in labor taxes can produce benefits both for environment and for employment. Nevertheless, the benefits and increase in employment are limited. In a model-based simulation with the use of the GEM-E3 model, by Kouvaritakis et al (2006), the results that arose show that in the case of an ETR, if the cuts are implemented on the social security contributions, the double environmental-employment dividend can be achieved. Bosquet (2000), through 139 simulations of the effects of a carbon/energy tax reform in 56 countries, proved that in the majority of cases emissions where reduced and employment increased. An interesting finding of this research was that in the long term there was higher possibility for negative effects to be created than in the short term. This finding indicates that carbo-energy tax shifts could be taken as temporary measures to boost employment. In the same research, in half of the simulations, GDP showed a decrease after the implementation of carbon

[4] We should keep in mind that taxes serve the purpose of raising revenues for the government.
[5] The terms "tax interaction effect" and "revenue recycling effect" are established by Goulder (1995).

taxes, while in 65% of the cases the reductions in social security contributions resulted in an increase of GDP. Another significant survey is the COMETR project which evaluated the results of ETR taken place in several European countries: Finland, Germany, the UK, the Netherlands, Denmark and Sweden. The results where encouraging, as fuel use and emissions where lower and economic activity was boosted. Again in these cases the revenue recycling effect was orientated in cut in social security contributions. The following table shows the first attempts of green tax reform in Europe and the orientation of the revenue recycling effect mainly in decreasing social security contributions. For most European countries, larger benefits could occur if the reductions in social security contributions are targeted at the unskilled labor force. Positive effects on GDP can be expected if the revenues are used to cut capital taxes,

Table 1

	Start Year	Taxes raised on	Tax cut	Magnitude
Sweden	1990	CO_2 SO_2 Various	PIT, Energy taxes on agriculture, Continuous education	2.4% of total tax revenue
Denmark	1994	CO_2 SO_2 Various	PIT, SSC, Capital income	Around 3% of GDP by 2002, or over 6% of total tax revenue
Netherlands	1996	CO_2	CPT, PIT, SSC	0.3% of GDP in 1996, or around 0.5% of total tax revenue
United Kingdom	1996	Landfill	SSC	Around 0.1% of total tax revenues in 1999
Norway	1999	CO_2 SO_2 Diesel Oil	PIT	0.2% of total tax revenue in 1999
Germany	1999	Petroleum Products	SSC	Around 1% of total tax revenue in 1999
Italy	1999	Petroleum Products	SSC	Less than 0.1% of total tax revenue in 1999

PIT: Personal income tax, CPT: Corporate tax, SSC: Social security contributions
Source: Bosquet (2000)

and if the environmentally related taxes are gradually implemented. Both GDP and employment effects depend on the size of tax shifts. A significant benefit would require significant cuts in labor taxation and therefore broad tax bases for environmentally related taxes are required, for example taxes on energy or transport. In general, the outcomes of the simulations show positive effects on GDP and employment when the energy tax is introduced gradually and the energy price increase does not exceed 4% to 5% per year (*OECD, 2000c*).

2.7. Static and dynamic efficiency of environmental taxes

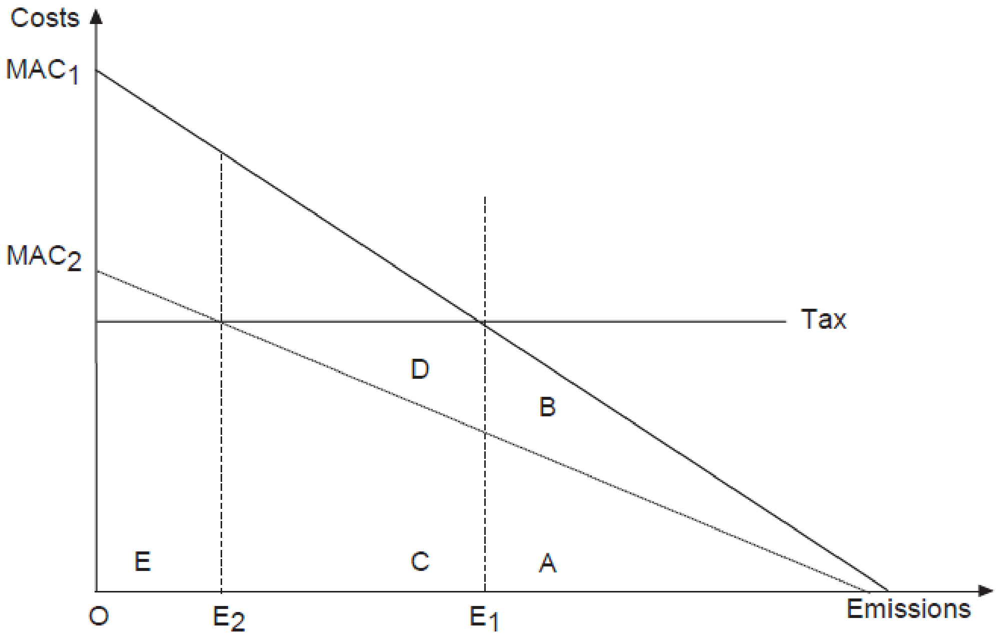
The advantage of economic instrument like environmental taxes, charges and tradable emission permits, in comparison to command-and-control strategies is that the former achieve static and dynamic efficiencies.

Unlike command and control regulation, which usually sets a uniform emission standard, MBIs tax all sources or economic agents with the same tax on the polluting activities and as a result marginal abatement costs are equalized between polluters (producers or consumers). When implementing an environmental tax or a tradable permit, firms, for example, have the flexibility to either reduce emissions/pollution if marginal abatement costs are lower, or to choose to be taxed or buy a permit, if their marginal abatement costs are higher than the tax. In that way abatement is done in the minimum cost for each firm.[6] Another example of static efficiency achieved by the implementation of environmental taxes, is the reduction of pollution due to their result in relative prices of goods and services. As mentioned before, taxes increase costs of production which result in increased prices of goods and services. Consumers tend to substitute away from heavily taxed goods and opt for cheaper alternatives, which in the case of environmental taxation, are less or non-polluting and harmful for the environment. Over time, this swift on demand for "clean goods" will require that industries swift for activities more environmentally friendly.

Economic instruments provide a constant incentive for polluters to further reduce pollution. Since taxes are levied on pollution (or close proxies), the lower the pollution emitted the lower the cost of the activity. Thus, firms are encouraged to make a swift in production technology, to develop innovative and cleaner production techniques, which will reduce the amount paid on environmental taxes or emission permits. Figure 6 demonstrates the benefit for a firm if it manages through technology to reduce is MAC, in parallel with the implementation of an environmental tax.

[6] It should be noted that marginal abatement costs differ across firms and industries. That is the reason why economic instruments are more effective than command and control strategies, since MBIs provide flexibility.

Figure 6



Source: Environmentally related taxes in OECD countries, OECD

With the initial MAC function, the firm reduces its pollution until E_1. The areas C, D and E represent the tax payments for the remaining emissions. When the MAC function shifts to MAC_2, the firm saves areas A, B, C and D, emissions are reduced to E_2 and E area represents the remaining tax instalments, owed to be paid by the firm with the polluting activity.

2.8. Concerns on the implementation of ETR

There are two main concerning issues regarding an environmental tax reform. The first one is the impact on competitiveness and the second one the impact on income distribution.

Competitiveness

The implementation of GTR might have effects on the competitiveness of an economy as a whole and the industrial competitiveness in particular. Countries with a large share of energy-intensive industries, might be affected, as the burden of the increase in energy prices through taxation will be beared heavily by those industries. Environmental taxation raises the cost of production of polluting industries and as a result companies can transfer the cost to the consumers and jeopardize their market share, or they could relocate in countries with lower taxation. In such case subsidies, tax exemptions and revenue-recycling schemes are used to prevent the reduction in profitability or relocation. The above issues are the main objectives in the opposition against green taxes, provided by industries' sector highly dependent on energy and resources. Another concern regarding competitiveness is the impact on international trade. Companies which bear the burden of environmental taxation could be affected in the case that the prices of their goods and services are disproportionately higher than those of countries with less green taxation. For that reason, domestic industries could be exempted from tax from cross-border trade, while at the same time taxes could be levied on imported polluting goods.

Income Distribution

Many environmental taxes are considered regressive, meaning that their effect on prices and lower wages fall disproportionately upon poorer households. Nevertheless, the final impact depends on the counteractive measure implemented. For example, an increase in energy taxes is balanced (or in what level) with a reduction in labor taxes and social contributions. The literature proposes two kind of measures: mitigation and compensation measures. Mitigation measures refers to policies adopted before the incidence of a tax. As an example, we could mention the case of a lower bound (might be on household income), lower than which, taxes are not levied. On the other hand, compensation measures, correct such injustices through lump-sum compensation schemes or tax reforms, with reduction of taxes on income and labor.

3. Environmental taxes and ETR in EU countries

In this chapter, we proceed with a description of the current status of environmental taxes in EU and some examples of GTR implemented already from 1990s.

3.1.Current status of environmental taxation in the EU

The most recent available data concerning environmental taxation in the EU is from 2017. In this year the total environmental tax revenue was 369 billion euro, which amounts for 2.4% of the European Union's total GDP and 6.1% of the total revenue from taxes and social contributions collected by the governments of the member states. The following table demonstrates the total amount of taxes and the share of each tax category. As we can see in the following table, the majority of the revenues is in the category of energy taxes and accounts for 76.9% of total environmental taxes, out of which 66% comes from fuel taxes.

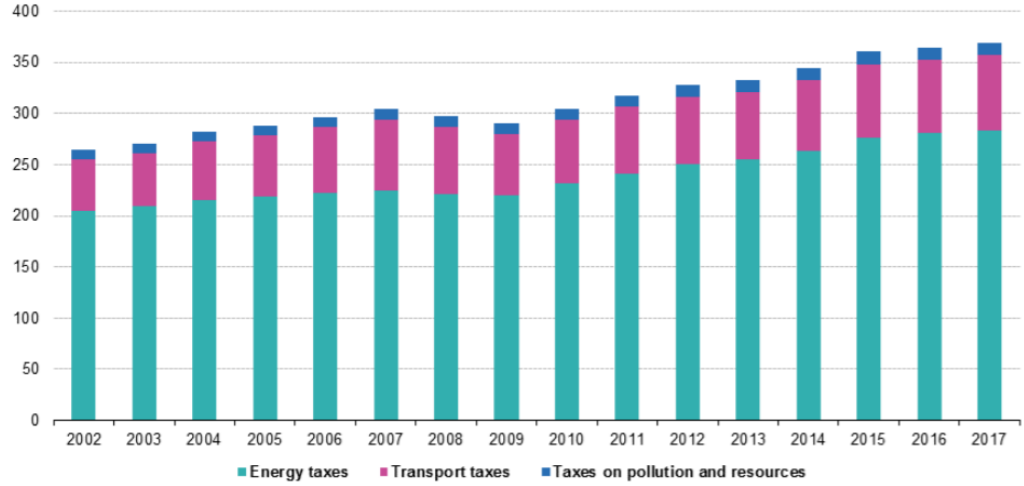
Table 2- Total environmental tax revenue by tax category, EU, 2017

	Million euro	% of total environmental taxes	% of GDP	% of total revenue from taxes and social contributions
Total environmental taxes	368 796	100.0	2.4	6.1
Energy taxes	283 467	76.9	1.8	4.7
Transport taxes	73 160	19.8	0.5	1.2
Taxes on Pollution/Resources	12 170	3.3	0.1	0.2

Source: Eurostat (2019)

The diagram displayed next shows the total revenue from each tax type for the period 2012 to 2017. It is clear that there is an increase in the total environmental tax revenues, which is owed mainly to the slight increase of energy tax revenues. For this period, the revenues increased by 2.2% on average each year. Revenues from energy taxes constitute the vast majority.

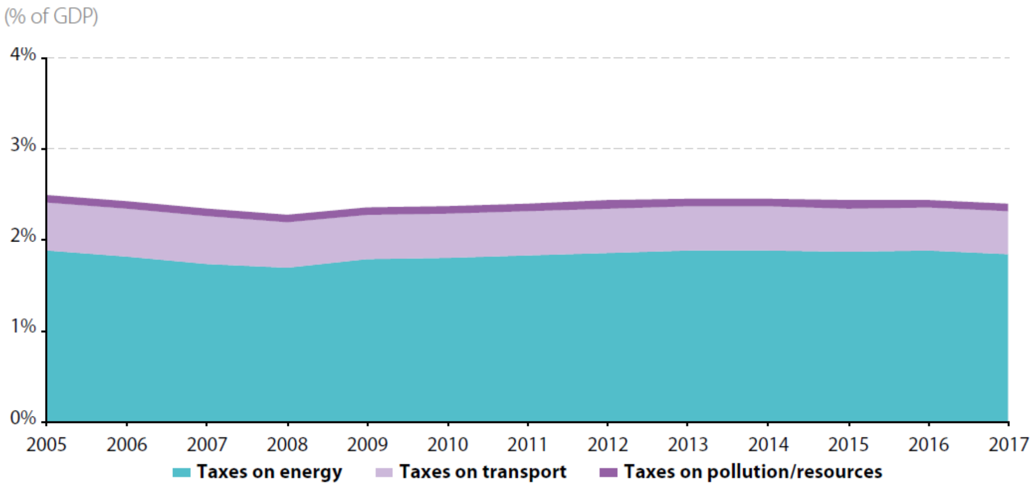
Figure 8- Total revenue from environmental taxes, EU, 2012-2017



Source: Eurostat (2019)

The next figure represents the trend in environmental tax revenues for the period 2005 to 2017. After s small growth in 2003 and 2004, the revenues remained flat, until 2007 to 2009 when the revenues presented a dip of 4%. The reason of this fall is quite simple: the economic and financial crisis. The following years, the revenues returned to their more or less stable route until 2017. It is worth mentioning that the change in revenues is the result of a change in tax rates but also an alteration in tax bases. While a tax rate increases, the relative tax base may be reduced due to the substitution or reduction of use of the base. An example is an increase in the tax rates concerning coal consumption. The economic agents might substitute away from the "dirty" commodity or reduce its usage. As a result, the expected raise in the revenues will be counteracted by the decrease in coal consumption. Such details may not be captured by this kind of data/diagrams.

Figure 9



Source: DG Taxation and Customs Union (2019)

A real example of the above analysis is the Dutch vehicle registration tax scheme. This scheme influenced a shift in the behavior of citizens, which resulted in a substitution of the vehicle used, with other smaller, less polluting and less taxed. Subsequently revenues were reduced, as the tax base was shrunk.

The following diagrams present each member state's structure of environmental taxes in relation to the corresponding GDP (figure 10) and the share of total revenues from taxes and social contributions (figure 11) for 2017. The country with the highest rate, for this year, was Greece (3.9%) followed by Slovenia and Denmark (both 3.7%). The level of environmental tax revenue relative to GDP did not reach 2% for six member states, Germany, Lithuania, Romania, Spain, Slovakia and Ireland. The country with the lowest revenues was Luxembourg (1.7%). In all countries, energy constitutes the largest share. However out of the EU-28, Serbia, a candidate for joining the EU, recorded the highest environmental tax revenue in terms of GDP and social contributions in 2016 (4.1% and 11.4% respectively).

As far as it concerns the share of total revenues of environmental from taxes and social contributions, Latvia (11.2%) presented the largest share, followed by Greece and Slovenia (both 10.2%). Among the states with the lowest rate we find Germany (4.6%), France and Belgium (5% both). Also, in this category, at the last place lies Luxembourg (4.4%).

According to Eurostat's data the EU's green tax revenue started to decrease in 2017, with the share of revenue in TSCs collected amounting for 6.1% in contrast to the stable level of 6.3% to 6.4% for a period of nine years (2009-2016).

Figure 10

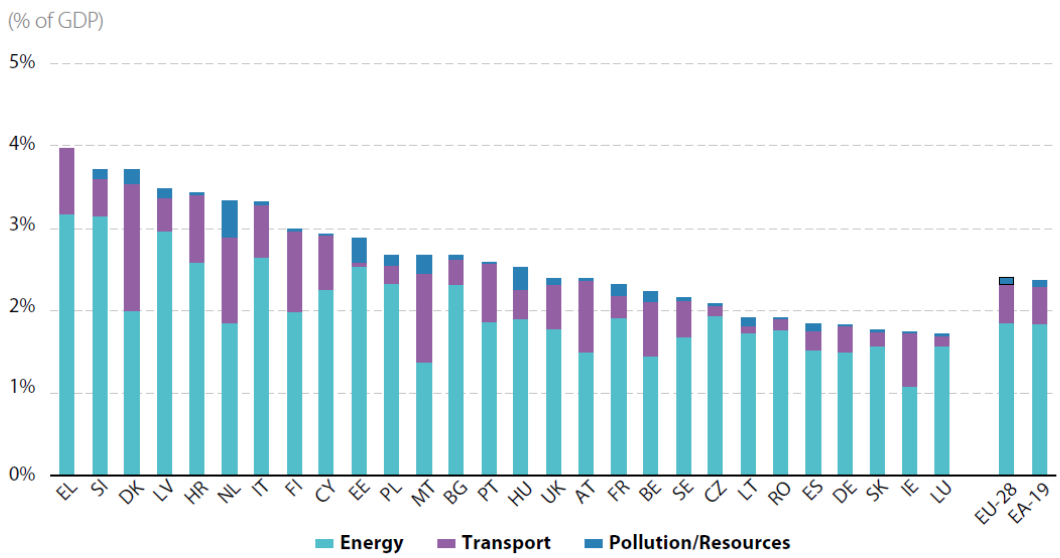
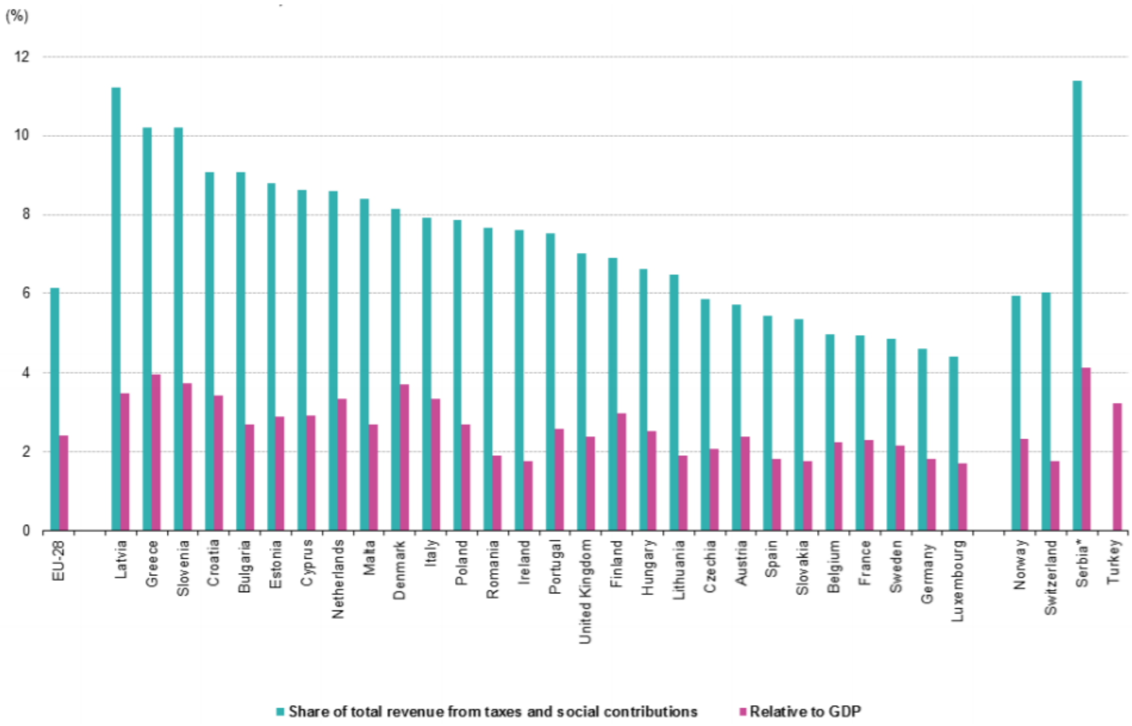


Figure 11

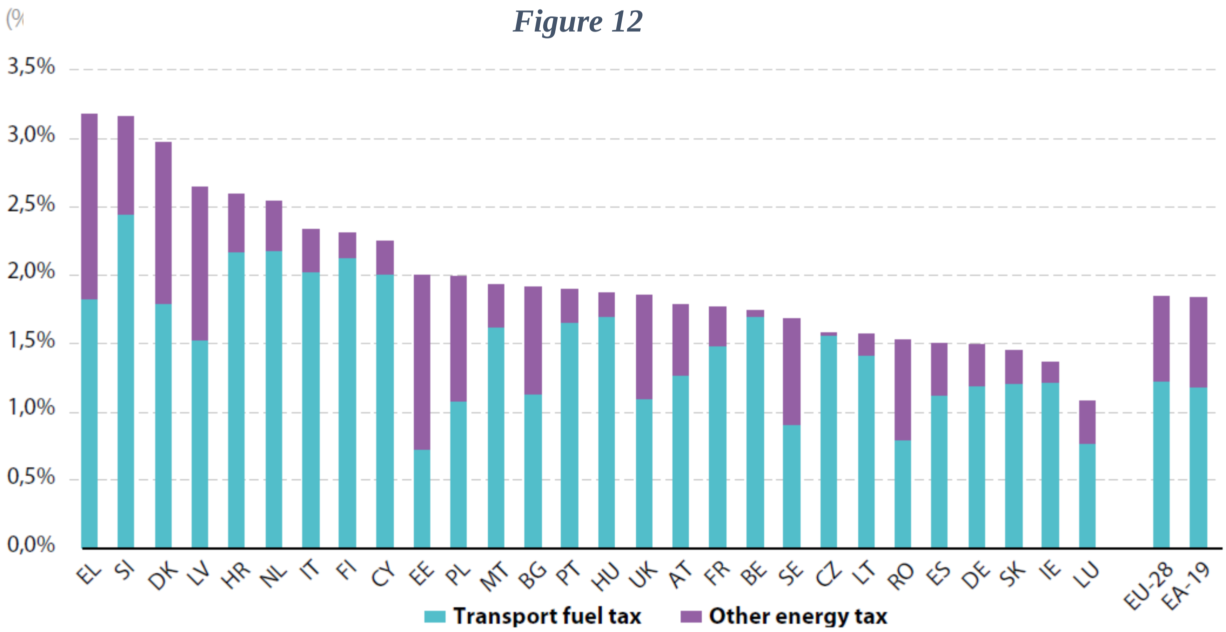


Source: Eurostat (2019)

Another interesting observation extracted from Figure 10 is that besides the large share of energy taxes followed by transport taxes in total environmental taxes, the share of taxes on pollution and resources are quite low, as some countries only recently introduced such taxes in their environmental taxes "mix". Greece and Germany are the countries have not implemented pollution or resource taxes yet.

The final diagram (figure 12) commented, demonstrates the structure of energy tax revenues for each member state for 2017. Energy tax revenues derive at around two thirds of transport fuel taxes. The highest total energy tax revenue is observed in Greece, Slovenia and Latvia, while the lowest is recorded in Luxembourg.

Figure 12



Source: DG Taxation and Customs Union (2019)

3.2. EU Emissions Trading System

In 2005 the EU established a cap-and trade scheme, the EU ETS. All EU member states along with Iceland Lichtenstein and Norway (EEA-EFTA countries) are covered by this emissions trading system. This scheme contains around 11000 plants of energy-intensive sectors (oil refineries, production of metals, aluminum, glass, cement, paper and many more), power plants and airlines (for flights within the EU area) and covers emissions of CO2, nitrous oxide (N2O), and perfluorocarbons (PFCs). The system covers around 45% of the EU's greenhouse gas emissions. The system operates as following: All installation covered by it are entitled to a certain “cap” in their emissions. This cap is gradually reduced in order to restrict the emissions. The industries participating can buy or receive emission allowances, which they can use or exchange with other industries. The EU ETS provides the opportunity for the industries covered by it to buy a limited number of emission credits from international emission-saving projects.

The purpose of this system, except for reducing GHG emissions, is also to motivate the industries to invest in innovative, more environmentally friendly production technologies. According to Borghesi et al. (2014) there is a high correlation between the implementation of the EU ETS and environmental innovation. However, the implication of the system regarding innovation might be different across sectors.

For example, Hoffman (2007) on his research on the German power plant sector, showed that innovation was limited due to the high pass-through effect in the electricity sector[7]. The results are different for large sample and cross sectoral analysis, where it is showed that the companies covered by EU ETS invest more in innovation than those that are unregulated (Calel & Dechezlepretre, 2012). Nevertheless, the difficulty for taking action towards innovative technology is found to energy-intensive industries. The costs of changing production technology are very high for these firms and given that investment cycles are long in these sectors, there are significant risks in investing in new technology, due to changes in regulation.

Another positive result of the EU ETS is the reduction of GHG. According to Martin et al. (2014), the companies participating emitted 210 million tons of CO2 (reduction of around 3%) less in comparison to non-participating ones.

Notwithstanding the concerns on the possible impact on competitiveness on the industries covered by EU ETS and the economy as a whole, when the system was introduced, a negative impact is not yet assured. This is a result of the use of exemptions and subsidies, which do not allow for negative impacts in competitiveness. On the other hand, these exemptions cancel the positive effects on energy efficiency and innovative technology.

3.3.Environmental Tax Reform in selected European countries

As it is already mentioned, the implementation of green tax reforms started in the 1990s in many countries. The Nordic countries are considered pioneers in ETR.

The first country to levy a tax particularly in CO2 emission was Finland. The uniform carbon tax was in effect in 1990. Nevertheless, the government provided tax exemptions, which later on favored energy intensive industries. Finland created a revenue-neutral reform, with the revenues from green taxes being used to cover the gap due to the reduction of other taxes. Norway imposed a tax on mineral oils in 1991, established a “Green Tax Commission” and gave emphasis in achieving a double dividend. Income taxes where reduced and renewable energy was promoted. Furthermore, Sweden in 1991 implemented a major tax reform. Income taxes where reduced while taxes on CO2 and Sulphur came to fill the gap. Ten years later, in the

[7] The pass-through effect is the result the EU ETS has on the cost of an industry and thus the relative increase in prices borne by consumers. This result reduces the demand and competitiveness of the industry.

same concept of strict revenue-neutral tax reforms, taxes on diesel and electricity were raised but offset with reductions in income taxes and social security contributions. All Nordic countries including Denmark and the Netherlands participated in the same wave of green tax reforms.

Except for Nordic countries, many other European ones took initiatives for ETR. The most known for its Ecological Tax Reform was Germany, which started in 1999. The reform was based on increases in electricity and mineral oil taxes which were addressed in cuts in pensions insurance contributions, both for employers and employees. The objectives of the reform were to accelerate innovation in production and energy efficiency, to promote RES and of course to reduce other distortionary taxes. Many other countries moved on to reforms based on green taxes with aim to reduce taxes on labor and boost employment, UK with the landfill tax and "climate change levy" (on the use of energy in industries) and Italy were among them.

4. Empirical application

4.1. Introduction

In this chapter we will perform a statistical analysis of the environmental tax revenues as GDP proportion and CO2 emissions of six European countries, Denmark, Germany, Greece, Romania, Spain and United Kingdom. Besides the descriptive statistics part we will try to prove the existence of correlation between these two variables. Following on from this, we will apply a causality test in the green taxes and CO2 emissions of one country, randomly chosen, Denmark.

The choice of the countries was based on geographical criteria. Denmark as a Scandinavian country, Germany as a central European, Romania as a country of East Europe, Greece as a Balkan, Spain as a Mediterranean country and United Kingdom as a north European state.

The part of descriptive statistics, the normality test, the correlation test and a forecasting in two countries' future taxes and emissions was conducted with the use of SPSS 24. The second part, the causality test is conducted with the econometric package E-VIEWS 11. All the data were collected by Eurostat's database and cover a period from1995 to 2017[8]. The tax revenues are expressed as percentage of GDP and the emissions in thousand tonnes.

4.2. Descriptive statistics

In this first part main descriptive statistic are presented. The sample is comprised of 138 time series observations. The median of CO2 emissions is 164959, the minimum is 37383 and the maximum is 924786 all in thousand tonnes. For environmental taxes, the median is 2.33%, the minimum is 1.57% and the maximum is 5.3%.

[8] See: https://ec.europa.eu/eurostat/data/database

Table 3

Descriptive Statistics

		CO2	Environmental Taxes
N	Valid	138	138
	Missing	0	0
Median		164959,5700	2,3350
Std. Deviation		290297,64637	0,94165
Minimum		37383,60	1,57

The following diagrams represent the distribution of CO2 emissions and environmental tax revenues (% GDP). It is clear that both variables do not follow the normal distribution. This is also confirmed by the Kolmogorov-Smirnov and the Shapiro-Wilk tests of normality.

Figure 13

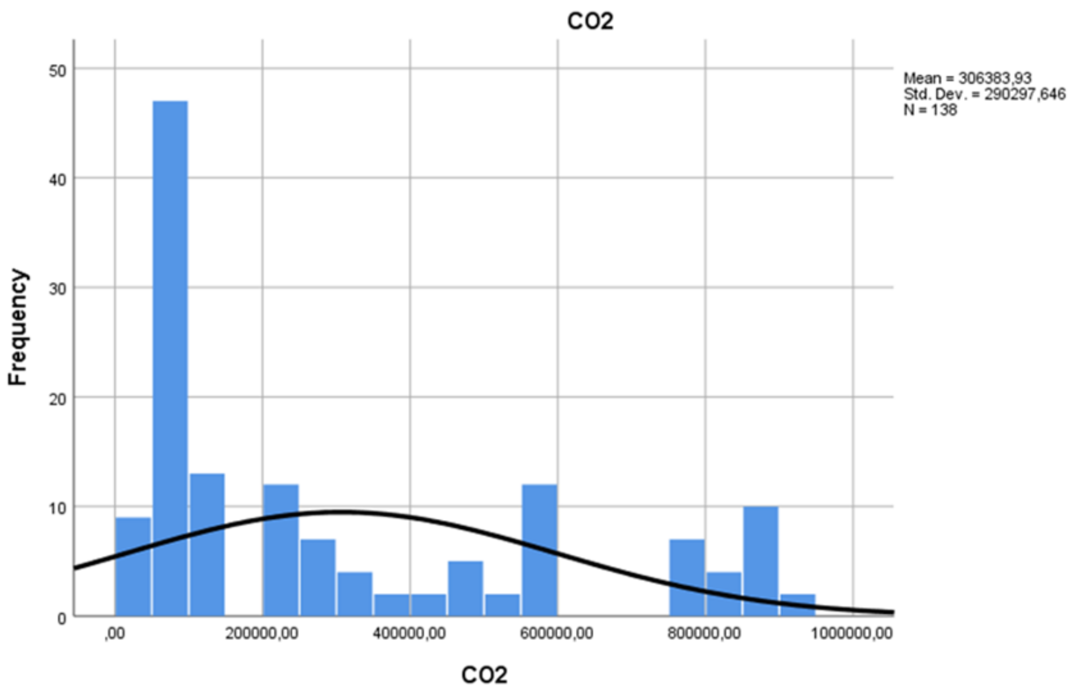
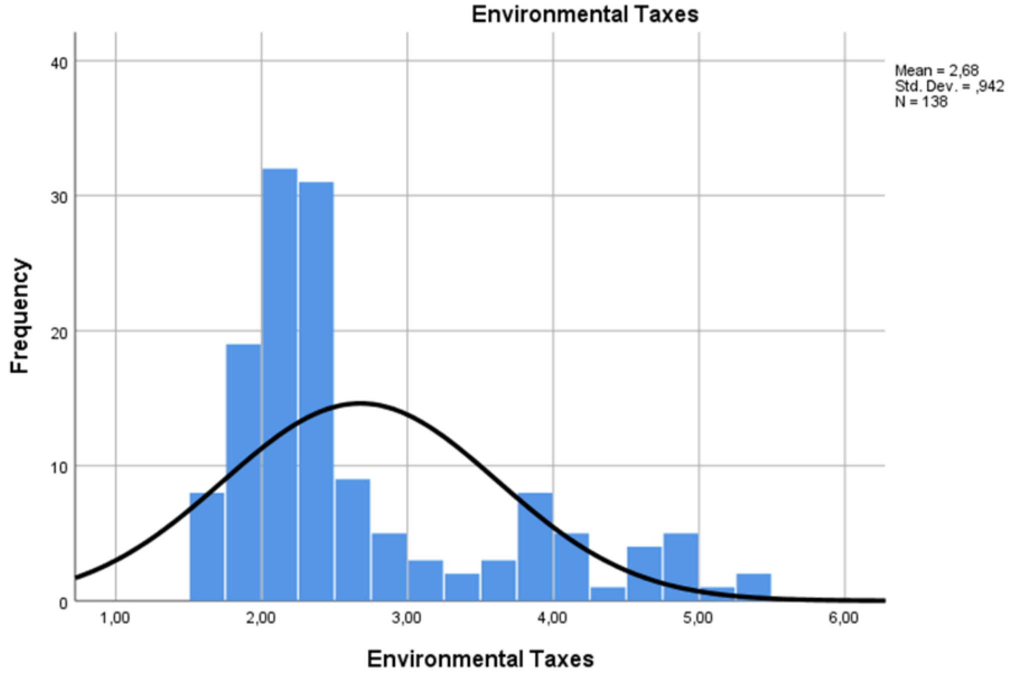


Figure 14



4.3. Normality test

Both tests of normality for both variables show that the null hypothesis (of normal distribution) is rejected, due to the nature of the variables.

Table 4

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
CO2	,248	138	,000	,807	138	,000
Environmental Taxes	,240	138	,000	,823	138	,000

a. Lilliefors Significance Correction

4.4. Correlation test

Table 5

Correlations

		CO2	Environmental Taxes
CO2	Pearson Correlation	1	-,395**
	Sig. (2-tailed)		,000
	N	138	138
Environmental Taxes	Pearson Correlation	-,395**	1
	Sig. (2-tailed)	,000	
	N	138	138

**. Correlation is significant at the 0.01 level (2-tailed).

The correlation test proves high negative correlation. Correlation can be placed between one and minus one (1 and -1). One is the highest positive correlation while minus one is the highest negative correlation. The Pearson factor is -0.395. The interpretation of this result is that the two variables CO2 emissions and environmental tax revenues are moving to different directions. The increase of environmental tax revenues brings the reduction of CO2 emissions and vice versa. The result is quite unexpected, if we consider that the CO2 emissions, as a tax base, should move to the same direction with the revenues. However, there are two possible explanations for that. The first is that the tax base might be shrinking, due to the effectiveness of environmental taxation, but the tax rate could be raised, in order for the respective revenues to remain stable. The other explanation is that the tax base is limited, because of the effectiveness of certain measures, such as subsidies for renewable energy, feed-in-tariffs and feed-in-premiums. This kind of measures decrease the CO2 emissions due to the substitution between conventional energy sources, as coal and oil, and renewable energy sources, as solar and wind. Such interaction cannot be captured by our analysis. This result depends on the specific policies implemented in each country. It should be pointed out that the correlation is strong as it is computed in a 1% significance level.

4.5. A statistical analysis and forecasting of Denmark's data

The following table includes the descriptive statistics data of Denmark for the two variables examined, CO2 emissions and environmental tax revenues (% GDP). The number of observations is 23, as the data collected are annual.

Table 6

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
CO2 emissions	23	769229,34	924785,70	842384,1035	48207,77831
Environmental Taxes	23	3,72	5,30	4,4648	,47731
Valid N (listwise)	23				

As it can be seen from the normality tests, both variables do follow the normal distribution.

Table 7

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Environmental Taxes	,172	23	,076	,922	23	,073
CO2 emissions	,126	23	,200	,934	23	,134

The correlation tests produced interesting results, if we compare them with the results of the previous analysis of the time series of the six countries. The correlation of the variables is highly positive (close to 1), in contrast to the correlation of the sample of the six countries. The strong degree of correlation is confirmed by the 1% level of statistical significance. The interpretation of this result is that a possible increase in CO2 emissions is accompanied by an increase of the environmental tax revenue and vice versa. This is the result of an expansion of the tax base.

Table 8

Correlations

		CO2 emissions	Environmental Taxes
CO2 emissions	Pearson Correlation	1	0.757**
	Sig. (2-tailed)		0.000
	N	23	23
Environmental Taxes	Pearson Correlation	0.757**	1
	Sig. (2-tailed)	0.000	
	N	23	23

**. Correlation is significant at the 0.01 level (2-tailed).

The following sequence plot of both variables demonstrates the absence of seasonality. Another interesting observation is the downward trend for CO2 emissions and environmental tax revenue. This is the result of the tax base, that might be due to the level of consciousness of the Dutch citizens. Denmark is one of the first countries that implemented ETR and the level and the Dutch society now collects the benefits generated by the reduction in use of environmental harmful products.

Table 9

Model Description

Model Name		MOD_1
Series or Sequence	1	CO2 emissions
Transformation		None
Non-Seasonal Differencing		0
Seasonal Differencing		0
Length of Seasonal Period		No periodicity
Horizontal Axis Labels		Date_
Intervention Onsets		None
Reference Lines		None
Area Below the Curve		Not filled

Applying the model specifications from MOD_1

Table 10

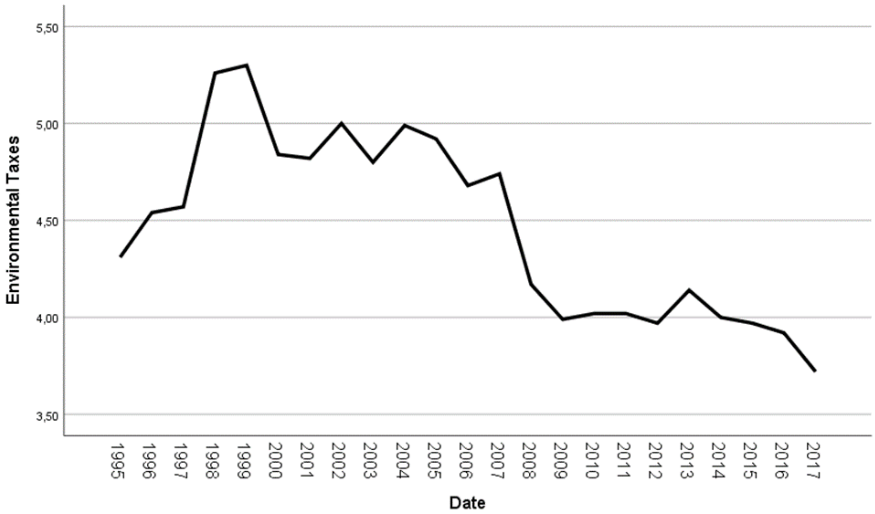
Model Description

Model Name		MOD_2
Series or Sequence	1	Environmental Taxes
Transformation		None
Non-Seasonal Differencing		0
Seasonal Differencing		0
Length of Seasonal Period		No periodicity
Horizontal Axis Labels		Date_
Intervention Onsets		None
Reference Lines		None
Area Below the Curve		Not filled

Applying the model specifications from MOD_2

Figure 15

Figure 16



Forecasting

The SPSS system made the choice of the models used in forecasting. The model HOLT was chosen for the CO2 emissions and the model SIMPLE for the environmental tax revenue.

Table 11

Model Description

			Model Type
Model ID	CO2 emissions	Model_1	Holt
	Environmental Taxes	Model_2	Simple

Model statistics

The interpretative ability of the models is considered to be very high, as it can be seen by both R^2, as 82.4% and 72.7% of the standard deviation of the CO2 emissions and the tax revenues respectively.

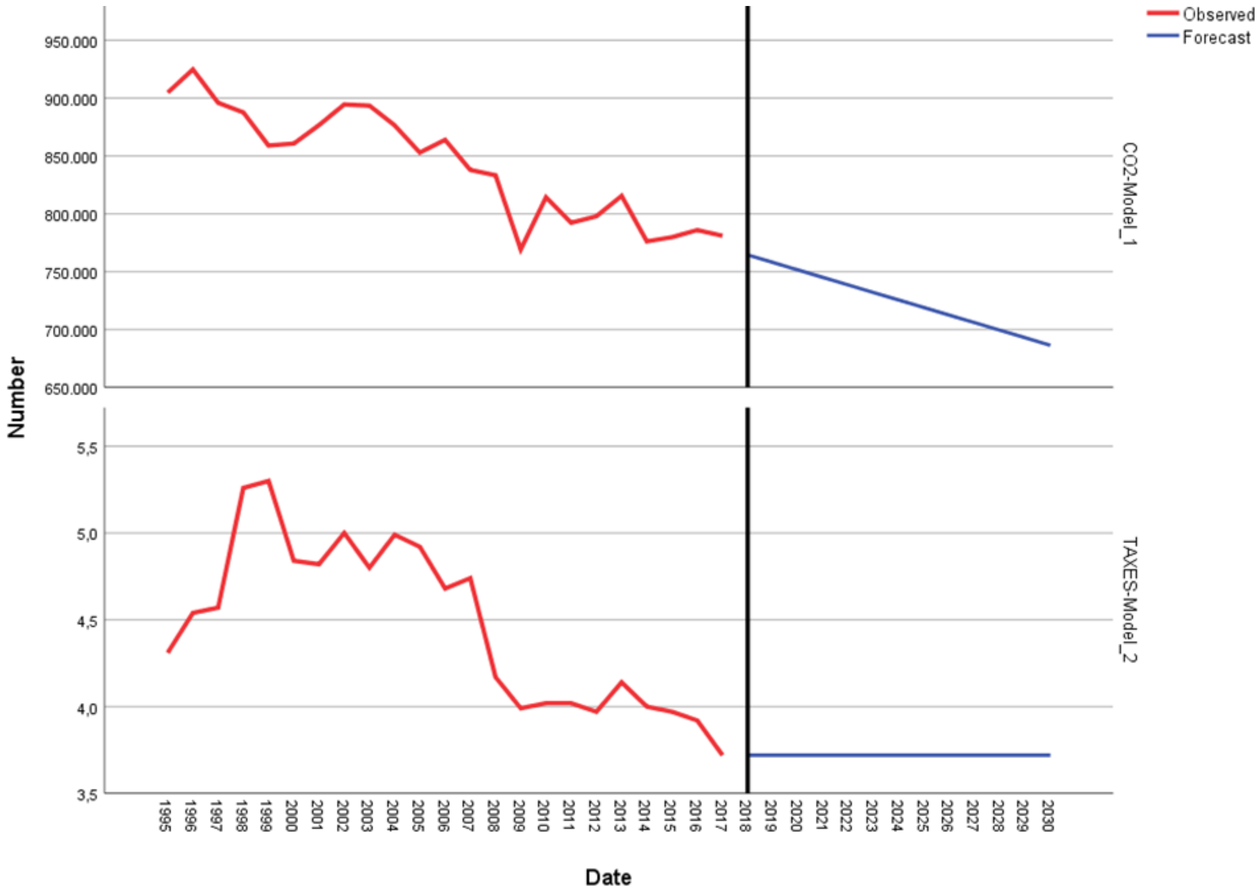
Table 12

Model Statistics

Model	Number of Predictors	Model Fit statistics: Stationary R-squared	Model Fit statistics: R-squared	Ljung-Box Q(18): Statistics	Ljung-Box Q(18): DF	Ljung-Box Q(18): Sig.	Number of Outliers
CO2 emissions-Model_1	0	,748	,824	20,135	16	,214	0
Environmental Taxes-Model_2	0	-,012	,727	17,177	17	,442	0

The diagrams following represent the forecasting of the future trends for the two variables. As it can be seen, CO2 emissions will continue to decrease until the period forecasted, 2030. Environmental tax revenues will follow a stable path, which is sensible if we consider the relatively small changes in their levels during the last years.

Figure 17



4.6. Testing the existence of a causal relation between Co2 emissions and revenues from environmental taxes

In this section we will perform a causality test in the relevant data of Denmark. The data cover the period from 1995-2017.

4.6.1 Stationarity

The first step in the process of testing causality of this time series is to prove the variables are stationary. In order to achieve this, we conduct four tests: the Augmented Dickey-Fuller, the Philips-Perron, the KPSS and the Perron (1997).

Augmented Dickey-Fuller

Starting with the time series of CO2 emissions, the null hypothesis of the ADF test is the existence of a unit root. The unit root is a stochastic trend in time series which makes them unpredictable. According to the ADF table, the null hypothesis cannot be rejected. The next step is the test of the first difference of the variable.

The ADF test for the first difference, proves the stationarity of the variable. The null hypothesis can be rejected. The absence of a unit root shows the stationarity of the variable.

Table 13

Null Hypothesis: CO2 has a unit root
Exogenous: Constant
Lag Length: 1 (Automatic - based on SIC, maxlag=4)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.183299	0.6614
Test critical values:	1% level	-3.788030	
	5% level	-3.012363	
	10% level	-2.646119	

*MacKinnon (1996) one-sided p-values.

Table 14

Null Hypothesis: D(CO2) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=4)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-7.059180	0.0000
Test critical values:	1% level	-3.788030	
	5% level	-3.012363	
	10% level	-2.646119	

*MacKinnon (1996) one-sided p-values.

Philips-Perron

The following test is the Philips-Perron. Although it uses the same null hypothesis with the ADF, it is considered to have some advantages. According to the test, the null hypothesis cannot be rejected in the level. For its first difference though, the CO2 variable is presented to be stationary.

Table 15

Null Hypothesis: CO2 has a unit root
Exogenous: Constant
Bandwidth: 0 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-1.193374	0.6582
Test critical values:	1% level	-3.769597	
	5% level	-3.004861	
	10% level	-2.642242	

*MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	5.20E+08
HAC corrected variance (Bartlett kernel)	5.20E+08

Table 16

Null Hypothesis: D(CO2) has a unit root
Exogenous: Constant
Bandwidth: 1 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-7.028993	0.0000
Test critical values:	1% level	-3.788030	
	5% level	-3.012363	
	10% level	-2.646119	

*MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	4.49E+08
HAC corrected variance (Bartlett kernel)	4.58E+08

KPSS

The next test, contrary to the previous, is a stationarity test. The null hypothesis is that the variable is stationary. The result of this test for the CO2 emissions is that the null hypothesis is rejected at a significance level of 1%. The first difference of the variable used in the test, appears to be stationary in its first difference. The null hypothesis is accepted.

Table 17

Null Hypothesis: CO2 is stationary
Exogenous: Constant
Bandwidth: 3 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.641345
Asymptotic critical values*:	1% level	0.739000
	5% level	0.463000
	10% level	0.347000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Residual variance (no correction)	2.22E+09
HAC corrected variance (Bartlett kernel)	6.92E+09

Table 18

Null Hypothesis: D(DCO2) is stationary
Exogenous: Constant
Bandwidth: 1 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.075371
Asymptotic critical values*:	1% level	0.739000
	5% level	0.463000
	10% level	0.347000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Perron unit root test

The Perron (1997) test is used to identify the existence of a one-time structural break in the time series. There is the possibility that a time series that seems to be non-stationary, had a structural break on the level. In this case the null hypothesis cannot be rejected.

Table 19

Null Hypothesis: CO2 has a unit root with a structural break in both the intercept and trend
Chosen lag length: 0 (Maximum lags: 4)
Chosen break point: 14.00000

	t-Statistic
Perron Unit Root Test	-4.459412
1% critical value:	-6.32
5% critical value:	-5.59
10% critical value:	-5.29

Augmented Dickey-Fuller

The same procedure is followed for the other variable, environmental tax revenues (%GDP). The ADF test in level fails to reject the hypothesis of the existence of a unit root, while in the 1st difference, the existence of a unit root is rejected.

Table 20

Null Hypothesis: TAXES has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on AIC, maxlag=4)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-0.739915	0.8162
Test critical values:	1% level	-3.769597	
	5% level	-3.004861	
	10% level	-2.642242	

*MacKinnon (1996) one-sided p-values.

Table 21

Null Hypothesis: D(TAXES) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on AIC, maxlag=4)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.460323	0.0023
Test critical values:	1% level	-3.788030	
	5% level	-3.012363	
	10% level	-2.646119	

*MacKinnon (1996) one-sided p-values.

Philips-Perron

The Philips-Perron test in level, as in the case of CO2 taxes, does not confirms stationarity. However, in the 1st difference, the null hypothesis is rejected.

Table 22

Null Hypothesis: D(TAXES) has a unit root
Exogenous: Constant
Bandwidth: 5 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-4.559552	0.0019
Test critical values:	1% level	-3.788030	
	5% level	-3.012363	
	10% level	-2.646119	

*MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	0.061223
HAC corrected variance (Bartlett kernel)	0.039149

Table 23

Null Hypothesis: TAXES has a unit root
Exogenous: Constant
Bandwidth: 0 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-0.739915	0.8162
Test critical values:	1% level	-3.769597	
	5% level	-3.004861	
	10% level	-2.642242	

*MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	0.059944
HAC corrected variance (Bartlett kernel)	0.059944

KPSS

The same as for CO2 stands for the KPSS test. In the level, the null hypothesis of stationarity is rejected in a level of statistical significance of 1%. In the 1st difference, the hypothesis of stationarity id accepted.

Table 24

Null Hypothesis: TAXES is stationary
Exogenous: Constant
Bandwidth: 3 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.504001
Asymptotic critical values*:	1% level	0.739000
	5% level	0.463000
	10% level	0.347000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Residual variance (no correction)	0.217921
HAC corrected variance (Bartlett kernel)	0.678946

Table 25

Null Hypothesis: D(TAXES) is stationary
Exogenous: Constant
Bandwidth: 2 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.273742
Asymptotic critical values*:	1% level	0.739000
	5% level	0.463000
	10% level	0.347000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Residual variance (no correction)	0.061585
HAC corrected variance (Bartlett kernel)	0.056712

Perron unit root test

The Perron unit root test in the trend shows the absence of a unit root with a structural trend. The null hypothesis is rejected.

Table 26

Null Hypothesis: DTAXES has a unit root with a structural break in the trend
Chosen lag length: 0 (Maximum lags: 4)
Chosen break point: 7.000000

	t-Statistic
Perron Unit Root Test	-5.501404
1% critical value:	-5.45
5% critical value:	-4.83
10% critical value:	-4.48

4.6.2 Cointegration

In order for the choice of the right model to be done, the variables should be checked for cointegration. The model used for cointegration is the Johansen cointegration test (Johansen and Juselius, 1990). The analysis is based on a VAR model, where the estimated optimal lag length is 1 according to Akaike information criterion (AIK). The test traces the cointegration between the two variables.

Table 27

Sample (adjusted): 3 23
Included observations: 21 after adjustments
Trend assumption: Linear deterministic trend
Series: TAXES CO2
Lags interval (in first differences): 1 to 1

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.512440	15.56385	15.49471	0.0488
At most 1	0.022537	0.478682	3.841466	0.4890

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

4.6.2 Causality

Granger Causality

The Granger causality test examines whether one variable brings about effects on the other. The test can be applied on stationary and non-stationary time series. The p-value of the first null hypothesis is lower than 5%. Thus, the null hypothesis is rejected. CO_2 emissions cause changes in environmental tax revenues. On the other hand, tax revenues do not impact on CO_2 emissions. The result of the causality test was expected, since an increase (or decrease) in emissions results in higher (lower) revenues.

Table 28

Sample: 1 23
Lags: 1

Null Hypothesis:	Obs	F-Statistic	Prob.
CO2 does not Granger Cause TAXES	22	9.63276	0.0058
TAXES does not Granger Cause CO2		0.31393	0.5818

Toda-Yamamoto test

We finalize this analysis with another test, the Toda Yamamoto causality test. The previous result is confirmed by this test. Tax revenues as a dependent variable are affected by CO_2 emissions, as the p-value is significantly lower than 5%.

Table 29

Sample: 1 23
Included observations: 21

Dependent variable: TAXES

Excluded	Chi-sq	df	Prob.
CO2	9.583613	2	0.0083
All	9.583613	2	0.0083

Dependent variable: CO2

Excluded	Chi-sq	df	Prob.
TAXES	0.722271	2	0.6969
All	0.722271	2	0.6969

5. Conclusions

The implementation of environmental taxation and environmental tax reforms has presented substantial progress in EU countries during the last 30 years. EU's contribution to that progress is of paramount importance, through the continuous renewal of environmental policy regulation, imposed on member states. This progress is obvious when observing the living standards of European citizens. As a matter of fact, the EEA's European Environment- state and outlook report (SOER) released the conclusion that over the past 40 years the implementation of environmental and climate policies has delivered substantial benefits for the functioning of Europe's ecosystems and for the health and living standards of its citizens (*EEA, 2015*)

Furthermore, it is clear that there is great potential in ETR and environmental taxes, due to their revenue-generating capability and the relative relief of the tax burden from income and labor taxes. Their revenue-generating capability lies, in particular, in the energy and transport sector, as the tax bases in these categories are quite extensive. However, revenues in EU show only a slight increase in recent years, mainly due to tax exemptions and subsidies, with concerns on industrial competitiveness and income distribution. As far as it concerns the effectiveness of ETR, although their effect is disputed, empirical studies show that benefits for employment can be achieved, in higher or limited levels. Further on, environmental taxes result in significant limitation of the pollution of the environment.

Another argument in favor of environmental taxes is the achievement of static and dynamic efficiency. Static efficiency is achieved when the abatement is done with the lower cost and also, due to the increase in the production cost and the relative prices of "dirty" commodities and services. In this case consumers substitute away from polluting-expensive goods and the companies have an incentive to turn to more environmentally friendly activities. At the same time, since taxes are levied on polluting goods and industries with polluting activities, those industries have the incentive to implement innovative technology, less harmful for the environment.

The main goal of environmental taxation is the correction of externalities and market failures. As a matter of fact, their goal is to correct the inequalities between those who pollute and the citizens and the environment. Thus, it is an issue of improvement of social welfare, reduction of inequalities, mitigation of climate change and a kind of social solidarity among all countries, that deal with the consequences of climate change.

An important fact that should be researched is the significance and perhaps the necessity of environmental taxation in the future. In light of researches and reports that predict the decrease of the base of labor taxes in EU countries, due to the expected demographic trends of shrinkage of the available labor force, environmental taxes could be proved appropriate to fill the gap in government revenues. The reduction of births and the ageing of the population will inevitably lead to a tax base erosion. At the same time, following the implementation of environmental policies and the respective measures, the improvement of energy efficiency and the increase in the use of renewable energy, will lead to another tax base erosion, that of energy taxes. These are issues with great consequences that worth being researched.

The statistical and econometric analysis provided two important results. The first one is the negative relation between CO2 emissions and environmental tax revenue (%GDP), in the sample of the six countries. This result leads to the conclusion that CO2 emissions move in the opposite direction of environmental tax revenue. Nevertheless, this result does not stand for any case and country. It depends on the different circumstances of each tax system, economy and society. The causal relation that was proven between the two variables was quite logical assumption. The test demonstrated that CO2 emissions result in changes in environmental tax revenues. The result was expected if we consider that energy taxes and respectively CO2 taxes constitute the largest tax base.

In conclusion, the concept of environmental taxation and green tax reform plays a central role in EU policy and is highly promoted. Europe has set as clear goals and priorities the protection of environment and the mitigation of climate change. Despite the increasing number of environmental taxes in force, the revenues are stagnating the last years. The European Union should invest more in designing policy measures, in this case taxes, and communicating their usefulness for the economy, for the society, for the environment.

Bibliography

Ahman, M., Nilsson, L. J. & Johansson, B., 2016. Global climate policy and deep decarbonization of energy-intensive industries. *Climate Policy 1*.

Alberici, S. και συν., 2014. *Subsidies and costs of EU energy: Final Report,* s.l.: Ecofys 2014 by order of: European Commission.

Borghesi, S., Cainelli, . G. & Mazzanti, M., 2015. Linking emission trading to environmental innovation: evidence from the italian manufacturing industry. *Research Policy 669*, 44(3).

Bosquet, B., 2000. Environmental tax reform: does it work? A survey of the empirical evidence. *Journal of Ecological Economics*, Issue 34, pp. 19-32.

Calel, R. & Dechezlepretre, A., 2012. Environemntal policy and directed technological change: evidence from the European carbon market. *22 Working Paper FEEM*.

COMETR, 2007. *Competitiveness Effects of Environmental Tax Reforms, Final report to the European Commission,* s.l.: DG Research and DG Taxation and Customs Union.

Corti-Varela, J., 2017. EU Emission Trading System, Competitiveness and Taxes on the Energy Sector. In: M. Villar, ed. *STATE AIDS, TAXATION AND THE ENERGY SECTOR,.* s.l.:Thomson Reut

Couture, T. & Gagnon, Y., 2010. An analysis of feed-in tariff remuneration models: Implications for renewable energy investment. *Energy Policy*, 38(2), pp. 955-965.

Dickey, D. And W. Fuller (1981). *Likelihood ratio statistics for autoregressive time series with a unit root*. Journal of the American Statistical Association 74, 1057-1072 ers, pp. 323-333.

EEA, 2005. *Market-based instruments for environmental policy in Europe,* s.l.: s.n.

EEA, 2015. *Evaluating 15 years of transport and environmental policy integration — TERM 2015: Transport indicators tracking progress towards environmental targets in Europe,* Copenhagen: EEA.

Ekins, P. & Speck, S., 2011. *Environmental Tax Reform (ETR): A Policy for Green Growth.* 1st edition ed. s.l.:Oxford University Press.

Ekins, P. & Speck, S., 2012. Impact on competitiveness: what do we know from modelling?. In: *Handbook of Research on Environmental Taxation.* s.l.:Edward Elgar Publishing Limited 2012.

Engle, R.F. and C.W. Granger (1987). Cointegration and error correction: representation, estimation and testing. *Econometrica* 55, 251-276.

European Commission, 2019. *Reflection paper-Towards a Sustainable Europe by 2030,* Brussels: COM(2019)22.

European Commission, n.d. *European Commission- EU ETS.* [Online] Available at: https://ec.europa.eu/clima/policies/ets_en#tab-0-0 [Accessed 12 November 2019].

European Environment Agency, 2016. *Environmental taxation and EU environmental policies,* Luxembourg: EEA Report/ No 17/2016.

Eurostat, 2013. *Environmental Taxes- A Statistical Guide,* Luxembourg: European Union.

Fisrt Global Conference of the Platform for Collaborations on Tax, 2018. *Taxation and SDG's,* New York: s.n.

Gago, A., Labandeira, X. & Lopez-Otero, X., 2014. A Panorama on Energy Taxes and Green Tax Reforms. *Review of Public Economics*, pp. 145-190.

Gaspar , V., Jaramillo, L. & Wingender, P., 2016. Tax Capacity and Growth: Is there a Tipping Point?.

Goulder, L. H., 1995. Environmental Taxation and the Double Dividend: A Reader's Guide. *International Tax and Public Finance*, Volume 2, pp. 157-183.

Granger, C.W.J. (1969). *Investigating causal relations be econometric models and cross-spectral methods*. Econometrica 37, 424-438.

Hoffmann, V. H., 2007. EU ETS and Investment Decisions: The case of the German Electricity Industry. *European Management Journal 464*, 25(6).

Johansen, S. (1988). *Statistical analysis of cointegration vectors*. Journal of Economic and Dynamics and Control 12, 231-254.

Johansen, S. and K. Juselius (1990). *Maximum likelihood estimation and inference on cointegration with application to the demand for money*. Oxford Bulletin of Economics and Statistics 52, 169-209.

Kosonen, K. & Nicodeme, G., 2009. The role of fiscal instruments inenvironmental policy. Taxation papers.

Kouvaritakis, N. et al., July 2005. *Impacts of energy taxation in the enlarged European Union, evaluation with GEM-E3,* s.l.: Study for the European Commission DG TAXUD.

Kwiatkowski D., P. Phillips, C.B.P. Schmidt and Y. Shin (1992). *Testing the null hypothesis of stationarity against the alternative of a unit root*. Econometrics 54, 159-178.

Laurent, E. & Le Cacheaux, J., 2010. Policy options for carbon taxation in the EU. *Document de travail del' OFCE*, Volume 2010-10.

Majocchi, A., 1996. Green Fiscal Reform and Employment: a Survey. *Environmental and Resource Economics,* December, 8(4).

Martin, R., Muûls, M. & Wagner, U. J., 2016. The Impact of the European Union Emissions Trading Scheme on Regulated Firms: What Is the Evidence after Ten Years?. *Review of Environmental Economics and Policy*, Winter, 10(1), pp. 129-148.

Millock, K., Nauges, C. & Sterner, T., 2004. Environmental taxes: A comparison of French and Swedish experience from taxes on industrila air pollution. *CESifo DICE Report*, 2(1), pp. 30-34.

OECD, 2000c. *Greening Tax Mixes In OECD Countries: A Preliminary Assessment*, Paris: OECD.

OECD, 2001. *Environmentally Related Taxes in OECD Countries.* s.l.:OECD.

Parry, I. W. H., Williams III, R. C. & Goulder, L. H., 1999. When Can Carbon Abatement Policies Increase Welfare? The Fundamental Role of Distorted Factor Markets,. *Journal of Environmental Economics and Management*, Issue 37, pp. 52-84.

Parry, I. W. H. & Oates, W. E., 1998. Policy Analysis in the Second-Best World. *Resources for the future discussion paper*, pp. 98-48.

Perron P. (1989). *The great crash, oil price shock and the unit root hypothesis*. Econometrica 57, 1361-1401.

Perron, P. (1997). *Further evidence on breaking trend functions in macroeconomic variables*. Journal of Econometrics 80(2), 355-385.

Pigou, A. C., 1920. *The Economics of Welfare.* London: Macmillan.

Pigou, A. C., 1928; 1947. *A study in Public Finance.* London: Macmillan.

Phillips P.C.B. and P. Perron (1988). *Testing for a unit root in time series regression*. Biometrica 75(2), 335-346.

Radov, D., Koenig, C., Fearnehough, H. & Peng, J., 2018. *Update on Energy Taxation and Subsidies in Europe: An Analysis of Government Revenues from and Support Measures for Fossil Fuels and Renewables in the EU and Norway,* s.l.: NERA.

Ramsey, F. P., 1927. A contribution to the theory of taxation. *Economic Journal 37*, pp. 47-61.

Sandmo, A., 1975. Optimal taxation in the presence of externalities. *Swedish Journal of Economics 77*, pp. 86-98.

Sandmo, A., 2000. *The Public Economics of the Environment.* Oxford: Oxford University Press.

Sandmo, A., 2011. Atmospheric externalities and environmental taxation. *Energy Economics*, Issue 33, pp. S4-S12.

Stiglitz, J., 2015. In praise of Frank Ramsey's Contribution to the Theory of Taxation. *The Economic Journal*, March, Issue 125, pp. 235-268.

Stiglitz, J. E., 1988. *Economics of the Public Sector.* 2nd edition ed. New York: W.W. Norton & Company.

Taxation and Customs Union, 2018, *Tax policies survey in the European Union*, Luxembourg

Taxation and Customs Union, 2019, *Taxation Trends in the European Union*, 1st edition, Luxembourg

The European Parliament and the Counsil, 2011. *Regulation (EU) 691/2011.* s.l.:s.n.

The United Nations Conference on Environment and Development, 1992. *The Rio Declaration on Environment and Development.* s.l., s.n.

Tietenberg, T. & Lewis, L., 2012. *Environmental and Natural Resource Economics.* 9th edition ed. s.l.:Pearson.

TNS political & social at the request of the European Commission,, 2017. *Special Eurobarometer 468 - Attitudes of European citizens towards the environment,* s.l.: European Union.

Toda, H.Y. and T. Yamamoto (1995). Statistical inference in vector autoregressions with possibly integrated processes. *Journal of Economics* 66, 225-250.

United Nations Environment Programme, 2003. *Handbook for the International Treaties for the Protection of the Ozone Layer.* Nairobi: Ozone Secretariat.

United Nations Framework Convention on Climate Change , 1997. *Kyoto Protocol to the United Ntions Convention on Climate Change.* s.l., s.n.

United Nations Framework Convention on Climate Change, 2016. *Paris Agreement.* s.l.:s.n.

United Nations, 2015. *Tranforming our World: The 2030 Agenda for Sustainable Development,* : A/RES/70/1.

Williams, R. C., 2016. *Environmental Taxation,* s.l.: Resources for the Future.

World Comission on Environment and Development, 1987. *Our Common Future.* s.l.:Oxford University Press.