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Tax structure and economic growth: Do OECD's policy recommendations still make sense?

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Abstract

This work aims to study the relationship between tax structure and economic growth. Arnold (2008) and other studies identified a tax and growth ranking concerning the impact the several tax categories on economic growth. This tax and growth ranking inspired several tax policy recommendations from the European Commission, OECD, and IMF but later studies questioned the robustness of the results and the accuracy of the policy recommendations. This work analyses a data set of 23 OECD countries in the period from 1970 to 2019 using the Pooled Mean Group (PMG) estimator to study the relationship between several tax categories and economic growth. Moreover, this work adds to the analysis of environmental taxes categories, which are very often neglected in studies of tax structure and economic growth. The empirical results support the policy recommendations for tax shifts from income taxes towards consumption and property taxes. Concerning corporate income taxes, the findings go against a major part of the literature by suggesting that they have a positive impact on economic growth (however with low robustness). The results also show the broad category of environmental taxes and its sub-category transport taxes as growth friendly, while the sub-category energy taxes have negative impact on growth.

JEL Codes: E62, H2, H3 O4; Q58

Keywords: Fiscal Policy; Tax structure; Economic growth; OECD; Environmental taxes; Transport taxes.

Resumo

Este trabalho tem como objetivo estudar a relação entre estrutura fiscal e crescimento económico. Alguns artigos, como o caso de Arnold (2008) identificam um ranking de impostos e crescimento, tendo em conta o impacto de cada tipo de imposto no crescimento económico. Este ranking inspirou várias recomendações de política fiscal feitas pela Comissão Europeia, OCDE e FMI, no entanto estudos posteriores questionam a robustez destes resultados e a assertividade das recomendações feitas por estas instituições. Este trabalho analisa um conjunto de 23 países da OCDE no período de 1970 a 2019 usando um estimador "Pooled Mean Group" para estudar a relação entre os diversos tipos de impostos e o crescimento. Além disto, este trabalho acrescenta à análise os impostos ambientais que são muitas vezes ignorados em estudos sobre a estrutura fiscal e o crescimento. Os resultados empíricos deste trabalho apoiam as recomendações de política de fiscais de diminuir o peso dos impostos sobre o rendimento e aumentar o peso dos impostos sobre o consumo e propriedade. Em relação aos impostos sobre o rendimento das empresas, os resultados vão contra uma parte significativa da literatura, ao sugerirem que estes impostos têm um impacto positivo no crescimento (embora com falta de robustez). Os resultados mostram ainda que a categoria dos impostos ambientais e a sua subcategoria respeitante aos impostos sobre os transportes são benéficos para o crescimento, enquanto a subcategoria que diz respeito aos impostos sobre a energia tem um impacto negativo no crescimento.

Códigos JEL: E62, H2, H3 O4; Q58

Palavras-chave: Política fiscal; Estrutura fiscal; Crescimento Económico; OCDE; Impostos ambientais; Impostos sobre transportes.

Index

List of Tables

List of Figures

1. Introduction

Taxes have a central role in economic policy. Taxes are defined by OECD as "compulsory unrequited payments to the general government or to a supranational authority" (OECD, 2020). In 2019, tax revenues represent an average 33.8 % of the Gross Domestic Product (GDP) for the OECD countries, having increased from 24.8% in 1965 (OECD, 2020). A clear trend of increasing public expenditures requires higher tax revenues (OECD, 2020).

The main purpose of tax systems is to raise the needed funds for government spending, but they have also other important roles as promoting income redistribution, resource allocation, fiscal consolidation, and economic stabilization. However, taxes create distortions in the economies as they affect economic agent's decisions about savings, investments, and labour supply. Taxes also affect firm's decisions on how much to produce, how many workers to hire and how much to spend in innovations. So, tax systems should be designed to minimize costs of compliance of taxpayers and the government's administrative costs (Johansson et al., 2008).

The magnitude of these distortions depends either on the amount of resources they extract from economic agents (tax levels) or on the way income is collected (tax structure). According to Arnold (2008), macroeconomic literature has neglected the role of tax structures in fiscal policy and economic growth over the past decades. In the analysis of taxation, is desirable to focus on tax structures rather than tax levels (and tax burdens) because differences on tax levels between countries are mainly caused by social choices concerning the adequate level of the government size and public spending, and this beyond the scope of analysis of tax policy, as Johansson et al. (2008) reminds. Although countries with different tax structures can achieve the same level of total tax revenue, there will be different distortionary effects on the economy. Therefore, some authors argue that changes in tax structures have more economic impact than changes in tax levels (Caucutt, 2003; Myles, 2000).

The importance of taxes in modern economies is unquestionable and due to their distortive impact in the economy, is crucial to keep in mind the impact on economic growth when making decisions about the structure of tax systems. There is no consensus about the impact of overall level taxation or public spending on economic growth, due to the opposite effects that can arise. On one hand, taxes create distortions that are detrimental to economic growth. On the other hand, taxes allow the government to raise funds to finance public

spending on infra-structures, education, health care and other services that are the basis for the growth of an economy (Barro,1990).

The focus of this dissertation is on the relationship between tax structure and economic growth. The purpose is to understand which taxes cause the most distortions to economic growth and which are the most favourable to growth. The analysis is focused on developed countries due to their stable and consistent tax systems, which provide more reliable information. Furthermore, the informal sector plays a significant role in tax policy decisions in developing countries (Gordon & Li, 2009). In this sense, the analysis is focused on OECD countries. The OECD is also one of the most important institutions concerning the study of taxation due to the collection of reliable and detailed data and by the promotion of studies in the area.

In the last decades, some International Organizations made policy recommendations regarding reforms of tax structures (European Commission, 2013; IMF, 2013; OECD, 2012), stating that the tax structures should be designed to be growth-friendly, by shifting the tax burden away from income taxes towards consumption and property taxes. These recommendations were largely based on studies that found evidence of a "tax and growth ranking", such as Arnold (2008) and Arnold et al. (2011) that studied a sample of 21 OECD countries over the period 1971 to 2004. This ranking suggests that corporate income taxes have the most negative impact on economic growth followed by personal income taxes, while taxes on consumption and especially taxes on property seem to have a positive correlation with the Gross Domestic Product per capita (GDPpc). However, more recent studies questioned the robustness of this results and questioned the policy recommendations made by some International Organizations (Arachi et al., 2015; Baiardi et al., 2019; Di Sanzo et al., 2017; Xing, 2012). The purpose of this work is to update the research from Arnold (2008) and Arnold et al. (2011), increasing the sample in years studied to the period 1970-2019 (avoiding the impact of the Covid-19 pandemic) and increasing the number countries to 23 OECD countries. The objective is to verify if the conclusions of Arnold (2008) still hold as the sample is increased both in years and countries, dedicating special attention to the robustness of the results and possible implications to tax policy recommendations.

In addition, these studies about a "tax and growth ranking" typically focus on the traditional tax categories: income taxes, consumption taxes, and property taxes. However, over the last few decades, there has been an increase in the discussion about climate change and the role of tax policy in addressing this issue. In some political reports, as the Annual

growth survey of European Commission of 2014 (European Commission, 2013), the environmental taxes are referred alongside consumption and property taxes as being growth friendly. Therefore, in this dissertation the environmental taxes are included in the study of the relationship between tax structure and economic growth.

Summarizing, this work contributes to the literature by updating the influential work of Arnold (2008), extending the period until 2019 and adding two countries to the sample. Moreover, the inclusion of environmental taxes alongside the traditional taxes on study about tax and growth is also an innovation compared to earlier literature. Regarding the environmental taxes, this work goes beyond and makes a breakdown of this category into the sub-categories of energy and transport taxes. In the case of transport taxes there is a lack of literature that looks to the relationship between these taxes and economic growth and so this study can be seen as pioneer in this regard.

The next chapter of this work is dedicated to review of the main literature about tax structure and economic growth. Chapter 3 concerns the description of data and methodology used in this work and chapter 4 contains the empirical results and their discussion. Finally, chapter 5 concerns the conclusions of this work.

2. Literature review

This chapter contains the review of the main literature that supports this work. The first section, 2.1, concerns the factors that influence the design of tax systems, while the second section, 2.2, is focused on the relationship between tax structure and economic growth and is divided into three sub-sections. The first sub-section, 2.2.1, is dedicated to literature about the several tax categories and the mechanisms through which the different taxes can influence economic growth. Sub-section 2.2.2 contains a description of the models of economic growth and how they incorporate the tax effects. Finally, the sub-section 2.2.3 is dedicated to the analysis of the main empirical evidence on the relationship between tax structure and economic growth.

2.1. Factors that influence tax decisions

Government's tax decisions are influenced by several factors. The government must make decisions about the tax burden (the total amount of tax revenues as percentage of GDP) and about the way taxation is distributed across the several types of taxes. In the literature, tax burden is generally considered to have an adverse effect on economic growth. For example, Barro (1990) argues that taxation appropriates resources that would be used to invest in the economy, thus having a negative impact on economic growth. Other empirical literature also confirms the negative relationship between the tax burden and GDP (Alinaghi & Reed, 2021; Cloyne et al., 2023; Engen & Skinner, 1992; Fölster & Henrekson, 2001; Plosser, 1993). In more specific terms, Cloyne et al. (2023) show that a tax cut of 1 percentage point can increase the GDP by around 0.5 to 1 percent. Similarly, Alinaghi & Reed (2021) show that a tax increase of 10 percent is associated with a decrease in the GDP annual growth of approximately -0.2 percent. The negative impact of taxes on the economy is mainly caused by the distortionary effects of taxes on labour and capital productivity (Engen & Skinner, 1992).

Moreover, when making taxation decisions, political authorities must choose between economic growth and income distribution. For example, the authorities need to decide the degree of progressivity of the tax system. A more progressive tax system means that resources are taken away from richest part of population in order to increase the public spending towards the part of population with lower income. For example, the results of Echevarría (2015) show that an increase in the income tax progressivity reduces the inequality

in the distribution, as it contributes to increases between 1 and 3.8% in the Gini coefficient. However, in the long run, this decrease in inequality can come as cost of lower economic growth (Koyuncu & Turnovsky, 2016). The aggregate savings can also be affected by increases in tax progressivity, resulting in a decrease in equilibrium growth (Echevarría, 2015). The degree of progressivity of the tax system may also affect the amount of taxes collected by the government, as Gandhi et al. (1987) shows that, by taking in consideration a potential effect of tax evasion, a more progressive tax structure can generate less tax revenues to the government compared to a regressive tax structure.

There are other factors that need to be taken in consideration by the political authorities, as the possibility of tax evasion and tax avoidance Tax evasion involves illegality practices in order to avoid the payment of taxes, while tax avoidance involves practices of tax postponement and tax arbitrage across income streams facing a different tax in order to reduce the amount taxes paid by an individual (Slemrod & Yitzhaki, 2002). Changes in the tax structure a country can impact the decisions of the household's consumption basket but also may lead to the households giving new instructions to their accountant, make changes in the IRS report, changing the timing of transactions and other kind of actions that can have impacts on the global tax revenue and welfare (Slemrod & Yitzhaki, 2002). Tax evasion can also influence the decisions of a country regarding the tax structure, as the empirical literature shows that evasion is significant higher in income taxes compared to value-added taxes (VAT) and that corporations tend to evade more than singular people (Gómez-Sabaini & Jiménez, 2012).

In addition, there are other factors that may affect decisions about tax structures, such as tax administration issues. For example, Musgrave (1969) reported a tendency from the economies to shift from excise, customs, and property taxes to corporate income and progressive individual taxes on income during the first half of the XX century. This shift was only made possible by the expansion of the market sector and relative decline of the rural sector, the higher concentration of employment in larger establishments and the increasing literacy of the population. The use of broad-based consumption taxes like VAT has increased recently due to the development of tax administration technologies. It has become progressively easier to collect taxes from organized business rather than from households. Therefore, the increasing adoption of taxes like VAT can be justified because it imposes compliance costs without raising administrative costs, by creating incentives for self-policing (Alt,1983). The compliance costs are the costs that taxpayers must bear in order to comply

with the tax system and mainly consist of the time and money that each individual spends for trying to obey the law (e.g., keeping records, paying private tax assistance, etc.). For other side, the administrative costs are the costs that the government must pay to run the tax system (Alt,1983). This includes the costs of collecting the tax revenues and costs associated with making the system credible, by applying penalties for tax avoidance. In general, taxes that increase compliance costs also increase administrative costs due to increased resistance (Alt,1983). Therefore, the ease of collecting taxes, due to administrative and compliance costs, is one of the most important reasons that explain the differences in tax structures between low-income and high-income countries. As Musgrave (1969) noticed, tax handles represent a restriction on total expenditure in countries with low income and affect their decisions regarding tax mix. This restriction decreases as GDP per capita increases, in a way that for high income countries the composition of revenues from taxes becomes a free policy choice.

Furthermore, when discussing potential reforms to the tax structure, it is important to consider the associated costs. The tax systems have become progressively more complex over the last decades and so tax reforms are highly costly both in terms of political constraints and in terms of their administrative burden (Baiardi et al., 2019). There are also costs that arise in the adaption process of firms, investors, and households to the new tax system (Johansson et al., 2008). In this sense, some literature identifies the so called "status quo bias" (Castanheira et al.,2012). Given the complexity and high costs of making big tax reforms, there is a tendency for the countries decide for the maintenance of status quo, even if it represents some efficiency losses. This is a hurdle that prevents the governments from implementing tax reforms, even if they are theoretically aimed at a more efficient tax system.

This section demonstrates that there are many different factors that influence decisions about tax levels and tax structure. However, as discussed above, this work will limit analysis and focus on the relationship between tax structure and economic growth.

2.2. Tax structure and economic growth

2.2.1. Tax structure

In terms of tax categories, OECD organizes the data into several categories and sub-categories according to tax incidence in the OECD tax classification (OECD, 2021). A major part of literature focus on three main tax aggregates, that this work refers as the "traditional

taxes": income taxes, consumption taxes, and property taxes. As mentioned earlier, this work also addresses the environmental taxes. This section contains a description of each tax category and a literature review of the main channels from which these different taxes can affect the economy.

(i) Income Taxes

The income taxes aggregate can be divided into two sub-categories: personal income taxes and corporate income taxes. The personal income taxes usually include social security contributions and payroll taxes (Arnold, 2008). Some OECD studies show that personal income taxes are more distortive to economic growth compared to consumption taxes, because they are more progressive and so as their tax revenue increases the negative impact on economic growth tends to be stronger (OECD, 2010). The substitution effect of lower taxes on labour enhances labour supply as the reward for additional work increases. For other side, the income effect lowers labour supply by raising households' income, resulting in an increase of leisure demand. As a result, the net effect on labour supply is unclear. These taxes also influence the decision of individuals to participate on the labour market (extensive margin) and the number of hours worked (intensive margin) (Takács et al.,2015).

Other studies found that hours worked are only modestly responsive to labour taxes, while the participation in the workforce is much more responsive (Heckman,1993). Additionally, income taxes and social security contributions applied on low wage workers can cause individuals to prefer staying on social benefits rather than participate in the job market (Brewer et al., 2010). Taxes on labour also have an impact on the demand side by increasing the costs of production and the prices of products. The effect is dependent on the elasticity of labour demand, which is how the production factor becomes more expensive will affect demand (Meghir & Phillips,2008). There is also an effect of labour income taxes on human capital accumulation, that depends on the progressivity of income tax (the higher the taxes on people with higher wages, the less worth is the accumulation of human capital (Meghir & Phillips,2008). The reason for this effect is that personal income taxes lower the returns on education, which discourages human capital accumulation (Myles, 2009). Labour taxes can also have an impact on firm's costs if the tax burden cannot be shifted into lower net wages. As shown by Pissarides (1998), lower taxes can decrease the costs of labour, and firms respond by expanding the labour demand. Therefore, the level of employment and the number of average hours worked can be influenced by personal income taxes.

Personal income taxes also affect the return to savings in addition to tax the income from which savings are made, and so may discourage savings (this tends to harm the financing for small and medium-sized companies) (Johansson et al., 2008). Moreover, taxes increase the labour cost in the host country and thus negatively influence foreign direct investment (FDI). For example, Hajkova et al. (2006) show that the effect of labour taxes on FDI may obstruct technology transfers and potential spillovers of the best practices from foreigners to domestic firms.

Moreover, personal income taxes also have important distorting effects on Total Factor Productivity (TFP). The decision to take risks through entrepreneurship can be influenced by the ambiguous effects of top marginal statutory rates on TFP. Taxes decrease the income of well succeed entrepreneur and so discourage the entrepreneurial activity, but at the same time high taxes can encourage the risk sharing with the government and this may foster entrepreneurial activity (Myles, 2009). Additionally, Vartia (2008) suggests that income taxes can reduce TFP, particularly in industries with high corporate profitability. Their findings indicate that social security contributions have a negative impact on TFP, particularly in industries with high labour intensity. Labour taxes also influence the relative prices of capital and labour, which may lead to an inefficient combination of these inputs, thus reducing TFP (Vartia, 2008). For another side, taxes on capital gains influence the demand for venture capital through entrepreneurs' career choice and the supply of funds (Poterba, 1989). Venture capital is a crucial source of financing start-ups, so taxes may diminish the positive effect of new firm entry on TFP growth.

Corporate income taxes are the other part of income taxes. Rather that non the individuals who own the corporation, corporate income taxes are imposed on the corporation as an entity. Corporate income taxes are seen as the most damaging to growth because they discourage investment in capital and productivity improvements (OECD, 2010). For example, Lee & Gordon (2005) find a significant negative correlation between statutory corporate tax rates and growth and estimate that a cut corporate taxes rates by 10% will increase annual growth by 1% or 2%. In addition, by decreasing the after-tax return of investment projects, corporate taxes can have a significant negative impact on the investment of firms. As Johansson et al. (2008) alert, the size of this impact depends on the degree of openness of the economy, with economies with higher degree of openness suffering more from high corporate taxes. The impact of corporate taxes on investment is also influenced by tighter product market regulations and higher administrative burden on firms that can

make investment decisions less responsive to cuts in corporate taxes (Alesina et al., 2005). Additionally, OECD reminds that most corporate tax systems create a big number of tax advantages for specific activities, typically retrieving resources away from new and more productive sectors that can have a greater contribution to economic growth (OECD, 2010). In similar way, Boersch-Supan (1998) show that corporate taxes distort the relative prices of factors, which can result in a reallocation of resources towards less productive sectors, as non-corporate sectors, which may reduce TFP. These taxes can also have an impact on TFP by undermining the firm's financing access, which can discourage entrepreneurial and risk-taking activities (Feldstein, 2006).

Corporate taxes influence financing decisions because they favour debt over equity, due to deductibility of interest from taxable profits (Johansson et al., 2008). This affects TFP because is distortive to the allocation of investment among industries, favouring the ones from whom is easy to increase debt and harming the ones that rely more on equity (Johansson et al., 2008). Within industries, corporate taxes also have a negative impact on investment in R&D, and so in TFP, namely by affecting more firms with fast-growing innovations that need more risk capital (Vartia, 2008). These effects are confirmed by empirical literature, like Schwellnus & Arnold (2008), that study a large set of firms from OECD countries and conclude that almost all firms see their productivity growth lowered by high corporate taxes, especially the ones that are catching up with technological frontier. The negative impact is bigger in more profitable sectors that have a larger tax base, which indicates that the tax component of user cost is responsible for the lower investment rates (Schwellnus & Arnold, 2008). This is why Gentry & Hubbard (2005) described corporate taxes as "successful taxes" because they disproportionately impact businesses that contribute more positively to overall productivity growth.

The Foreign direct investment (FDI) is also affected by corporate taxation, with the size of the impact depending on tax treatment of cross-border income (Hajkova et al., 2006). The impact of this type of taxes on capital formation through FDI is also influenced by the size of economy, with bigger economies being able to attract FDI for their large financial markets even though they keep high rates of corporate taxes (Johansson et al., 2008). The impact of FDI in smaller economies is likely to be more significant, and thus they will suffer more without it. Corporate taxes also decrease the presence of foreign multinational enterprises and so they can obstruct technology transfers and knowledge spillovers to domestic firms (Hajkova et al., 2006).

The high complexity of corporate tax codes is also worth to have in mind because high complex codes raise the costs for firms and the administrative costs for the government that will absorb some resources that would be used for productive activities, what causes productivity and efficiency losses. (Johansson et al., 2008).

(ii) Consumption Taxes

Consumption taxes can be classified as general consumption taxes, usually VAT or taxes on sales of a large range of goods and services, or they can be applied on specific products like tobacco and alcohol in which the distortion effects are desirable because these products are considered dangerous to public health. The effect of VAT and excise duties on consumption depends on product price elasticities. This means that demand for goods with low price elasticities is not significantly affected by taxes and so, there is a small distortion effect on economic growth (Takács et al., 2015). Consumption taxes are seen as less distortive to the decisions of the economic agents, because they are more efficient than income taxes, both in terms of administrative costs and payments, and so a system that rely more on taxes on consumption can have a positive impact on the labour market (Takács et al., 2015). In addition, these taxes apply the same rates on present and future consumptions (assuming rates constant over time) and so don't affect the rate of return on individual's savings choices as income taxes do. So, they are considered as more friendly to private savings compared to income taxes (Johansson et al., 2008).

However, consumption taxes can also cause distortions on the economy, for example by reducing the purchasing power of wages and so negatively affecting the labour supply (Johansson et al., 2008). The prices are increased by these taxes, resulting in a reduction in the real reward for working and a negative impact on labour supply. They can also reduce labour demand in short-term as they increase wages and labour costs. The size of these effects depends on the labour market settings, like the bargaining systems (Johansson et al., 2008).

Taxes on consumption can also affect firms that produce non-traded goods if non-uniform rates are applied. But the spread of general consumption taxes, like VAT, means that they tend to be more uniform in most OECD countries, and so it's expected that consumption taxes have small adverse effect on growth (Arnold et al., 2011). Furthermore, Baiardi et al. (2019) alert that taxes on consumptions have broader tax bases than labour taxes because the choices of consumption can be financed by other sources of income than

wages, and this may help to reduce the distortions in the economy, keeping a constant level of tax revenues. Consumption taxes can also have an impact on the consumption pattern. For example, relatively higher taxes on goods that are complementary to leisure (e.g., golf clubs) can have an effect of encouraging work. Similarly, the relatively low taxes on goods that are complementary to work (e.g., childcare) can also stimulate work (Johansson et al., 2008).

Johansson et al. (2008) also points out the international dimension when analysing the impact of the consumption taxes. By increasing the prices paid by the consumer, these taxes can lead to decrease the consumption of goods from countries with higher consumption taxes and induce consumption of products from countries with lower taxes. For other side, consumption taxes have the advantage of being destination-based taxes, because these taxes are refunded on exports and applied to imports and thus aside from the effect referred above, destination-based consumption taxes are not likely to affect the pattern of international trade (OECD, 2010).

Is also important to mention that consumption taxes are less progressive than personal income taxes, or can even be regressive, and so increasing the share of consumption taxes in the tax structure relatively to personal income taxes reduces progressivity and causes impacts on the income distribution across households. In the same way, as referred in a report from OECD (OECD, 2010), a shift from corporate income taxes to consumption taxes will increase wealthy inequality by boosting the price of shares, due to the increase in the after-tax present value of the company and will also likely increase the income inequality by dropping the capital income taxation (OECD, 2010). A tax reform that reduces the share of income taxes towards consumption taxes can produce more incentives to work, to save and to invest and consequently stimulate economic growth. For other side, it can undermine the income distribution objectives (OECD, 2012).

Most of the literature considers consumption taxes to be growth-friendly, but some empirical research shows that the impact of VAT on economic growth is non-linear. Gunter et al. (2019) study 51 countries from 1970 to 2014 and conclude that when the tax rates are low the effects on economic growth are essentially zero. Then, they conclude that in countries with higher initial VAT tax rates and larger rates changes the damage on GDP can be more significant that countries with lower VAT tax rates.

(iii) Property Taxes

The category of property taxes is relatively heterogenous and the impact on the economy differs among the several sub-taxes. One of the advantages of property taxes is that they have a more stable tax base and so the tax revenue is more predictable, partly due to lower cyclical fluctuation in property values (Joumard & Kongsrud, 2003). Property taxes can also promote greater accountability, especially when used to finance local governments. Property taxes are also more difficult to evade from because building and lands are highly visible and immobile, and this nature of taxes is especially appealing in times of increasing international mobility of the bases of other types of taxes.

Real estate taxes have a small impact on growth, as they don't have any impact on labour or investment decisions. For other side, taxes on donations and welfare may cause distortions in saving and investing. Taxes on capital transfers and financial transactions can also have negative impact on investment, by increasing the cost of capital (Takács et al., 2015). Taxes on inheritance and net wealth can distort the allocation of capital, the motivation to save and may lead to transfers of wealth to offshore accounts. However, inheritance taxes are usually considered to have low distortionary impacts as most inheritances are unplanned and they are a hedge against the uncertain date of death (Auerbach, 2006).

Furthermore, higher recurring real estate taxes can shift a portion of housing investment to higher-yielding sectors, thereby fostering economic growth (OECD, 2010). The drawback is that they discourage housing transactions and allocate housing to most productive usage. Property transaction taxes discourage people from buying and selling houses, which discourages them from moving to areas that can have more labour demand (OECD, 2010). Recurrent taxes on land and buildings do not influence decisions concerning the labour supply, investment on human capital, production and innovation as other types of taxes do, and so are considered more growth friendly (Johansson et al., 2008). Taxes applied on net wealth have a potential low distortive effect on the economic activity and they can have a positive impact on the redistribution of income from the rich population to the poorer. However, as Johansson et al. (2008) points out, these taxes can have an effect of discouraging savings and may lead to wealth transfer for offshore accounts. Finally, property taxes on land and buildings, if well designed, can also affect the development and use patterns of land in some regions. For example, if taxes on vacancy properties and underdeveloped land are low, they may encourage the under-utilisation of land, leading to reduced supply in land destinated for housing (Johansson et al.,2008).

(iv) Environmental Taxes

The last tax category is related to environmental tax revenues. According to the OECD's Environmental Policy Instruments (NIP) database, environmental taxes are divided into four subcategories: energy, transport, pollution, and resources (OECD, 2019). Energy taxes pertain to energy products that are used for transport (petrol and diesel) and stationary purposes (fossil fuels and electricity), including all CO2-related taxes. Taxes on transport concern taxes on the transport services (one-off import or sales taxes, recurrent taxes on registration or road use and other transport taxes) and taxes on motor vehicles, excluding however taxes excise taxes on automotive fuels. The subcategory of pollution includes taxes on: SOx and NOx emissions, taxes on ozone-depleting substances, taxes on discharge of wastewater, taxes on packaging (e.g., plastic bags), on final disposal of solid waste and other waste-related taxes. Finally, the sub-category of resources taxes contains taxes on water extraction, forest products, hunting and fishing taxes, mining royalties, excavation taxes (the category excludes the fees and charges related to water supply) (OECD, 2019). The revenues from auctioning emission allowances, like the Emissions Trading System of the European Union, are included in the revenues from energy taxes (OECD, 2017). However, the OECD points out that data on environmental tax revenues should be interpreted with caution, as revenues can change due to various independent or interrelated factors. For example, decreases in revenues can be caused by erosion on tax base, which represents a benefit from an environmental perspective. For other side, this decreases in tax revenues can be caused by declines on tax rates, that can be see as harmful from an environmental perspective (OECD, 2019).

Regarding their impact on the economy, there is some disagreement in the literature. In the long run, environmental taxes can have opposite effects on growth, as demonstrated by Ono (2003). They lead firms to emit a lower flow of pollution, providing a better quality of environment for next generations, allowing them to allocate more resources on savings and investment, that contribute to economic growth, instead of spending on pollution abatement. For other side, higher tax rates increase the burden on businesses, and this may have detrimental impacts on economic growth. Moreover, Hassan et al. (2020) noticed that there the impact of environmental taxes on growth depends on the initial level of GDPpc of a country, concluding that green taxes can promote the economic growth in rich countries, however when introduced in poor countries they are more likely to decrease the economic growth.

Other literature, as Bovenberg & Heijdra (1998), found that increases on environmental taxes will make future generations benefit from smaller stocks of physical capital (damaging the economy), but benefit from a larger stock of natural (or environmental) capital. This means that the new generations will have a better world in terms of environmental welfare, but will have less physical capital at disposal, resulting in lower growth rates in the long-term (Bovenberg & Heijdra, 1998). Likewise, Wang et al. (2015) show that green taxes can decrease pollution but may produce a distortion in the return to capital and so cause a decrease on economic growth. In order to reduce pollution, firms should undertake abatement activities that result in higher production costs. Higher production costs decrease the return on capital and the incentives to invest, resulting in lower levels of economic growth (Ricci, 2007). However, Hettich (1998) argues that this increase in abatement activities lead to a lower final output net of abatement at the expense of household consumption. This reduction in private consumption causes a substitution away from leisure to time dedicated to studying, contributing to the accumulation of human capital, and therefore promoting economic growth. Moreover, Bovenberg & de Mooij (1997) suggest that green taxes increase the quality of the environment, which leads to an improvement in the productivity of inputs, and thus an increase on productivity of TFP. The prospect of having a better environment for the future may also encourage the savings of households and therefore increase the investment in the economy, resulting in higher growth rates in long term. Environmental taxes can also lead to greater research intensity, inducing a reallocation of resources towards R&D activities, which boosts economic growth (Hart, 2008; Nakada, 2004).

In the literature, is very often referred the double dividend effect of tax shifts towards environmental taxes (Pearce, 1991). The hypothesis of the double dividend effect argues that environmental taxes can both contribute to improve the quality of the environment and to improve the economic efficiency and economic growth. This improvement on economic efficiency and growth is obtained by using the revenues from environmental taxes to decrease the share of distortionary taxes on the economy (Pearce ,1991). Moreover, Abdullah & Morley (2014) refer that the causality relationship of the double dividend effect can also run on the opposite direction from the GDP to taxes, as an increase on the income and wealth of the country can also increase the capacity and the inclination of the country to increase the rates of the environmental taxes.

In addition, Pautrel (2009) mentions the "generational turnover effect" that influences the impact of environmental policy on economic growth. This effect occurs when a new generation is born, and a portion of the existing population dies at a given time. The new population is born without financial assets, meaning that their consumption is below the average, which results in a decrease in the growth rate of aggregate consumption. Considering this effect, Pautrel (2009) shows that with the introduction of the negative impact of pollution on the life expectancy on an AK growth model, the relationship between environmental taxes and economic growth is reversed U-shaped. When the tax levels are low, there is a positive impact on the growth rate because the positive effect of the lower pollution on the life expectancy leads the generational turnover effect to offset the crowding-out effect on the investment (increases in taxes causes increases in the interest rate). For other side, for higher tax levels, the impact on growth is negative because the positive impact on health is lower than the crowding-out effect.

As mentioned earlier, it is possible to break environmental taxes into 4 different sub-categories. The data from the OECD Environment Statistics show that energy taxes and transport taxes are the most relevant sub-categories in terms of weight. The literature identifies three main channels for the effects of energy taxes on economic growth: physical capital, human capital, and eco-innovation. Energy taxes raise the relative prices of the fossil fuels, that is a production factor in the economy, leading to a drop on the quantity of fossil fuels used in the process of production, ultimately reducing the productivity of physical capital (Bovenberg & Heijdra, 1998; Ono, 2003). For other side, by decreasing the levels of pollution emissions, the energy taxes have a positive impact on the learning capacity of students, strengthening human capital accumulation that contributes to economic growth (Gradus & Smulders, 1993). In terms of eco-innovation, energy taxes can positively impact economic growth by encouraging investment in environmental technologies (Hart,2008; Nakada, 2004). In an empirical study in 31 OECD countries between 1994-2013, Hassan et al. (2022) confirms the effects of the three channels referred above. The authors also find that energy taxes are negatively sensitive to the level of public debt and so suggest that the governments should try to minimize the negative effects of the energy taxes on growth by using a part of the revenues from energy taxes to reduce public debt. Concerning transport taxes, there is a lack of literature on the impact of transport taxes on economic growth. Some studies, analyse the impact of transport taxes on the labour market and conclude that the impacts can have better outcomes than what was previously believed (De Borger & Van

Dender, 2003; Parry & Bento, 2001). These studies also suggest that using revenue from congestion taxes to provide better access to public transportation is less efficient than using this revenue to reduce labour taxes. By using these revenues to reduce labour taxes, Parry & Bento (2001) show that transport taxation can stimulate labour supply.

2.2.2. Models of economic growth

As far as economic growth models are concerned, there are two main types of models in the literature: exogenous models and endogenous models. The exogenous models (or classical models) were developed by Solow (1956) and Swan (1956). Solow introduced the concept of steady state and suggested that capital accumulation is not enough to guarantee a continuing growth, with the model predicting that consumption and output per capita reach certain limit, unless there is technical progress. According to Solow's model, countries with low capital stock tend to grow faster than those with higher levels of capital stock due to economic convergence (Solow, 1956). Technical progress is thus the source of growth, but it is considered exogenous in the model.

Further studies studied the impact of taxation on economic growth using a neoclassical growth model as a framework (Becker, 1985; Feldstein, 1974). The main conclusion of this literature is that high income taxes cause lower economic growth rates. However, this effect seems to be too weak to explain the difference in growth rates between countries. Neoclassical models show that the steady-state growth rate is only influenced by exogenous technical progress, and so economic policies can only affect economic growth during the path towards the steady-state. Moreover, this effects on the transition path will likely not have big impact on the growth rate, given that transitional dynamics tend to play a small role in process of growth, as pointed out by (King &Rebelo,1993).

Other authors, as Feldstein (1974), show that taxes can impact the capital accumulation by influencing the factor distribution of disposable income and by changing the net yield on capital through changes on propensity to save. Feldstein's model also shows that taxation can produce changes in profits. The transfer of money from the private sector to the government causes a decrease on savings and a decrease in the capital intensity of production, therefore lowering the real wage and reducing the capital intensity of production. This lowers the real wage and increases the gross rate of return. In addition, Feldstein (1974) also argues that taxes can affect the overall saving rates of the economy and that this impact depends on

the variance in savings propensities between labour and capital and on the elasticity of these savings rates to the net rate of interest.

Given the difficulty of exogenous growth models in explaining the impact of fiscal policy on economic growth, the endogenous growth theory was developed (Lucas Jr., 1988; Barro, 1991). In endogenous growth models, economic growth is considered a sustained process results of multiple individual economic decisions that affect the economy through different mechanisms. The accumulation of human capital increases the labour supply and explains how education influences economic growth. Investment in research and development by the firms contributes to physical capital accumulation and thus enhances growth. The role of the government through taxation can have opposite effects on growth. As Barro (1990) shows, for one hand, taxation appropriates resources that would be used for physical capital accumulation and in other hand the revenues generated from taxes can be used as productive government spending and indirectly enhancing private production. So, taxation impacts the choices of households and firms, and this affects the rate of economic growth. The combination of these different decisions determines the rate of economic growth. In the case of income taxes, Barro (1990) shows the existence of an inverted U-shaped relationship between the growth rate in steady-state and income tax rates. Additionally, some literature identifies income taxes as distortionary taxation arguing that higher income taxes can lead to a decrease in the capital/labour ratio for the private sector substituting away from the input whose production is taxed (physical capital) (Rebelo, 1991). For another side, consumption taxes are classified as non-distortionary, having no impact on economic growth (Rebelo, 1991). So, in endogenous growth models the impact of taxes on growth depends on the tax structure and on the type of public expenditure that is financed by taxes (Bleaney et al., 2001).

As pointed out by Rebelo (1991), economic policies that lead to lower real interest rate generate growth effects in endogenous growth models but only have level effects (for example changes on the capital/labour ratio) in exogenous growth model.

However, there is not clear a consensus about the best theoretical framework to use. According to Arnold (2008), with the literature divided between exogenous and endogenous models, a convincing empirical framework should not force a choice between them. Therefore, Arnold (2008) uses a model that presents an empirical specification derived from both an augmented Solow-Swan-type model and an endogenous growth model inspired in Lucas's model (Lucas Jr, 1988).

2.2.3. Empirical evidence

This sub-section contains a literature review of the empirical evidence on tax structure and economic growth. Some literature distinguishes taxes between distortionary (income taxes) and non-distortionary (consumption taxes) concerning the effect on economic growth (Kneller et al.,1999). Empirical studies indicate that 1% rise in distortionary taxes could lead to a decrease of 0.1 to 0.2 percent on GDP growth (Kneller et al.,1999). Other works, as Rebelo (1991) and Widmalm (2001) also suggest that personal income taxation is negatively correlated with growth and that consumption taxes stimulate growth.

Later studies, as Arnold (2008) and Arnold et al. (2011), turned up to be more influential in terms of policy recommendations. These studies introduce several tax structure indicators into panel regressions of GDPpc, using annual data of 21 OECD countries over the period from 1971 to 2004 in an error-correction setup with a Pooled Mean Group (PMG) estimator. Their conclusions suggest a "tax and growth ranking' in which property taxes seem to be the least harmful for long-run GDPpc, followed by consumption taxes with both taxes presenting positive coefficients in the regressions. For other side, the income taxes provide negative coefficients, with the splitting between personal income taxes and corporate income taxes showing that the latter have the most negative impact on the economic growth. The empirical evidence suggests that a revenue-neutral shift of 1% of tax revenues from income taxes to consumption and property taxes would increase GDPpc by 0.25% to 1% in the long run (Arnold et al., 2011). These conclusions have been confirmed by Ormaechea & Yoo (2012), that use a sample of 69 countries, including a similar number of high, middle, and low-income countries. These results inspired tax policy recommendations from the OECD, IMF, and European Commission (European Commission, 2013; IMF, 2013; OECD, 2012).

However, more recent works have questioned the robustness of these conclusions. For example, Xing (2012) suggest that the results of the relationship between tax structure and economic growth are less general and are very sensitive to the method of estimation used in the error correction model and on the sample of countries and period considered. For example, this study finds no robust ranking between corporate income taxes, personal income taxes and consumption taxes concerning the impact on GDPpc, only finding that property taxes have a positive impact on economic growth, but just under some assumptions.

Furthermore, Baiardi et al. (2019) replicate the analysis of Arnold et al. (2011) for the same countries and period, with and without clustering the standard errors. The analysis

confirms the results with unclustered standard errors, but the results are not significant when clustering the standard errors. They indicate that the inconsistent results from previous literature are mainly caused by the different and essentially arbitrary options about the sets of countries and years that the authors use in their analyses. Additionally, Di Sanzo et al. (2017) support that property taxes are less harmful for economic growth, but do not find convincing evidence preferring consumption taxes over income taxes. Their findings suggest that the negative effects of taxes on growth only become strong and statistically significant when the tax burden is greater than 30%. Other studies, like Arachi et al. (2015) confirm the preference of consumption taxes over labour taxes in terms of effects on growth, however they find no evidence in terms of ranking the capital and labour taxes between them. However, when they use tax ratios as a measure of the tax structure, they find that taxes on labour are more harmful for growth than capital taxation. In summary, several studies call into question the recommendations of international organizations, such as the OECD, the European Commission, or the IMF, according to which these recommendations are based on unfavourable empirical results.

Following this, the aim of this study is to verify if these recommendations still make sense when updating the sample. This work is an update of the articles of Arnold (2008) and Arnold et al. (2011), increasing the sample to the period from 1970 to 2019 and increasing the number of countries to 23 OECD countries. Other contribution for the literature is the inclusion of environmental taxes alongside the traditional taxes on study about tax and growth is also an innovation compared to earlier literature. Moreover, in this work there is a breakdown of environmental taxes into energy taxes and transport taxes. Especially in the case of transport taxes there is lack of literature studying the relationship between them and economic growth, and so this is also a relevant contribution to the literature by this dissertation.

3. Data and Methodology

This chapter concerns the description of the data and methodology used in this work. The first section, 3.1, is dedicated to the derivation of the baseline growth model, the second section, 3.2, contains the estimation approach used and the section 3.3 concerns the description of the data set and the variables used in this work.

3.1 Baseline growth model

For the baseline growth models, this work will follow the model used by Arnold (2008). The model assumes a technology with constant returns to scale and the output is modelled as function of physical capital, human capital, and labour. The aggregate production is assumed to be Cobb-Douglas type, and the production at time t is given by the following equation:

$$Y(t) = K(t)^{\alpha} H(t)^{\beta} \big(A(t)L(t)\big)^{1-\alpha-\beta} \quad [3.1]$$

In equation (3.1) Y stands for the output, K stands for physical capital, H stands for human capital and stands for L for labour. The term α refers to the partial elasticity of output in terms of physical capital and β refers to the partial elasticity of output with respect to human capital. The term $A(t)$ is the level of technological and economic efficiency, that here is assumed to be labour augmenting. The parameter $A(t)$ can be decomposed into two elements, the first is $I(t)$that is economic efficiency that is affected by institutions and public policies and the other term is $\Omega(t)$that is the level of exogenous pure technological process and is a merely function of time (Arnold,2008). So, because $I(t)$ is influenced by public policies it can be written as function of policy variables that will be represented by a vector $V(t)$.

The time paths of the terms on the right-hand side of equation (3.1) can be defined by the equations (3.2) to (3.5), as demonstrated by Bassanini & Scarpetta (2001):

$$\dot{k}(t) = s_k(t)A(t)^{1-\alpha-\beta}k(t)^{\alpha}h(t)^{\beta} + (n(t)+d)k(t) \quad [3.2]$$

$$\dot{h}(t) = s_h(t)A(t)^{1-\alpha-\beta}k(t)^{\alpha}h(t)^{\beta} + (n(t)+d)h(t) \quad [3.3]$$

$$\dot{A}(t) = g(t)A(t) \quad [3.4]$$

$$\dot{L}(t) = n(t)L(t) \quad [3.5]$$

Where $y = Y/L$ (output intensive term), $k = K/L$ (physical capital-intensive term) and $h = H/L$ (average human capital). Moreover, s_k represents the investment rate in physical capital, s_h stands for the investment rate in human capital, n is growth rate of labour, g is the rate of technological change and d is the common depreciation rate. As explained by Bassanini & Scarpetta (2001), the investment in human capital or the stock of human capital can be used at a certain time. In this work, the human capital is proxied by the average years of education of the working population following Arnold (2008) and so the growth expression will include the stock of human capita (h^*). From these equations, it is possible to derive the steady-state path output as:

$$\Delta \ln y^*(t) = ln\, A(t) + \frac{\alpha}{1-\alpha} ln s_k(t) + \frac{\beta}{1-\alpha} ln\, h^*(t) + \frac{\alpha}{1-\alpha} \ln (g(t) + n(t) + d) \quad [3.6]$$

The g term is not observable, and it is not possible to distinguish its parameter from the constant term empirically, as explained by Bassanini & Scarpetta (2001). Then, from this steady-state path output equation, Bassanini & Scarpetta (2001) show how to derive the baseline growth equation, which is presented below.

$$\Delta \ln y(t) = a_0 + \emptyset \ln y(t-1) + a_1 ln s_k(t) + a_2 \ln h(t) + a_3 n(t) + a_4 t + a_5 V(t) + \varepsilon(t) \quad [3.7]$$

The term y is the output measure, which is used in logs and is also included in the lagged output on the right-hand side of the equation. The term a_0 is a set of country fixed effects, t is function of time and the term a_4 corresponds to time effects. The term $\emptyset$ is the convergence parameter, s_k is the propensity to accumulate physical capital (presented in logs), h is the measure of stock of human capital (also presented in logs) and n is the growth rate of working population. The parameter ε is an error term and the term V represents the policy variables in the model and is the term where the tax elements can be included.

3.2 Estimation approach

In terms of estimation approach, some literature uses data as average of 5 or 10 years, but this would imply a significant loss of information that would make difficult to account for some country heterogeneity. For this reason, Arnold (2008) suggests that a better alternative is to use annual data in a fixed effects framework and model the transitional dynamics instead of taking the information loss that will arise by using averages of several years. So, to account for the dynamics of the output that are off equilibrium, an attractive option is to use an error correction model. In this model, independent variables are added both in levels and first differences to capture dynamic transitions. The dependent variable is also included in lags.

To study a dynamic panel data model, there are two extreme models that are often used by the literature as noticed by Pesaran et al. (1999). The first, is the Mean Group (MG) estimator that allows for heterogeneity of all coefficients, intercepts, and slopes, because it estimates a separate equation for each country while the coefficients for the overall panel are computed as unweighted averages of the individual coefficients. This estimator can produce consistent estimates for the average of parameters, but it does not take into account that some parameters may be equal across countries. The MG estimator allows for heterogeneity in both short- and long-run relationships. The second alternative method is the traditional pooled estimator or dynamic fixed effects (DFE) estimator. With this estimator, the intercepts are allowed to be different across countries, but all other coefficients and error variances are restricted to being equal across countries. So, with the DFE estimator, both long-term and short-term coefficients are constrained to be equal across countries.

Following this, Pesaran et al. (1999) proposes an intermediate estimator, the Pooled Mean Group (PMG) estimator. This estimator combines pooling and averaging, allowing for differences in intercepts, short-run coefficients, and error variances across groups. However, it restricts long run relationships to be the same across countries. The authors justify this imposition of homogeneity in the long run, arguing that long run relationships between variables are very often similar across groups due to budget or solvency constraints, arbitrage conditions, or common technologies that impact all countries in a similar way. If the sample only contains OECD countries is reasonable to assume that these countries experience similar behaviors in the long run, given their easy access to common technologies and also the intense trade relations between them (Arnold et al.,2007). Pesaran et al. (1999) also shows that for samples with large number of periods, the DFE and MG estimators can potentially

produce inconsistent and misleading estimates for the average values of the parameters in dynamic panel data models. The PMG estimator addresses a critical problem in empirical growth studies, namely the parameter of heterogeneity. This estimator helps to overcome a part of the problem by assuming the homogeneity of the long run coefficients while it allows the heterogeneity in the short run coefficients and error variances to vary across countries. By allowing heterogeneity in short run, the PMG estimator is less restrictive compared to DFE or Ordinary Least Squares estimators. Short-term relationships are focused on country-specific heterogeneity that is mainly caused by different responses to stabilization policies, external shocks, or financial crises for each country. For example, Duval et al. (2007) shows that there are important differences between OECD countries in terms of the ability to keep the output close to the potential output in the aftermath of shocks. This suggests that the adjustment process towards the equilibrium output path may be different across countries. However, in terms of long run relationships heterogeneity is less of a concern. It seems reasonable to think that long-run relationship between tax structures and growth may follow similar economic principles in all OECD countries even when there are differences around the equilibrium path as explained above. In this sense, as Arnold et al. (2011) argue, the assumption that all slope coefficients entirely unrelated across countries may represent loss of efficiency. To summarize, the PMG estimator assumes that: error terms are uncorrelated and are distributed independently of the regressors, i.e., the explanatory variables can be treated as exogenous; the existence of a long run relationship between the dependent variable and the explanatory variables and that long run parameters are homogenous across countries (Pesaran et al., 1999).

Taking equation (3.7) as a basis, it is possible to incorporate the assumptions of the PMG estimator to compute the equation that is used as a basis for the regressions:

$$\Delta \ln y_{i,t} = a_{0,i} + \emptyset_i \ln y_{i,t-1} + a_{1,i} ln\, s_{i,t}^{K} + a_{2,i}\, lnh_{i,t} + a_{3,i} n_{i,t} + \sum_{j=4}^{m} a_{j,i} V_{i,t}^{j} + a_{5,i}\, t + b_{1,t} \Delta lns_{i,t}^{K} + b_{2,i}\, \Delta lnh_{i,t} + b_{3,i} \Delta n_{i,t} + \sum_{j=4}^{m} b_{j,i}\, \Delta V_{i,t}^{j} + \varepsilon_{i,t} \quad [3.8]$$

In this equation (3.8), the terms a_0 and a_5 correspond to specific country effects and time effects, respectively. The rest of a terms represent the long run coefficients of the relationships between the different variables and the output. For another side, the b terms correspond to the short tun coefficients of the relationships between the different variables

and output. As previously mentioned, the introduction of environmental taxes is one of the contributions of this study compared to earlier works like Arnold (2008). In this sense, is possible to decompose the term V into two different terms related with tax policy: the term T for the traditional taxes (income taxes, consumption taxes and property taxes) and the term Env that represents the environmental taxes. The equation (3.9) below shows the equation that is used is used later in the regressions with the inclusion of these new terms:

$$\Delta \ln y_{i,t} = a_{0,i} + \emptyset_i \ln y_{i,t-1} + a_{1,i} ln\, s_{i,t}^{K} + a_{2,i}\, lnh_{i,t} + a_{3,i} n_{i,t} + \sum_{j=4}^{m} a_{j,i} T_{i,t}^{j} + a_{5,i}\, t + \sum_{j=4}^{m} a_{j,i} Env_{i,t}^{j}\ b_{1,t} \Delta ln s_{i,t}^{K} + b_{2,i}\, \Delta lnh_{i,t} + b_{3,i} \Delta n_{i,t} + \sum_{j=4}^{m} b_{j,i}\, \Delta T_{i,t}^{j} + \sum_{j=4}^{m} b_{j,i}\, \Delta Env_{i,t}^{j}\ \varepsilon_{i,t} \quad [3.9]$$

In terms of tax instruments, even though the focus of this work is on tax structure and not on tax levels, there are significant differences in the overall tax burden between countries and so the tax burden is included as a control variable in the regressions to avoid spurious correlations. In this sense, is important to take in mind some problems that can arise with the inclusion of tax burden in the regressions, as alerted by Kneller et al. (1999) and Arnold (2008). Given that the sum of revenues of all tax indicators (tax burden) is included as control variable in the regression, any change in the revenue from a specific tax indicator influences the quantity of taxes that is raised by the rest of the taxes to keep the same overall tax revenues. So, if the share of revenues in the total tax revenues for all taxes is included simultaneously in regression, while is also included the tax burden as control variable, this may result in an over-identified equation. So, this means that in the regressions it is not possible to have a growth effect of one tax category without a simultaneous impact of the other tax category if the total tax revenues are controlled. Thus, to control to this potential econometric problem, this study will follow the approach of Arnold (2008), that omits one tax element at a time, with the interpretation that the omitted element is left free to close the system. The tax element that is omitted in each regression can be considered the residual that would be reduced if one of the tax elements included in the regression increases. This approach is convenient, because it allows assessing tax reforms under the assumption on tax revenue neutrality, while modelling which type of tax would be reduced as the other one is raised. For example, in the next section column 1 of Table 1 excludes the category of Consumption and Property Taxes. Given that, is possible to interpret the coefficient of the

Income Taxes as the long run effect on the GDPpc that would result if a certain country relied more on income taxes, while adjusting the share of consumption and property taxes in order to keep the amount of total tax revenues constant.

3.3 Data

The data set consists of 23 countries from OECD and the period under analysis is from 1970 to 2019[1]. As mentioned earlier, this work is based on the study of Arnold (2008), that uses 21 OECD countries and analyses the period 1971-2004. In terms of dataset, the upgrade of this dissertation compared to Arnold (2008) is the inclusion of two countries (Luxembourg and Korea) and the period from 2005 to 2019.

Concerning the variables, for the dependent variable is used the GDPpc, that is computed by the real GDP in US dollars and purchasing power parities (PPPs) divided by the population aged between 15 and 64 years. The GDPpc is included as a logarithm and in first lags. The data on working population is also used to compute the variable of population growth, which consists of the growth rate of the population aged between 15 and 64 years. The data for these variables was taken from the OECD Statistics database. In terms of physical capital accumulation, the indicator used is the propensity to accumulate physical capital (or investment rate) that is proxied by the ratio of non-residential gross fixed capital formation in terms of GDP. The indicator is included as a logarithm in the regression, and the data was taken from the OECD Economic Outlook No. 107. Human capital stock is represented by the average number of years of schooling of population over 25 years and is included in as logarithm in the model. The data from 1970 to 1990 is from Barro & Lee (2013) database and from 1991 to 2019 is from the United Nations Development Programme, Human Development Report (UNDP HDR, 2020). The data from Barro & Lee (2013) is provided at five years intervals and so the gaps were filled using linear interpolation in the period 1970-1990 to compute the annual data.

In terms of tax instruments, the data on tax burden, income taxes, consumption taxes and property taxes is from OECD Revenue Statistics. The tax burden is given by the total tax revenues as percentage of GDP. The different tax categories are presented as a percentage

[1] - The countries are: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Korea, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, United States.

of the total tax revenues. For the environmental taxes, energy taxes and transport the data used is only from 1995 to 2019 due to data availability limitations and the data was taken from OECD Environment Statistics. The data on these taxes is also presented as a percentage of the total tax revenues. Additionally, the regressions incorporate time controls. Several tests were performed with the baseline growth regression using no time controls, linear time controls and nonlinear controls and the latter option as proved to be the most consistent. To include the nonlinear time controls in the regressions is used five-year period dummies in the total of 10 dummies (these dummies are included in the short-term part of equation and one dummy is omitted at time to execute the regression). Table 3 in appendix contains more information on what kind of taxes are included in each tax category. Annex II provides a detailed description of the missing data and the data obtained through interpolation.

Below, is possible to find several figures that show the relationship between the several tax categories and the GDPpc. Figure 1shows that in most countries the percentages of total tax revenues in terms of GDP (tax burden) are around or above 30% and a significant part is even above 40%. Is also possible to see that some of the lowest values of GDPpc are correlated with low percentages of tax burden and some of the highest values of GDPpc are associated with tax burden around 35%. Figure 2 shows the relationship between income taxes and GDPpc and shows that this is the tax category with highest weight on total tax revenues, with a big part of values around 60%. This figure also shows that the highest values of GDPpc are associated with share of income taxes above 60%. In figure 3, is possible to see that consumption taxes are one of the most relevant tax categories with a big part of values around or above 30 % of total tax revenues. Figure 4 shows that property taxes represent the category with lower weight on total tax revenues in the group of traditional taxes. Figure 5 presents the relationship between the environmental taxes and GDPpc and shows that they also represent a low share of total tax revenues with the most values between 4% and 8%. In figures 6 and 7 is possible to see that concerning environmental taxes, the energy taxes are the most relevant in terms of weight, compared to the transport taxes.

Figure 1. Relationship between Tax Burden and GDPpc

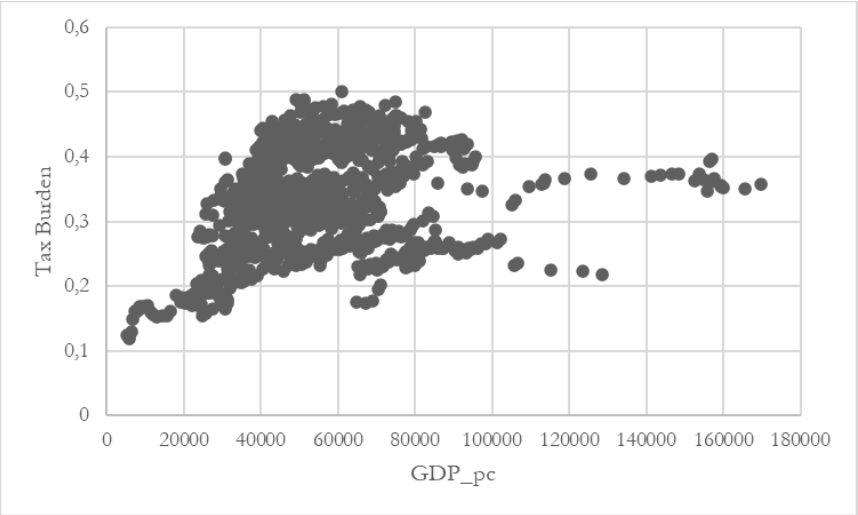


Figure 2. Relationship between Income Taxes and GDPpc

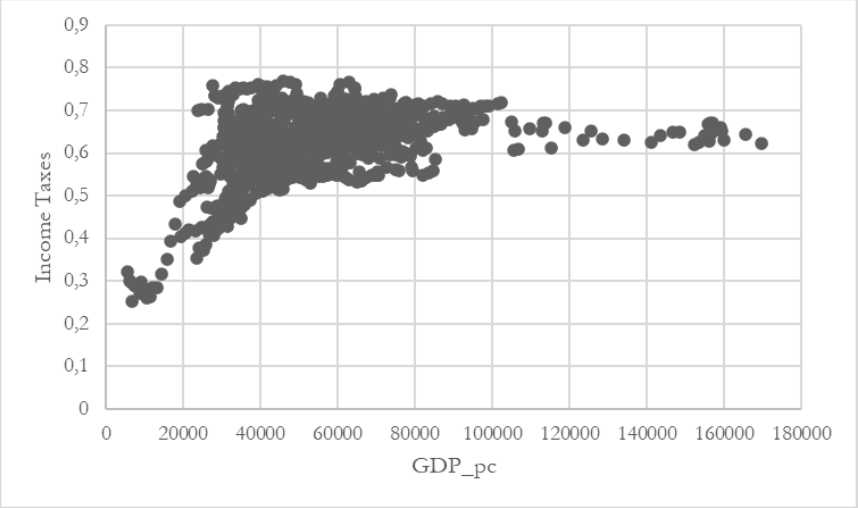


Figure 3. Relationship between Consumption Taxes and GDPpc

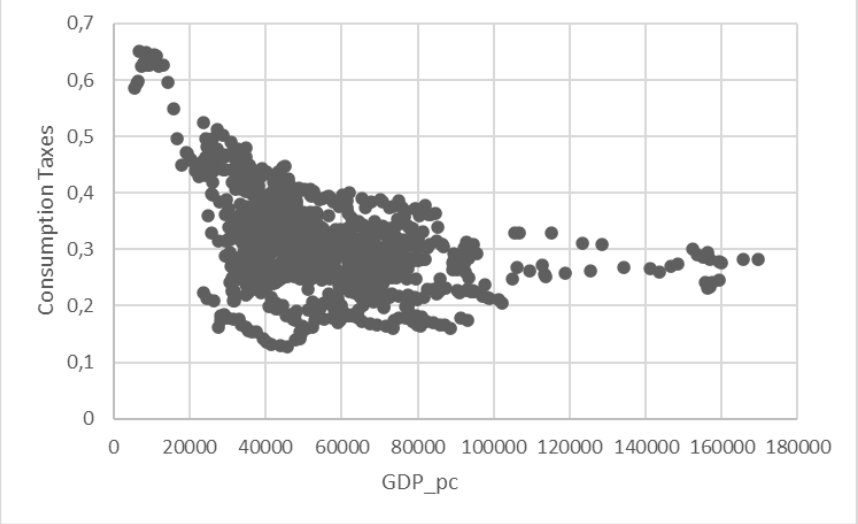


Figure 4. Relationship between Property Taxes and GDPpc

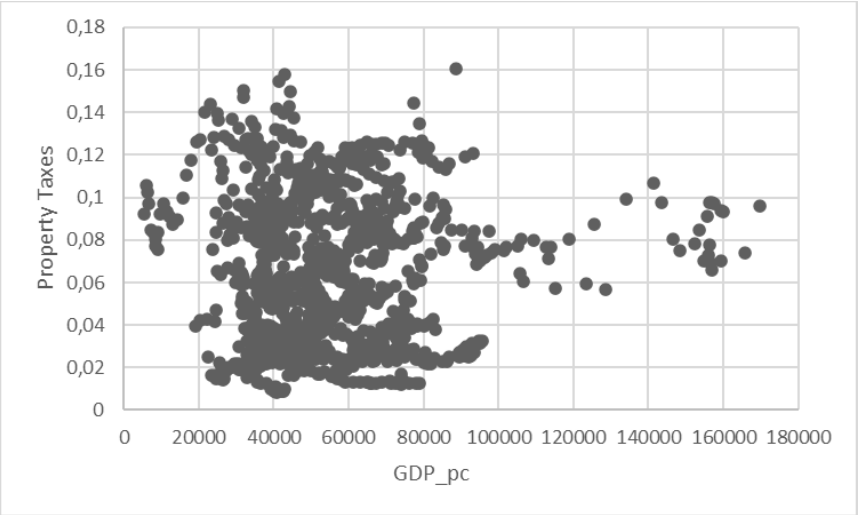


Figure 5. Relationship between Environmental Taxes and GDPpc

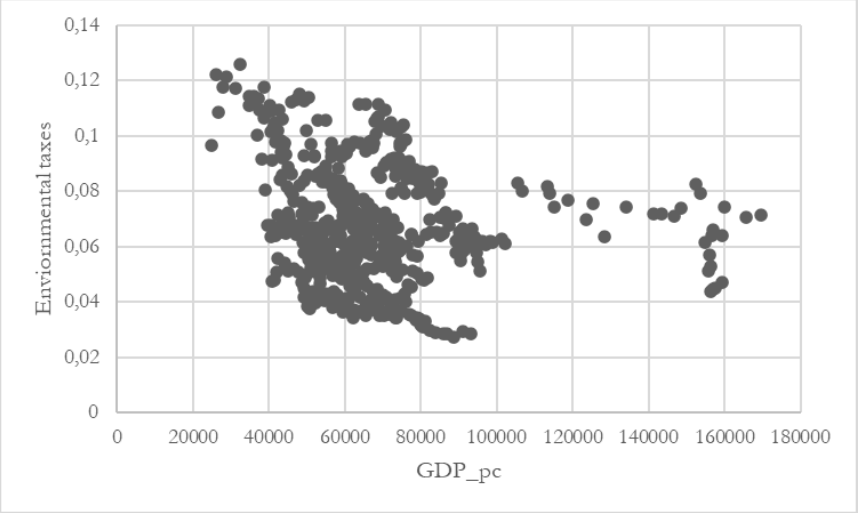


Figure 6. Relationship between Energy Taxes and GDPpc

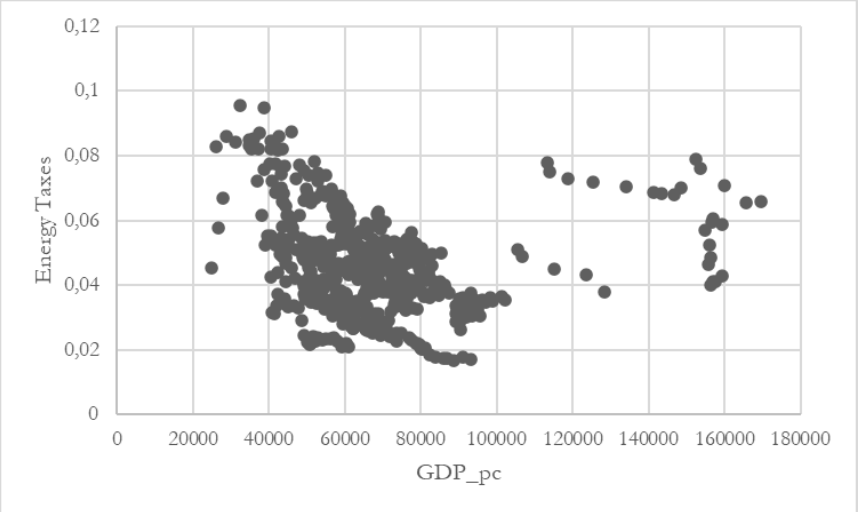
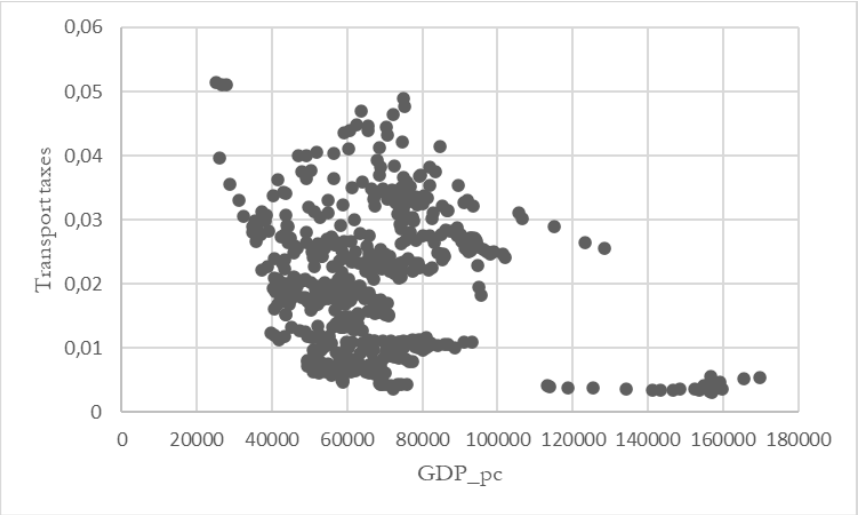


Figure 7. Relationship between Transport Taxes and GDPpc



4. Results and Discussion

This chapter presents the empirical results and their discussion. The chapter is divided into two sections, with the first, 4.1, concerning the results for the traditional and the second section,4.2, containing the results and discussion for environmental taxes.

4.1 Traditional taxes results

Table 1(presented below) contains the results for the regressions including the traditional tax categories with coefficients for the long run. Frist is possible to analyse the coefficients of the inputs of the growth equation. There are no significant changes in the coefficients of these variables across the different regressions. The signs of the coefficients are in accordance with previous literature (Arnold, 2008). The physical and human capital have positive coefficients, which means they have a positive correlation with GDPpc and contribute positively to economic growth. The population growth presents negative values but with small absolute values meaning that it has slightly negative impact on economic growth.

Concerning tax burden, the coefficients for the four regressions are positive and statistically significant. These results differ from the findings of most literature, like Arnold (2008), Baiardi et al. (2019), or Xing (2012), that report a negative and statistically significant relationship between the overall tax burden and the GDPpc. However as mentioned in the previous section, tax burden is only included as a control variable and the interpretation of the coefficient is not relevant for this study.

In respect of the tax categories in Table 1, column 1 includes the broad income taxes in the regression. This column 1 shows the long run effect on the GDP of a tax reform towards the broad category of income taxes, considering that this reform would be financed by a decrease of the share of consumption and property taxes in the total taxation. The coefficient is statistically significant and suggest that increases of 1 percentual point in the income taxes will lead to a decrease of 1.44% in the GDPpc (ceteris paribus). These results confirm the findings of the literature that increases in income taxes are associated with lower levels of economic growth (Arnold, 2008).

In column 2, there is a breakdown of the income taxes into personal income taxes and corporate income taxes, with both coefficients being statistically significant. The coefficient of personal income taxes is negative and higher than the coefficient of broad income taxes. These findings confirm the results of the literature (Arnold, 2008). For other

side, the corporate income taxes have a significant positive coefficient, contradicting the results of Arnold (2008) and of most literature that show the corporate income taxes with the most negative impact on economic growth. However, there is studies that also found that the corporate income taxes are positively correlated with economic growth (Angelopoulos et al., 2007; Widmalm, 2001).

Turning the focus of the analysis into the consumption and croperty taxes, column 3 of Table 1 shows the results of both categories being considered together. The coefficient is significant and positive with a value of 1.42. Finally, column 4 shows the results with the split between consumption and property taxes. The coefficients are both significant and positive, with property taxes having a much higher coefficient. These results confirm the finding of a broad literature that show consumption taxes and property taxes as being growth enhancing and with the property taxes being the ones with more positive impact on economic growth (Arnold, 2008).

As discussed in the previous section, some literature, like Kneller et al. (1999) distinguish the taxes between the direct and distortionary taxes (income taxes) and indirect and non-distortionary taxes (consumption and property taxes) as respect of the impact on economic growth. The results of Table 1 show that income taxes have a negative coefficient and thus can be considered as distortionary taxes to economic growth. The results also show that consumption and property taxes have positive coefficients and so can be classified as non-distortionary taxes concerning the effects on economic growth. Then, is possible to conclude that the results of Table 1 confirm the conclusions of Kneller et al. (1999).

As mentioned earlier this work aims to update the results of Arnold (2008) by increasing the period under analysis and adding two countries to the data set. The results of Table 1 confirm most of the findings of Arnold (2008), but not all of them. The evidence of Table 1 shows that the income taxes, the personal income taxes, the consumption taxes, and the property taxes present the same signs as shown by Arnold (2008). It is also interesting to notice that the coefficients of this tax components in Table 1 present higher absolute values compared to the findings of Arnold (2008). However, concerning the corporate income taxes the positive and significant coefficient shown in column 2 of Table 1, suggests that these taxes can be considered as growth friendly. This result goes against the conclusions of Arnold (2008) that classifies this tax component as the most harmful for economic growth. Therefore, is possible to conclude that as previous noticed for some literature, the results of Arnold (2008) present a lack of robustness and are sensitive to the choice of the data set.

Table 1. Regressions results with traditional Taxes.

DepVar: Log GDPpc	(1)	(2)	(3)	(4)
Physical capital	0.09(0.05)*	0.08(0.05)	0.10(0.05)**	0.11(0.05)**
Human Capital	0.95(0.11)***	1.03(0.11)***	0.96(0.12)***	0.98(0.11)***
Population Growth	-0.03(0.01)***	-0.04(0.01)***	-0.03(0.01)***	-0.03(0.01)**
Control variable				
Tax Burden	0.97(0.29)***	0.93(0.28)***	0.96(0.28)***	0.67(0.27)**
Tax variables				
Income Taxes	-1.44(0.33)***			
Personal Income Taxes		-1.61(0.34)***		
Corporate Income Taxes		1.02(0.39)***		
Consumption & Property Taxes			1.42(0.33)***	
Consumption Taxes				0.90(0.32)***
Property Taxes				3.95(0.69)***
Nº Observations	1125	1106	1123	1123

Standard errors in brackets. * Significant at 10%level. ** significant at 5% level. *** significant at 1% level.

4.2 Environmental taxes results

Table 2 (presented below) shows the results of growth regressions with environmental taxes. The tax burden is again included as a control variable. The regressions in Table 2 concern only the period 1995-2019, due to limitations in the data available on environmental taxes. Table 2's results reveal some differences in the coefficients of the growth equation inputs compared to Table 1. In the first column of Table 2, the coefficient of human capital is not significant, and the value is close to 0, while the coefficients of human capital in Table 1 are around 1. Second column of Table 2 shows that the coefficient for

physical capital is significant and negative, which goes against the results of the literature (Arnold, 2008) and the results of Table 1. These differences in the growth regression inputs are mainly caused by the difference in sampling periods between the two tables[2].

In terms of taxes, column 1 of Table 2 shows the results for the regressions with the broad environmental taxes. The coefficient is statistically significant and strongly positive, meaning that environmental taxes have a positive relationship with the GDPpc. These results contradict some important articles on this regard. For example, the results from Abdullah and Morley (2014) show that increases in environmental taxes do not seem to have a strong impact on economic growth. Other articles, like Tchapchet-Tchouto et al. (2022) show that an increase of environmental taxes has a statistically significant and negative impact on GDP. Additionally, Hassan et al. (2020) finds no statistical evidence of the relationship between the environmental taxes and GDP in short and long run. However, when they allow the environmental taxes to interact with the initial level of GDPpc of each country, the results show that environmental taxes are negatively correlated with economic growth. Therefore, the article shows that the initial real GDPpc level influences the relationship between the environmental taxes and economic growth. The results suggest that that environmental taxes can have a positive impact on the economic growth in countries with higher initial levels of GDPpc, but in poor countries the environmental taxes can have a negative impact on the economic growth. In this work, the sample consists of 23 rich and developed countries and so the significant coefficient and positive coefficient of the environmental taxes in Table 2, confirms the conclusions of Hassan et al. (2020) that in rich countries the environmental taxes can have a positive effect on growth.

Even though, these important studies find no relationship or even a negative relationship between environmental taxes and economic growth, the results of column of Table 2 are supported by some studies. For example, Mirović et al. (2021) shows that the long run coefficient between the environmental taxes and the GDP is positive and that 1% increase in environmental taxes can increase the GDP by 0.23%. Moreover, the evidence from Dökmen (2012) shows a significant and positive coefficient between an increase of environmental taxes and GDP. In addition, there is more literature that conducts a different

[2] - In the annex, there are presented the results of the baseline growth regressions for the sample period considered in Table 1 (1970-2019) and for the period considered in Table 2 (1995-2019). The results show that for the regression with the complete sample the coefficients are all significant and present the expected signs, while for the sample 1995-2019, the coefficients for physical capital and human capital are not significant.

type of analysis, evaluating the impact of environmental taxes on GDPpc based on the way they are utilized. The broad conclusion is that the environmental taxes have a positive impact on economic growth, if they are associated with a decrease in the distortionary tax rates (as income taxes) (Nakada, 2010; Oueslati, 2014).

In column 2 there is a breakdown of environmental taxes into energy taxes and transport taxes. It is possible to see that energy taxes have a statistically significant and negative coefficient while transport taxes have a significant and strongly positive effect on GDPpc. This shows that even though environmental taxes seem to be enhancing growth, there are some environmental taxes that can have negative effects on economic growth. In terms of literature comparison, there are articles that confirm this negative coefficient. The study of Rotemberg & Woodford (1994) shows that an implementation of 1% energy tax implies a reduction of 0.110 percent of GDP in the first year. However, studies like Wang et al. (2018) found that energy taxes can have a positive but small impact on GDP. Moreover, a work from the European Commission (European Commission, 2011) shows that the effects of energy taxes on GDP depends on how the revenues from these taxes are used. If the revenue is used to reduce the labour costs, it can have positive impact on GDP, but only around 0.33 percentage points. However, if the revenues are used in the form of lump-sum transfer to households or to fiscal consolidation does not have positive effects on GDP. Concerning the transport taxes there is not much empiric literature that studies the relationship between them and GDPpc.

Table 2. Regression results for Environmental Taxes

DepVar: Log GDPpc	(1)	(2)
Physical capital	0.20(0.10)*	-0.13(0.05)**
Human Capital	0.02(0.27)	1.08(0.09)***
Population Growth	-0.08(0.02)***	-0.18(0.00)**
Control variable		
Tax Burden	4.14(1.20)***	2.01(0.34)***
Taxes variables		
Environmental taxes	15.32(4.3)***	
Energy Taxes		-3.93(0.78)***
Transport Taxes		18.08(2.54)***
Observations	542	546

Standard errors in brackets. * Significant at 10%level. ** significant at 5% level. *** significant at 1% level

4.3 Robustness tests

As mentioned earlier, several articles raised concerns about the robustness of the conclusions of Arnold (2008) and Arnold et al. (2011). This dissertation applied the same approach as these studies, so it is important to test the robustness of the results of Table 1 and 2. The tables containing the results for all robustness tests are presented in annex I

Frist, some tests were performed using some control variables that the literature often refers to as having an impact on GDPpc levels: inflation and trade openness. The measure of inflation considered here is the rate of growth of the private final consumption deflator. The trade openness measure is determined by the sum of exports and imports of goods and services as a percentage of GDP. The coefficients of these variables are statistically significant and show the expected signs, with inflation being negative related to GDPpc and trade openness being positive correlated with GDPpc. In terms of the tax elements, there are no significant changes in the coefficients compared to the results of Table 1.

One of the problems that is often referred in studies of growth models with tax policy variables, is the potential occurrence of endogeneity bias. According to Arnold (2008), tax revenues tend to increase during expansion and decrease during recession, which could cause endogeneity bias in regressions. Consumption and the property taxes tend to be more stable over time and are not likely to have strong correlations to business cycles. However, income taxes may be more affected by cyclical components. In a similar way, environmental taxes may also be subject to endogeneity bias.

In this sense, some tests are performed to account for potential endogeneity, by purging the tax instruments of potential correlations with business cycles. It is possible to do this by regressing tax instruments by potential output or output gap (more details on these variables on table 3 in appendix). Frist, the tax instruments are regressed (using a linear regression) by the output gap. These linear regressions include first and second lag and the quadratic terms of each lag of the output gap and there is one regression for each country. Then, the residuals of these regressions are used as tax indicator in the growth regressions. The same method is also applied using the potential output instead of the output gap to purge the tax instruments of correlations with the business cycle. Additionally, the tax instruments are also regressed by both the potential output and the output gap simultaneously and then by using the residuals as tax indicators in the growth regression. Finally, the same method was applied but using the potential output and the output gap sequentially to purge the tax instruments of possible correlations with the business cycle. To do so, the tax instruments are regressed by the output gap (using the first and second lag and the quadratic terms of both lags) and then the resultant residuals are regressed by the potential output (using also the first and second lag and the quadratic terms of both lags). Then, the residuals of these last regressions are used as tax instruments in the growth regression. These methods were applied to income, corporate, and environmental taxes, which are more likely to be affected by endogeneity bias, as explained above. For corporate income taxes, one additional method was applied to instrument the tax indicator of corporate income taxes. The tax instrument of corporate income taxes is regressed using four own lags and then the residuals are used as tax element on the growth regression. The results of this several tests confirm the robustness of the results of Table 1 and 2. The income taxes tend have negative coefficients and the environmental taxes have always positive coefficients. In terms of corporate income taxes, the robustness tests are not conclusive with the results showing different signs.

Another concern that arises from the literature is the potential effect of the tax burden on the coefficients of the tax instruments. For example, Di Sanzo et al. (2017) suggest that negative effects of the taxes on economic growth are stronger for countries with the tax burden above 30%. Given that, some tests are performed to verify this potential effect of tax burden. The sample is divided between countries with a tax burden above and below the average. In annex the results of the regressions using these 2 groups of countries are presented and is possible see that the coefficients tend to be slightly higher in the group of countries with a tax burden above the average compared to the group of countries with tax burden below the average. Taking this into account is important to test if the results of the effects of tax burden are statistically significant. So, in the growth regressions are included dummies for tax burden and crossed dummies with the tax instruments (these are obtained by multiplying the tax burden dummies for each tax category). The results show that the coefficients of the cross-dummies of the several taxes are not significant indicating that the tax burden does not have a significant impact on the relationships between taxes and the GDPpc.

Therefore, with the results of these several robustness checks, it is possible to have some guarantee about the robustness of the conclusions presented in sections 4.1 and 4.2.

5. Conclusion

This dissertation analyses a data set of 23 OECD countries in the period 1970-2019. The aim of this work was to update the work of Arnold (2008) that found evidence of a "tax and growth ranking" that was the basis for policy recommendations by European Commission, OECD, and IMF (European Commission, 2013; IMF, 2013; OECD, 2012). However, later studies questioned the robustness of the findings of Arnold (2008) and consequently the policy recommendations made by some International Organizations. This "tax and growth ranking" of Arnold (2008) reported corporate income taxes as the most harmful for economic growth, followed by personal income taxes. For another side, consumption taxes and property taxes were classified as growth enhancing, with the latest category having the most positive impact on the economic growth. Therefore, the policy recommendations were towards a tax shift from income taxes to consumption and property taxes. The work of Arnold (2008) does not include the environmental taxes, and so one of contributions of these dissertation is to add the environmental taxes to the discussion of this tax and growth ranking. Some earlier literature studied the impact of environmental taxes on economic growth alone, but this contributes to the literature by including the environmental taxes and the sub-categories of energy taxes and transport taxes alongside the traditional taxes when assessing the impact on economic growth. The methodology and data for the growth regression inputs is the same for all these tax categories and so this allows a direct comparison between the several empirical results. In the specific case of transport taxes, is very hard to find literature that assess their impact on economic growth. So, this work can be considered pioneer on this regard and can inspire some future research on this relationship.

The empirical results presented in section 4, confirm that the broad category of income taxes is negatively correlated with GDPpc and thus can be considered as harmful growth. However, when making the breakdown between personal income taxes and corporate income taxes the results contradict the findings of Arnold (2008), that the latest has the most negative impact on economic growth. In fact, the findings of Table 1 show that the coefficient of corporate income taxes is statistically significant and positive, even though the robustness checks described in section 4.3 show that this result should be interpreted with caution. The personal income taxes present a negative coefficient in relation to GDPpc as expected. The results also show consumption and property taxes with the expected positive signs and with property taxes appearing with highest coefficient. In terms of

environmental taxes, there is not a clear consensus in the literature of how they impact economic growth. The results of Table 2 show a significant and strongly positive coefficient for the environmental taxes, much higher compared to the other taxes categories mentioned above. Doing the breakdown of environmental taxes into energy taxes and transport taxes, the results show energy taxes with a significant and negative coefficient and transport taxes with a significant and strongly positive coefficient (with a higher value than the broad environmental taxes). These results show that even though that the environmental taxes seem to be growth friendly, some environmental taxes like energy taxes seem to have a negative impact on growth. This result is very interesting considering that the energy taxes are the most relevant category inside the environmental taxes according to the data from OECD Environment Statistics. This indicates that the positive effect on growth of the rest of sub-categories of environmental taxes is very significant.

Regarding environmental taxes is also important to notice that earlier literature found evidence that they can have positive effects on economic growth in rich countries but can negatively affect growth in poor countries. The sample of this work consists of 23 OECD countries that are part of group of rich countries. Therefore, the empirical results confirm that environmental taxes have a positive impact on growth in rich countries, but future research is needed to confirm if the effect would be the same considering a set of poor countries. The findings of this work also show that the categories that seem to have the most positive impact on growth, property, and environmental taxes, are simultaneously the categories with the lowest share on total tax revenues with values below 10% in most countries. Therefore, future research can be dedicated to this topic to understand if the positive coefficients can be related to the fact that these categories have a low weight on the total tax revenues.

As mentioned earlier, one of the main concerns in this work was about the robustness of the empirical results. The several robustness tests performed show that except for corporate income taxes, the results for all tax categories can be considered as robust.

To summarize, is possible to conclude that the evidence from this work supports the OECD's policy recommendations of tax shifts from income taxes towards consumption and property taxes. However, the evidence shows that in the case of the corporate income taxes (considered to be most harmful for economic growth by this reports) the policy recommendations should be made with caution, as there seems to be a lack of robustness on the results for this category. The evidence also supports that the broad environmental

taxes and the sub-category of transport can be considered as growth friendly, however energy taxes seem to have a negative impact on economic growth.

6. Appendix

Table 3. Description of the Variables

Variable	Description of variables	Source
Real GDPpc (in logs)	Real GDP per head of Population aged between 15 and 64 years expressed in US dollars, constant prices, constant PPPs reference year 2015	OECD National Accounts Database
Physical capital accumulation (in logs)	Ratio of non-residential gross fixed capital formation to GDP	OECD economic outlook 107
Population Growth (in percentage)	Growth rate of population aged between 15 and 64 expressed in percentage	OECD Employment and Labour Market Statistics
Stock of human capital (in logs)	Average number of years of schooling for population with over 25 years	Barro-Lee (2018) and UNDP HDR (2020)).
Tax Burden (% of GDP)	Total tax revenues as percentage of GDP	OECD Revenue Statistics database
Income Taxes (% total taxes revenues)	Taxes on individual income and capital gains, social security contributions and payroll (categories 1000,2000 and 3000 of OECD classification of taxes)	OECD Revenue Statistics database
Personal Income Taxes (% total taxes revenues)	Taxes on individual income, social security contributions and payroll (categories 1100,2000 and 3000 of OECD classification of taxes)	OECD Revenue Statistics database
Corporate Income taxes (% total taxes revenues)	Taxes on capital gains (category 1200 of OECD classification of taxes)	OECD Revenue Statistics database
Consumption Taxes (% total taxes revenues)	Taxes on goods and services and other taxes (categories 5000 and 6000 of OECD classification of taxes)	OECD Revenue Statistics database
Property Taxes (% total taxes revenues)	Recurrent taxes on immovable property, net wealth, estates, inheritances and gifts, financial and capital transactions, non-recurrent taxes and other property taxes (category 6000 of OECD classification of taxes)	OECD Revenue Statistics database
Environmental taxes (% total taxes revenues)	Taxes on energy products; transport equipment, transport services, pollution, and natural resources	OECD Environment Statistics
Energy taxes (% total taxes revenues)	Taxes on energy products (like fossil fuels and electricity) including the ones used in transportation, like petrol and diesel. Also includes all CO2-related taxes.	OECD Environment Statistics

Transport taxes (% total taxes revenues)	Includes taxes on one-off import or on transport equipment, recurrent taxes on ownership, registration or use of motor vehicles, and other taxes related with transport.	OECD Environment Statistics
Output Gap (% of potential GDP)	Difference between the actual GDP and the Potential Output	OECD Economic Outlook No 107
Potential Output	Calculated suing the Gross domestic product (in USD, at constant PPP) and the ratio of potential to actual real GDP of the total economy	OECD Economic Outlook No 107
Inflation (in logs)	Growth rate of the price deflator private final consumption expenditure in national currency	AMECO Database
Trade Openness (% of GDP)	the sum of exports and imports of goods and services as percentage of GDP	OECD National Accounts Database
Time controls	Five year period dummies: 1970-1974, 1975-1979,1980-1984, 1985-1989, 1990-1994, 1995-1999,2000-2004, 2005-2009,2010-2014, 2015-2019	

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8. Annex I

Robustness tests

Table 4. Additional regressions with tax instruments.

DepVar: Log GDPpc	(1)	(2)	(3)
Physical capital	0.12(0.05)**	0.12(0.05)**	0.12(0.05)**
Human Capital	1.07(0.12)***	1.07(0.12)***	1.05(0.12)***
Population Growth	-0.04(0.01)***	-0.04(0.01)***	-0.04(0.01)***
Control variable			
Tax Burden	0.80(0.29)***	0.80(0.28)***	0.87(0.30)***
Tax variables			
Personal Income Taxes		-1.39(0.35)***	-4.14(0.74)***
Corporate Income Taxes	2.44(0.38)***		-1.69(0.72)**
Consumption Taxes	1.53(0.37)***	1.03(0.36)***	-2.49(0.69)***
Property Taxes	4.44(0.76)***	2.68(0.68)***	
Nº Observations	1104	1106	1104

Standard errors in brackets. * Significant at 10%level. ** significant at 5% level. *** significant at 1% level.

Table 5. Baseline growth regressions with two different periods considered.

DepVar: Log GDPpc	1995-2019	1970-2019
Physical capital	0.07(0.06)	0.09(0.05)*
Human Capital	-0.07(0.18)	0.81(0.10)***
Population Growth	-0.02(0.01)*	-0.05(0.13)***
Nº Observations	552	1127

Standard errors in brackets. * Significant at 10%level. ** significant at 5% level. *** significant at 1% level.

Table 6. Robustness tests with Inflation and trade openness

DepVar: Log GDPpc	(1)	(2)	(3)	(4)
Physical capital	-0.008(0.08)	0.01(0.08)	0.11(0.06)**	0.12(0.06)**
Human Capital	0.99(0.20)***	1.38(0.22)***	0.23(0.13)*	0.76(0.15)***
Population Growth	-0.08(0.03)***	-0.09(0.03)***	-0.07(0.02)***	-0.06(0.02)***
Tax Burden	-0.19(0.47)	-0.44(0.47)	0.51(0.36)	0.35(0.35)
Income Taxes	-1.22(0.48)**		-1.52(0.38)***	
Consumption & Property Taxes		1.13(0.47)**		1.75(0.42)***
Inflation	-0.10(0.02)***	-0.11(0.02)***	-0.07(0.01)***	-0.06(0.01)***
Trade Openness			0.69(0.13)***	0.24(0.08)***
Nº Observations	1024	1022	1024	1022

Standard errors in brackets. * Significant at 10%level. ** significant at 5% level. *** significant at 1% level.

Table 7. Endogeneity tests with correction for business cycle using output gap.

DepVar:Log GDPpc	(1)	(2)	(3)	(4)
Physical capital	0.18(0.05)***	0.18(0.05)***	-0.16(0.07)**	-0.30(0.08)***
Human Capital	0.42(0.09)***	0.35(0.09)***	1.13(0.11)***	1.32(0.14)***
Population Growth	-0.03(0.01)***	-0.06(0.01)***	0.03(0.01)**	0.02(0.01)*
Tax Burden	1.59(0.30)***	1.46(0.30)***	2.21(0.44)***	-0.20(0.23)
Income Taxes (regressed by output gap)	-2.18(0.30)***	-1.52(0.28)***	2.23(0.30)***	
Share of Corporate Income Taxes in Income Taxes (regressed by output gap)		2.10(0.29)***		
Share of Corporate Income Taxes in Income Taxes(instrumented)			1.41(0.39)***	
Environmental Taxes (regressed by output gap)				0.01(0.01)*
Nº Observations	696	690	658	496

Standard errors in brackets. * Significant at 10%level. ** significant at 5% level. *** significant at 1% level.

Table 8. Endogeneity tests with correction for business cycle using potential output.

DepVar:Log GDPpc	(1)	(2)[1]	(3)	(4)
Physical capital	0.09(0.05)*		0.12(0.07)*	-0.07(0.05)
Human Capital	0.29(0.09)***		0.08(0.13)	2.06(0.12)***
Population Growth	-0.04(0.01)***		-0.06(0.01)***	0.01(0.01)
Tax Burden	1.82(0.35)***		1.73(0.42)***	3.32(0.37)***
Income Taxes(regressed by potential output)	-1.90(0.37)***		-1.54(0.48)***	
Share of Corporate Income Taxes in Income Taxes(regressed by potential output)				
Share of Corporate Income Taxes in Income Taxes(instrumented)			3.29(0.62)***	
Environmental taxes(regressed by potential output)				0.05(0.01)***
Nº Observations	696		660	496

Standard errors in brackets. * Significant at 10%level. ** significant at 5% level. *** significant at 1% level.

1 – No convergence achieved by Stata for this regression.

Table 9. Endogeneity tests with correction for business cycle using output gap and potential output simultaneously.

DepVar:Log GDPpc	(1)	(2)	(3)	(4)
Physical capital	0.09(0.05)	0.19(0.03)***	-0.55(0.16)	-0.44(0.13)***
Human Capital	1.55(0.11)***	0.84(0.08)***	1.61(0.24)***	2.63(0.26)***
Population Growth	-0.04(0.01)***	-0.01(0.01)	0.03(0.02)*	-0.02(0.01)
Tax Burden	2.78(0.28)***	1.21(0.24)	0.78(0.51)	5.13(0.90)***
Income Taxes(regressed by output gap and potential output simultaneously)	-0.96(0.29)***	-0.47(0.29)	2.50(0.74)***	
Share of Corporate Income Taxes in Income Taxes(regressed by output gap and potential output simultaneously)		0.99(0.24)***		
Share of Corporate Income Taxes in Income Taxes(instrumented)			-0.44(0.42)	
Environmental taxes (regressed by output gap and potential output simultaneously)				0.10(0.04)**
Nº Observations	696	696	660	496

Standard errors in brackets. * Significant at 10%level. ** significant at 5% level. *** significant at 1% level.

Table 10. Endogeneity tests with correction for business cycle using output gap and potential output sequentially.

DepVar: Log GDPpc	(1)	(2)	(3)	(4)
Physical capital	0.08(0.04)*	0.16(0.05)***	-0.49(0.15)***	-0.07(0.06)
Human Capital	1.46(0.11)***	0.35(0.09)***	1.53(0.23)***	1.88(0.13)***
Population Growth	-0.02(0.01)**	-0.04(0.01)***	0.02(0.02)	0.02(0.01)***
Tax Burden	2.77(0.31)***	1.35(0.30)***	0.54(0.50)	0.20(0.24)
Income Taxes(regressed by output gap and potential output sequentially)	-0.49(0.17)***	-0.97(0.30)***	2.66(0.69)***	
Share of Corporate Income Taxes in Income Taxes(regressed by output gap and potential output sequentially)		2.09(0.33)***		
Share of Corporate Income Taxes in Income Taxes(instrumented)			-0.76(0.45)*	
Environmental taxes(regressed by output gap and potential output sequentially)				0.06(0.01)***
Nº Observations	696	696	660	496

Standard errors in brackets. * Significant at 10%level. ** significant at 5% level. *** significant at 1% level.

Table 11. Regressions with Tax Burden Dummies for Income Taxes.

DepVar: Log GDPpc	Countries with Tax Burden above the average	Countries with Tax Burden below the average[1]	Total sample
Physical capital	-0.001(0.09)		0.10(0.06)*
Human capital	1.44(0.18)***		1.15(0.12)***
Population Growth	-0.01(0.02)		-0.05(0.01)***
Income Taxes	-1.82(0.50)***		-1.21(0.41)***
Tax Burden Dummy_Income taxes			-0.80(0.60)
Nº Observations	539		1125

Standard errors in brackets. * Significant at 10%level. ** significant at 5% level. *** significant at 1% level.

1 – No convergence achieved by Stata for this regression.

Table 12. Regressions with Tax Burden Dummies for Personal Income Taxes and Corporate Income Taxes.

DepVar:Log GDPpc	Countries with Tax Burden above the average	Countries with Tax Burden below the average	Total sample
Physical capital	-0.02(0.09)	0.21(0.07)***	0.05(0.05)
Human capital	1.29(0.16)***	0.99(0.16)***	1.11(0.10)***
Population Growth	-0.01(0.02)	-0.06(0.02)***	-0.04(0.01)***
Personal Income Taxes	-2.33(0.53)***	-1.34(0.42)***	-0.84(0.31)***
Corporate Income Taxes	-0.09(0.50)	0.52(0.42)	1.21(0.36)***
Tax Burden Dummy_PersonalIncomeTaxes			-1.92(0.60)***
Tax Burden Dummy_CorporateIncomeTaxes			-1.66(0.64)***
Nº Observations	539	567	1106

Standard errors in brackets. * Significant at 10%level. ** significant at 5% level. *** significant at 1% level.

Table 13. Regressions with Tax Burden Dummies for the aggregate of Consumption and Property Taxes.

DepVar: Log GDPpc	Countries with Tax Burden above the average	Countries with Tax Burden below the average	Total sample
Physical capital	-0.001(0.09)	0.24(0.06)***	0.10(0.05)*
Human capital	1.44(0.18)***	0.70(0.14)***	1.19(0.12)***
Population Growth	-0.01(0.02)	-0.05(0.02)***	-0.04(0.01)***
Consumption and Property Taxes	1.82(0.50)***	0.80(0.33)**	1.17(0.39)***
Tax Burden Dummy Consumption&PropertyTaxes			0.78(0.58)
Nº Observations	539	584	1123

Standard errors in brackets. * Significant at 10%level. ** significant at 5% level. *** significant at 1% level.

Table 14. Regressions with Tax Burden Dummies for Consumption and Property Taxes.

DepVar:Log GDPpc	Countries with Tax Burden above the average	Countries with Tax Burden below the average	Total sample
Physical capital	-0.07(0.09)	0.25(0.06)***	0.10(0.05)*
Human capital	1.29(0.16)***	0.75(0.16)***	1.09(0.11)***
Population Growth	0.01(0.02)	-0.06(0.02)***	-0.03(0.01)**
Consumption Taxes	0.89(0.48)*	0.37(0.35)	0.69(0.36)*
Property Taxes	6.43(1.38)***	2.50(0.76)***	2.18(0.72)***
Tax Burden Dummy_ConsumptionTaxes			0.24(0.58)
Tax Burden Dummy_PropertyTaxes			3.96(1.46)***
Nº Observations	539	584	1123

Standard errors in brackets. * Significant at 10%level. ** significant at 5% level. *** significant at 1% level.

Table 15. Regressions with Tax Burden Dummies for Environmental Taxes.

DepVar: Log GDPpc	Countries with Tax Burden above the average	Countries with Tax Burden below the average	Total sample
Physical capital	0.01(0.10)	0.40(0.06)***	-0.16(0.06)***
Human capital	0.19(0.16)	1.58(0.18)***	2.23(0.17)***
Population Growth	-0.01(0.02)	-0.002(0.01)	0.001(0.01)
Environmental Taxes	4.74(1.55)***	7.24(1.81)***	3.16(2.06)
Tax Burden Dummy_ Environmental Taxes			2.17(2.05)
Nº Observations	264	278	542

Standard errors in brackets. * Significant at 10%level. ** significant at 5% level. *** significant at 1% level.

Table 16. Regressions with Tax Burden Dummies for Energy and Transport taxes.

DepVar: Log GDPpc	Countries with Tax Burden above the average	Countries with Tax Burden below the average	Total sample
Physical capital	0.42(0.05)***	-0.50(0.12)***	-0.34(0.07)***
Human capital	0.17(0.10)*	2.20(0.24)***	1.88(0.15)***
Population Growth	-0.01(0.01)	0.10(0.02)***	0.06(0.01)***
Energy Taxes	-1.04(0.64)	-6.57(0.96)***	-6.96(0.70)***
Transport Taxes	15.15(2.79)***	9.71(3.65)***	7.11(2.65)***
Tax Burden Dummy_EnergyTaxes			11.03(1.63)***
Tax Burden Dummy_TransportTaxes			3.95(4.34)
Nº Observations	264	282	546

Standard errors in brackets. * Significant at 10%level. ** significant at 5% level. *** significant at 1% level.

9. Annex II

Missing data and Data obtained by Interpolation

Concerning the variables of physical capital and lagged GDPpc, there are some missing values. These variables are part of the baseline growth equation that is the basis to all regressions and tests executed on this dissertation. Therefore, the missing values for these variables were filled using interpolation. For the variable lagged GDPpc the missing values were obtained by using reverse linear interpolation. In the case, of the variable of physical capital there are some missing values of the component private non-residential and government gross fixed capital formation. The missing values were obtained using the average of 10 next years (starting in the first year with a value) of ratio between the Private non-residential and government gross fixed capital formation and the Total gross fixed capital formation. Using the value of this ratio for each country, the value of the Private non-residential and government fixed capital formation was estimated using the value of Gross Fixed capital formation for each year. Then the measure of physical capital is obtained by ratio between the estimate of Private non-residential and government fixed capital formation and the GDP (here the GDP is in market prices and national currency). Table 17 provides a description of the values obtained by interpolation for each variable. In terms of tax instruments there are some missing data as well. Table 18 provides a description of the data that is missing for each variable.

Table 17. Data obtained by Interpolation.

Variable	Values obtained by interpolation
GDP_pc lagged	Austria:1969; Belgium:1969; Finland:1969; Germany:1969; Norway:1969; Spain:1969; Switzerland:1969; Japan:1969; New Zealand:1969; Ireland:1969; Luxembourg:1969; Portugal:1969; United States:1969; Italy:1969.
Physical Capital	France: 1970 to 1979; Germany: 1970 to 1990; Greece: 1970 to 1994; Ireland: 1970 to 1989; Luxembourg: 1970 to 1994; Norway: 1970 to 1977; United Kingdom: 1970 to 1977.

Table 18. Description of missing data

Variable	Missing values
Tax Burden	Korea:1970 and 1971.
Income Taxes	Korea:1970 and1971.
Personal Income Taxes	Korea:1970,1971; Portugal: 1970 to1988.
Corporate Income Taxes	Korea:1970,1971; Portugal: 1970 to1988.
Consumption Taxes	Korea:1970 and 1971; Spain: 1993.
Property Taxes	Korea:1970 and1971.
Environmental Taxes	Canada:2015 to 2019; Korea: 2015 to 2019.
Energy Taxes	Korea: 2017 to 2019.
Transport Taxes	Canada: 2019; Korea: 2015-2019