UNIVERSIDADE FEDERAL DE PERNAMBUCO
PHILOSOPHY AND HUMAN SCIENCES CENTER
POLITICAL SCIENCE
DEPARTMENT OF POLITICAL SCIENCE
GRADUATE PROGRAM IN POLITICAL SCIENCE

CHRISTIAN DE ALMEIDA BRANDÃO

Green Influence, Economic Realities, and Political Landscapes: Understanding Carbon Tax Determinants in Europe using Machine Learning

RECIFE
2024

CHRISTIAN DE ALMEIDA BRANDÃO

Green Influence, Economic Realities, and Political Landscapes: Understanding Carbon Tax Determinants in Europe using Machine Learning

Master's Thesis presented as a requirement to obtain the title of Master in Political Science by the Graduate Program in Political Science at the Federal University of Pernambuco.

Concentration Area: International Relations
Research Line: International Politics

Advisor: Prof. PhD Rodrigo Barros de Albuquerque.

Recife

2024

Catalogação na fonte
Bibliotecária Maria do Carmo de Paiva, CRB4-1291

B817g Brandão, Christian de Almeida.
Green influence, economic realities, and political landscapes : understanding carbon tax determinants in Europe using machine learning / Christian de Almeida Brandão. – 2024.
125 f. : il. ; 30 cm.

Orientador: Prof. PhD. Rodrigo Barros de Albuquerque.
Dissertação (Mestrado) - Universidade Federal de Pernambuco, CFCH. Programa de Pós-Graduação em Ciência Política, Recife, 2024.
Inclui referências e anexo.

1. Ciência Política. 2. Política ambiental. 3. Aquecimento global. 4. Carbono - Impostos. I. Albuquerque, Rodrigo Barros de (Orientador). II. Título.

320 CDD (22. ed.) (BCFCH2024-131)

CHRISTIAN DE ALMEIDA BRANDÃO

Green Influence, Economic Realities, and Political Landscapes: Understanding Carbon Tax Determinants in Europe using Machine Learning

Master's Thesis presented as a requirement to obtain the title of Master in Political Science by the Graduate Program in Political Science at the Federal University of Pernambuco.

Recife, 23 de Fevereiro de 2024

BANCA EXAMINADORA:

Prof. Dr. Rodrigo Barros de Albuquerque
Supervisor

Profª Dra. Elia Elisa Cia Alves
External Examiner

Prof. Dr. Rafael Mesquita de Souza Lima
Internal Examiner

AGRADECIMENTOS

Em primeiro lugar, quero expressar minha profunda gratidão ao professor Rodrigo Barros de Albuquerque. Além de orientar este trabalho, ele tem sido meu mentor acadêmico desde a graduação. Agradeço pelas incontáveis horas dedicadas, pela paciência, pelos valiosos conselhos e pelas oportunidades proporcionadas.

Também estendo meus agradecimentos aos professores Elia Elisa Cia Alves e Rafael Mesquita de Souza Lima por aceitarem o convite para participar da banca, dedicando tempo para avaliar este trabalho e fornecer valiosos apontamentos na avaliação do projeto de pesquisa. Especial reconhecimento ao professor Rafael Mesquita de Souza Lima pelos ensinamentos na disciplina de Potências Intermediárias, que não apenas enriqueceram minha formação, como também geraram a semente do meu primeiro artigo publicado, em coautoria com o professor Rodrigo Barros de Albuquerque.

À minha família, expresso minha imensa gratidão por toda a inspiração e suporte. Principalmente a minha mãe, Vera, e meu padrasto, Eric, que acompanharam de perto o processo de escrita desta dissertação e sempre me apoiaram incondicionalmente. A meu pai, Christian, e minha madrasta, Carol, que sempre acreditaram em minha capacidade e me incentivaram a avançar. Um agradecimento especial à minha avó, Jussara, professora aposentada pela Universidade Federal da Bahia, que sempre foi um exemplo de sabedoria, tanto na vida cotidiana quanto acadêmica. Agradeço ao meu irmão, Felipe, por ser um exemplo de transformação, perseverança e pelo eterno laço de irmandade que compartilhamos. Aos meus irmãos mais novos, Julia, Olivia e Davi, agradeço pelos, tão necessários, momentos de descontração.

A todos os amigos e amigas, meu profundo agradecimento pelos momentos compartilhados e por serem verdadeiros portos seguros para mim. Destaco a Júlia e Paula pela constante disposição em ajudar, a Aylla pelas boas risadas, a Beatriz por todo o incentivo e a Sheylla pelos conselhos. Meu agradecimento especial a Valdo pela paciência, confiança, amor e dedicação em todos os momentos, especialmente nos momentos de ansiedade em que duvidava da conclusão deste trabalho.

Por fim, expresso minha gratidão à Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) pelo financiamento concedido. Agradeço à Universidade Pública, de forma geral, e a todos os docentes e servidores que a compõem. Também dedico meu reconhecimento a todos que defendem a autonomia universitária e a educação como um direito universal, público e gratuito.

“In a dark place we find ourselves, and a little more knowledge lights our way.”

(Star Wars: Episode III - Revenge of the Sith, 2005)

ABSTRACT

This research develops classification trees, a machine learning method, to interpret and predict the implementation and variation of carbon taxes in Europe. As our planet's temperature increases and the effects of climate change intensify, an increasing number of governments are implementing carbon pricing measures to reduce emissions. Carbon taxes are an interesting mechanism, as they are simple to introduce, generate revenue, and have been proven to reduce emissions. Despite these merits, as of 2020, only 21 countries worldwide have implemented carbon taxes, with 15 of those situated in Europe, and many of these taxes feature comparatively low rates. To better understand this intricate landscape, the classification trees are utilized to investigate two hypotheses concerning the effects of cabinet ideology and the influence of green parties on carbon tax implementation and price variation. By incorporating ideological features into the models, this research recognizes that carbon taxes do not exist in a political vacuum, and that the advice of economists and environmentalists only goes so far. The two models related to the price variation demonstrated the importance of the green parties performance in the election, although their presence in cabinet does not prevent price decreases. Interestingly, no cabinet that experienced a substantial vote share for green parties and did not have very low government debt decrease their carbon taxes. The models also indicated that being a Right-wing cabinet does not prevent price increases, and that earmark revenues are associated with carbon tax increases. On the other hand, the decision tree model for the tax's implementation demonstrated the importance of the Left-Right cleavage when the GDP per capita (PPP) is lower than 39 thousand dollars. In wealthier countries, the creation of a carbon tax was associated with a strong liberal democratic system, the absence of a crippling debt burden, the occurrence of a natural disaster during the cabinet's tenure, and not being completely relying on fossil fuels for energy consumption. The ideological features were deemed relevant to the three models, further demonstrating the importance of political considerations in the realm of climate policy research.

Keywords: environmental regulations; decision-making model; emission taxation; ideological cleavage.

RESUMO

Esta pesquisa desenvolve árvores de classificação, um método de aprendizagem de máquina, para interpretar e prever a implementação e variação de impostos sobre carbono na Europa. À medida que a temperatura do planeta aquece e os impactos das mudanças climáticas aumentam, mais governos adotam medidas de precificação de carbono para reduzir as emissões. Os impostos sobre carbono são notáveis por sua simplicidade de introdução, capacidade de gerar receitas e comprovada eficácia na redução de emissões. Apesar de seus méritos, até 2020, apenas 21 países em todo o mundo haviam implementado impostos sobre carbono, sendo 15 na Europa, muitos com taxas relativamente baixas. Para melhor compreender esse cenário complexo, as árvores de classificação são utilizadas para investigar duas hipóteses relacionadas aos efeitos da ideologia do gabinete e à influência dos partidos verdes na implementação e variação de preços do imposto sobre o carbono. Ao incorporar características ideológicas nos modelos, essa pesquisa reconhece que os impostos sobre carbono estão inseridos em um contexto político, e que as recomendações de economistas e ambientalistas tem impacto limitado. Os modelos relacionados à variação de preços destacaram a importância do desempenho dos partidos verdes nas eleições, embora sua presença no governo não impedisse reduções de preços. Surpreendentemente, nenhum governo com uma parcela significativa de votos para os partidos verdes e sem uma dívida governamental muito baixa reduziu os impostos sobre carbono. Além disso, os modelos indicaram que ser um governo de direita não impediu aumentos de preço, e receitas vinculadas foram associadas a aumentos nos impostos sobre carbono. Por outro lado, o modelo de árvore de decisão para a implementação do imposto destacou a importância da divisão Esquerda-Direita em países com um PIB per capita (PPC) inferior a 39 mil dólares. Em nações mais ricas, a criação de impostos sobre carbono foi associada a um sistema democrático liberal robusto, ausência de uma enorme dívida governamental, ocorrência de desastres naturais durante o mandato do governo e uma não dependência completa de combustíveis fósseis para o consumo de energia. As características ideológicas mostraram-se relevantes para todos os modelos, reforçando a importância das considerações políticas na pesquisa de políticas climáticas.

Palavras-chave: regulamentações ambientais; modelo decisório; tributação de emissões; clivagem ideológica.

LIST OF ILLUSTRATIONS

LIST OF TABLES

SUMMARY

1 INTRODUCTION

Humanity is living in borrowed time. Every year, humans release more carbon dioxide into the atmosphere, which intensifies climate change and its effects. Despite 22 global conferences between 1995 and 2022 aimed at curbing carbon emissions, there has been a disheartening 58% increase in global emissions from 1995 to 2021. The European Union (EU) together with the United Kingdom, on the other hand, have decreased its emissions by more than 25%[1], in the same period. The EU has ambitious targets for the next decades, a 55% reduction between 1990-2030 and complete decarbonization of the economy by 2050.

European countries have used different techniques to lower their carbon emissions, one of them is carbon pricing. Within Europe, carbon pricing takes two main forms: emission trading systems (ETS), the biggest being the EU ETS operating at the European level, and carbon taxes implemented at the national level. This research proposal aims to investigate the latter. The first carbon tax in the world was enacted in Finland in 1990, it was followed in the next years by its Nordic partners (Sweden and Norway in 1991, and Denmark in 1992). Carbon pricing appeared in the international stage with the Kyoto Protocol[2] in 1997, as one of the mechanisms to reduce carbon emissions.

Although this initiative has become more popular in recent years, receiving the support of the World Bank[3], in 2020, only 22 countries in the world have a carbon price in place, with 15 being in Europe, and ten in the European Union. The Emission-weighted tax rate[4] per carbon ton ranged from almost 0 dollars in Poland to over 48 dollars in Sweden. Considering the world's total emissions, in 2015, the average cost of carbon emissions was only about 1 dollar per carbon ton (Dolphin; Pollitt; Newbery, 2019).

Despite the significance of carbon taxation research, a predominant portion of existing studies, primarily conducted by economists, focuses on efficiency and economic aspects (Schaffer, 2021; Skovgaard et al., 2019; Harrison, 2010). While efficiency is undoubtedly crucial, it is imperative to recognize that public policy decisions are often swayed by political factors, particularly the preferences of the governing parties. The energy transition is a political process in which there is no guarantee a decarbonization policy will be the outcome (Hess; Renner, 2019).

This research aims to develop a robust decision tree model, a popular machine learning method, with the capability to predict the actions of European governing cabinets

[1] https://shorturl.at/hnrtL
[2] International treaty that commits state parties to reduce their greenhouse gasses emissions.
[3] https://www.worldbank.org/en/programs/pricing-carbon/why-price-carbon
[4] https://www.rff.org/publications/data-tools/world-carbon-pricing-database/

concerning the implementation and rate of a carbon tax. More precisely, the study utilizes a classification tree to investigate whether factors, such as the ideological stances of the governing coalition and other political/structural variables, play significant roles in predicting the creation and variations in the carbon tax rate.

Deploying a tree-based model allows for the enhancement of the understanding of patterns and associations of carbon tax policy in Europe. This method assists in identifying variables statistically linked to specific outcomes, offering insights into potential influencing factors, which is particularly important for the features that have not undergone thorough investigation, such as the ideological ones. Tree models also offer the advantage of being easily understandable, even for individuals without statistical or machine learning background. This characteristic is valuable for disseminating academic knowledge to a broader audience, especially in a policy-relevant area like carbon tax research. The model has the potential to enhance the predictability of decision-making in emission taxation, at a time when policymakers face growing pressure to reduce carbon emissions.

Decision tree models employ the terminology of "target variable" and "features" rather than dependent variables, independent variables, and control variables. In the context of this research, the target variable is the variation in the averaged Emission-weighted carbon tax rate by cabinet, while the features encompass political and economic data associated with each cabinet. This research is guided by two hypotheses. The first posits that cabinets leaning Left/Gal/Pro-EU are expected to associate with the creation and increase in carbon taxes, while cabinets leaning Right/Tan/Anti-EU are anticipated to be associated with a decrease in carbon taxes and "No tax" scenarios. The second hypothesis suggests that the inclusion of a Green party in the coalition or a strong electoral performance by green parties is expected to be linked with the creation and increase in carbon taxes. Conversely, the absence of a Green party in the coalition or weak electoral performance by green parties is expected to be associated with a decrease in carbon taxes and "No tax" scenarios.

The countries included in the research are the United Kingdom, Norway, and the European Union's members, excluding Italy, Cyprus, and Malta. Italy's exclusion is due to cabinet and party instability (Hess; Renner, 2019), while Cyprus and Malta are not part of the RepDem (The Representative Democracy Data Archive) database (Hellstrom et al., 2023). Examining European carbon taxes is pivotal, as the continent has consistently been at the forefront of global initiatives to combat climate change. Without the active involvement of Europeans, the progress in decarbonization efforts would be significantly compromised (McCright; Dunlap; Marquart-Pyatt, 2015; Hess; Renner, 2019).

The first chapter will concentrate on carbon taxes, underscoring their importance to the promotion of emissions' reduction, and elucidating their theoretical framework. Additionally, it will review cases where the creation of carbon taxes were possible, and explore cases where the tax failed, either to be implemented or increased. The second chapter will present the ideological cleavages, how they shape party preference on environmental policy, and their significance in the study of carbon taxes.

The third chapter delineates this research's methodology. It explains decision tree models, and demonstrates how the target variable and features were constructed. Furthermore, it justifies the selection of the features and detailing their sources. Moving forward, the fourth chapter unveils the classification trees, presenting their statistical metrics, the decision tree plots, and the feature importance plots. It analyses these models in light of the first two chapters, associating the models' insights with the existing literature. Additionally, to improve this research's robustness, alternative models were constructed.

Against this backdrop, the present research endeavors to enhance the political science understanding of carbon taxes, addressing a gap in the literature concerning the political constraints within carbon pricing mechanisms (Dolphin; Pollitt; Newbery, 2019). Additionally, this study aims to make a distinctive contribution to the existing body of literature by specifically focusing on a climate policy, namely the carbon tax. This stands in contrast to the predominant trend in the literature, which generally centers on broader attitudes toward environmental policies (Jagers; Harring; Matti, 2017).

2 CARBON TAX

This first chapter presents a literature review encompassing the primary concepts and experiences related to carbon taxes. The chapter is divided into four topics. The first one covers what is carbon taxation, what are its differences compared to emission trading systems, the rationale (theoretical framework) behind implementing carbon taxes and their revenue use, and the main criticisms on the policy, including concerns about carbon leakage. The second topic provides an overview and a historical summary of carbon taxation initiatives in the world, as well as the main differences between carbon taxes and other environmental taxes.

The third topic outlines the factors contributing to the political viability of carbon taxes worldwide, mapping policies predominantly in Europe, as well as in Argentina, Uruguay, Japan, South Africa, and the Canadian province of British Columbia. The final topic scrutinizes unsuccessful attempts to implement or increase carbon taxes in Australia, Canada, Germany, France, and Portugal.

2.1 The importance of carbon taxation

The State plays a pivotal role in driving the climate transition, as voluntary environmental collective action is unlikely to occur organically. To address this, the government can intervene by implementing measures that modify individual behaviors, thereby stimulating collective action (Jagers; Harring; Matti, 2017). There is a widely held consensus that carbon pricing serves as a crucial tool for mitigating carbon emissions and is indispensable in formulating effective climate policies (Criqui; Jaccard; Sterner, 2019; Haites, 2018; Pereira et al., 2016).

The implementation of carbon pricing policies generally relies on two main instruments: carbon taxes and emission trading systems (ETS) (Levi; Flachsland; Jakob, 2020). While carbon taxation is primarily a national policy with varying adoption across countries, before 2020, only two ETS existed in Europe: one in Switzerland; and the other at the European Union level. Later on, the United Kingdom, upon exiting the EU, has also enacted an emission trading system mirroring the EU's approach. Recently, Germany and Austria have also implemented a national ETS to complement the broader European initiative. It is noteworthy that both countries are currently undergoing a transition phase, having implemented a carbon tax until the auctioning phase in 2026. While the German initiative was included in this research, the Austrian one was not, due to the timeframe of the study.

While emissions trading systems can establish carbon emissions limits for the companies within their purview and leverage market signals to encourage emission reductions where economically efficient, carbon taxes offer a simpler alternative. Carbon taxes have the capacity to generate more revenue and enable direct taxation of consumers, facilitating behavior change (Schaffer, 2021). Another significant distinction lies in the fact that carbon taxes are determined by the carbon content of fossil fuels, whereas emissions trading systems rely on verified emissions. The latter encompasses not only emissions from fuel combustion but also includes fugitive and industrial processes emissions (Dolphin; Pollitt; Newbery, 2019).

The two mechanisms can also be differentiated by considering that within emissions trading systems, the government establishes the quantity of emissions, while market forces dictate the prices. In contrast, for carbon taxes, it is the government that sets the price, with the market determining the quantity of emissions (Thisted; Thisted, 2020). In essence, both forms of carbon pricing share a common objective: to internalize the costs of climate change externalities onto polluters (Pigou, 1932).

As articulated by Pigou (1932), when private individuals or businesses engage in activities causing pollution without bearing the full environmental cost, a market failure occurs, wherein the price mechanism fails to accurately reflect the true social costs. To remedy this, taxes serve as a mechanism to internalize externalities, aligning private costs with social costs. When compared to a top-down regulation, carbon taxes are a less invasive way to internalize this externality (Pereira et al., 2016).

The theoretical framework of carbon taxes is straightforward: the government selects the emissions sources subject to taxation and determines the unit rate for emissions. Typically expressed in tonnes of carbon or carbon equivalents for other emissions, the tax price increases with higher carbon concentrations. Various metrics, such as the estimated social cost of carbon or predetermined emissions' reduction rates, can inform the definition of the tax rate (Haites, 2018).

Revenue generated from the tax can be allocated in diverse ways, falling into three primary categories based on their destinations: general funds, revenue recycling, and green spending. The funds may contribute to the general budget, be utilized for tax reductions, provide rebates for businesses or low-income groups, or support environmentally friendly initiatives such as enhancements in energy efficiency. In 2013, 72% of the revenue generated by carbon taxes was either directed into the general budget or earmarked for revenue-neutral initiatives (Carl; Fedor, 2016).

There is a widespread consensus affirming the efficacy of a carbon tax in reducing carbon emissions. Studies examining European countries highlight that the implementation of a carbon tax has resulted in a modest reduction in carbon emissions (Ghazouani et al., 2020; Sen; Vollebergh, 2018). In Sweden, carbon taxes are attributed to a significant achievement: a nearly 11 percent reduction in transport emissions from 1990 to 2005 (Andersson, 2019). While some authors, like Green (2021), contend that carbon pricing shows limited effectiveness in emission reduction, he acknowledges that carbon taxes have demonstrated greater success than emission trading systems.

A significant aspect of the criticism directed towards this policy revolves around the imperative need to escalate its prices for a more pronounced impact on emissions. Research suggests that, on average, a one-euro increase in the effective carbon price leads to a 0.7% reduction in emissions, underscoring the direct correlation between tax effectiveness and pricing levels (Sen; Vollebergh, 2018). The Organization for Economic Co-operation and Development (OECD), drawing from Kaufman et al. (2020), establishes three price benchmarks: 30 euros per tonne of CO2 by 2025 (decarbonization by 2060); 60 euros per tonne of CO2 by 2030 (decarbonization by 2060); and 120 euros per tonne of CO2 by 2030 (decarbonization by 2050).

The European Union and the United Kingdom have committed to decarbonization by mid-century, with some EU member states, such as Finland aiming for 2035 and Germany for 2045. However, given the current carbon pricing rates, considering ETS and carbon tax, only three countries (France, Sweden, and Finland) approach the 30 euros per tonne of CO2 benchmark. It's important to highlight that those three countries have Emission-weighted carbon tax rates above 30 euros, so the EU ETS initiative only complements the tax. It is evident that for carbon taxes to fully leverage their potential in emission reduction, there is a pressing need for widespread adoption and increased rates across more European countries (Errendal; Ellis; Jeudy-Hugo, 2023).

Table 1 - Current Carbon taxes in Europe

Country	Year launched	Emission-weighted carbon tax rate (last cabinet) S $/tCO2
Poland	1990	<0.01
Estonia	2000	0.01

Latvia	2004	0.44
United Kingdom	2013	3.30
Norway	1991	3.51
Slovenia	1996	4.45
The Netherlands	2021	5.91
Portugal	2015	12.91
Germany	2021	13.00
Denmark	1992	13.94
Ireland	2010	20.69
Luxembourg	2021	21.62
France	2014	29.59
Finland	1990	36.87
Sweden	1991	52.01

Source: Own elaboration, with data from Carbon Pricing Dashboard (World Bank, 2023) and World Carbon Pricing database (Dolphin; Xiahou, 2022).

Another argument against carbon taxes and carbon pricing in general focuses on competitive concerns, particularly the issue of carbon leakage (Arlingahus, 2013). Carbon leakage becomes a risk when the costs of climate policies prompt companies to relocate to jurisdictions with lower environmental standards, evading these policies. This scenario results in an economic loss for the country with higher environmental protection standards and/or carbon pricing, all while maintaining the same level of harm to the planet (Dechezleprêtre et al., 2019). Industries that are both energy-intensive and resistant to electrification are deemed particularly vulnerable to carbon leakage, especially if they operate in sectors with intense international competition.

Fearing the potential for its pioneering climate policies to induce carbon leakage, the European Union took proactive measures by enacting legislation to establish the world's first Carbon Border Adjustment Mechanism (CBAM). This mechanism essentially functions as an import tax applied to specific products—such as cement, iron, and steel—depending on their carbon content. The tax rate varies in sync with the pricing dynamics of the EU ETS. Notably,

if the seller can substantiate that carbon taxes were duly paid during the production process, the corresponding amount is deducted from the import tax[5].

Through this pioneering policy, the European Union seeks to prevent carbon leakage, laying the groundwork for the removal of exemptions or free allowances for energy-intensive industries. This approach indirectly compels the decarbonization of industries in other countries, generating what is known as a "negative leakage" effect. This occurs as the carbon price signal extends to countries lacking a carbon pricing policy, essentially "leveling the playing field" (Lanzi et al., 2013). It's crucial to note that the EU's stance has not been without criticism, with some jurisdictions, including the Brazilian government, accusing the EU of engaging in trade protectionism. The Brazilian government contends that the CBAM violates international law, and the Brazilian National Confederation of Industry asserts that the mechanism would create barriers to international trade[6].

Despite being a politically charged concern and a perpetual source of anxiety for policymakers, there is a notable absence of concrete evidence demonstrating the existence of carbon leakage, at least on a measurable scale. In fact, a majority of studies have failed to identify statistically significant effects of carbon pricing on the overall competitiveness of the electrical and industrial sectors in OECD and G20 countries (Venmans; Ellis; Nachtigall, 2019). This lack of evidence may be attributed to other factors preventing carbon leakage, or possibly the result of the low carbon prices and the exemptions or other advantages extended to industrial sectors.

Emissions-intensive industries covered by the EU ETS have been granted numerous free allowances, tradable in the market, as a preventative measure against carbon leakage. Consequently, when the carbon price decreases, investors anticipate a potential decline in the profitability of these companies (Arlingahus, 2013). To illustrate, a mere two percent of all industrial carbon emissions in OECD and G20 countries are valued at 30 euros per carbon ton or higher. This calculation takes into account Emissions trading systems, carbon taxes, and taxes on fossil fuels (Venmans; Ellis; Nachtigall, 2019).

Even within multinational firms, where the global structure of the company could theoretically facilitate carbon leakage, there is no substantive evidence indicating that the EU ETS has led to such leakage. This observation holds true even when examining countries without climate policies, particularly focusing on energy-intensive and trade-exposed companies (Dechezleprêtre et al., 2019). While carbon taxes and emission trading systems

[5] https://taxation-customs.ec.europa.eu/carbon-border-adjustment-mechanism_en
[6] https://shorturl.at/cipIZ

represent distinct policy approaches, insights gleaned from research on the potential competitiveness effects of emission trading systems can be particularly illuminating (Skovgaard et al., 2019). Notably, there is a scarcity of studies in this area covering carbon taxes, primarily due to industries often being granted exemptions from high carbon taxes (Venmans; Ellis; Nachtigall, 2019).

Examining the employment implications, Dussaux (2020) discovered that in France, carbon taxes succeeded in curbing energy consumption and carbon emissions without adversely affecting industry-level employment. However, the author contends that a segment of production and workforce transitioned from energy-intensive to energy-efficient companies.

2.2 Carbon taxation in the world and the difference between carbon and environmental taxes

Despite their acknowledged utility, it's important to note that carbon taxes are a relatively recent and not yet widely adopted policy globally. Finland enacted the first carbon tax in 1990, with Japan and Australia[7] in 2012 being the first countries outside Europe to explicitly tax carbon emissions. Mexico was the first country in the Americas to implement a carbon tax on the national level in 2015, the mechanism reached South America with Colombia and Chile in 2017. In Africa, South Africa remains the only country to have such a tax, created in 2019.

The Emission-weighted carbon tax presents great variation throughout the world, and most of the initiatives are concentrated in Europe. As can be seen in the table below:

Table 2 - Emission-weighted carbon tax variation in 2020.

Continents	Maximum	Minimum	Countries with carbon tax
Americas	$2.34	$0.56	4
Africa	$7.02	$7.02	1
Europe	$48.81	<$0.01	15
Asia	$1.79	$1.79	1
Oceania	$0	$0	0

Source: own elaboration, with data from World Carbon Pricing database (Dolphin; Xiahou, 2022).

[7] Australia ended its tax in 2015.

The implementation of carbon pricing mechanisms can be divided in three time frames: the first wave (1990-2000); the intermission (2000-2008); and the second wave (2008-2019). The first period was marked by the first carbon taxes in Europe, especially in the Nordic countries. At this time, the public was starting to recognize that climate change was a serious threat to the planet and that countries had to lower their carbon emissions. In the intermission period, the grand innovation was the creation of the EU ETS, as for carbon taxes, only Latvia implemented a new carbon tax. This period was also characterized by the absence of large and ambitious climate conferences (Thisted; Thisted, 2020).

In the second wave, International Organizations such as the International Monetary Fund began to promote carbon pricing, while two big international climate conferences took place (2009 Copenhagen Summit and COP21 in Paris). More countries in Europe, such as France and the United Kingdom, and outside of Europe, such as South Africa, adopted carbon taxes. Initiatives also occurred at the provincial level with British Columbia's carbon tax, and emission trading systems in Chinese's provinces. An important feature of the second wave was that carbon pricing passed from "why implement this policy" to "how can we implement it" (Thisted; Thisted, 2020).

Distinguishing between carbon taxes and environmental taxes is crucial. A carbon tax specifically targets the content of CO2 in fossil fuels or carbon emissions, while environmental taxes encompass a broader spectrum of levies aimed at enhancing or safeguarding the environment. Environmental taxes encompass diverse initiatives, ranging from carbon taxes to levies on plastic bags and fees on plane tickets. Additionally, some authors categorize energy taxes as part of environmental taxes, and the OECD incorporates fuel excise taxes in its computation of "Effective Carbon Rates[8]".

This research focuses exclusively on carbon taxes as the subject of investigation. This choice stems from the distinct nature of carbon taxes, which impose a direct and explicit penalty on carbon emissions (Dolphin; Pollitt; Newbery, 2019). Even when compared to emission trading systems, the burden of carbon taxes appear to be more publicly salient (Carl; Fedor, 2016). This characteristic also distinguishes carbon taxes from other forms of taxation, such as energy tax or fuel excise taxes. For instance, Brazil lacks a carbon tax but levies fuel excise taxes. Notably, although fuel taxation emerged as a prominent political issue in 2021 and 2022 during the dispute between President Bolsonaro and state governors, it was not

[8] https://stats.oecd.org/Index.aspx?DataSetCode=ECR

conceived as a measure aimed at curbing carbon emissions. Instead, it was perceived merely as a means to generate revenue for state governments.

As the primary objective of this study is to construct classification trees that incorporates the influence of party ideology on carbon taxation, it is crucial that the tax's environmental aspect is transparent to the public. When a government endeavors to introduce or modify the carbon tax's pricing, it becomes imperative to articulate the environmental motivations or impacts of such actions to the public. The primary focus of these discussions revolves around behavioral change, with the revenue generated from this tax being essentially a secondary aspect (Schaffer, 2021). This distinction is evident in the case of Brazil, where the legitimacy of fuel excise taxes was not anchored in climate change considerations, but rather centered on the tax rate's fiscal burden.

To enact carbon taxation while trying to avoid engaging in direct political debates on the subject, certain provinces in both Canada and the United States have opted for an indirect approach. Rather than explicitly designating these measures as taxes, alternative terms such as "fees" or "charges" are employed. This strategic choice allows for the augmentation of taxes on energy and fuel excise without overtly associating them with explicit emissions reduction goals (Rabe; Borick, 2012).

Viewing indirect taxation as a form of carbon pricing can lead to unintended distortions, as illustrated by the situation in France prior to the introduction of the national carbon tax. Notably, coal used for industrial purposes enjoyed tax exemption, whereas natural gas, emitting nearly 50% less CO2 than coal[9], was subjected to taxation (Sénit, 2012). While carbon taxes are directly tied to the carbon content of fossil fuels, rendering them more resilient against distortions, their impact on the overall economy varies. For instance, the Swedish carbon tax predominantly influences the transport sector (Andersson, 2019). In contrast, British Columbia's tax spans all carbon emissions from combustion, encompassing 77% of the province's total emissions in the year the tax was instituted (Harrison, 2013).

2.3 What makes a carbon tax politically viable?

Previous studies suggest that carbon tax implementation is driven by three primary factors: climate change mitigation; political considerations; and fiscal policy innovation. Climate change mitigation is associated with the desire to reduce carbon emissions, be it because of national targets or to abide by international obligations. The political aspect refers to the ideology of ruling coalitions, as well as governmental institutions and the structure of

[9] https://shorturl.at/kIP57

the electoral system. Fiscal policy innovation encompasses a wide range of measures, from necessity to increase government revenues to reforms that result in an overall reduction in the total tax share of GDP (Rabbia, 2023; Bothner et al., 2022).

These causes are undoubtedly not mutually exclusive, governments often have a combination of motives driving the implementation of carbon taxes, with the institutional aspects influencing the overall result in a structural way. Bothrner et al. (2022), while observing the creation of carbon taxes in six European countries, highlight the importance of "push and pull factors." They suggest that when governments face substantial fiscal pressure, and the cabinet is receptive to environmental concerns, there is a strong incentive for the adoption of carbon taxes. The authors also contend that, as climate change becomes an increasingly urgent issue, environmental considerations will play a more prominent role in decisions related to carbon taxation.

This synergy of motives can be seen in the introduction of carbon taxes in the Nordic countries, which created the tax under similar circumstances and coordinated its implementation in the Nordic Council (Thisted; Thisted, 2020). The introduction of the Swedish carbon tax stemmed from the ruling cabinet's heightened focus on climate change concerns (Andersson, 2019). This initiative was coupled with the imperative to implement a tax reform that would reduce direct taxation without straining the government's budget. Additionally, the election of green party members to the Swedish parliament for the first time played a pivotal role in shaping the decision (Sterner, 1994). The creation of the tax was further facilitated by the elevated level of political trust in the political system (Criqui; Jaccard; Sterner, 2019).

Similarly to the Swedish case, the implementation of Finland's carbon tax was enabled by a combination of the cabinet's commitment to reducing direct taxation without causing disruptions to the government's budget. Additionally, a heightened environmental awareness, fueled by the Chernobyl nuclear accident in 1986 and the Toronto climate conference in 1988, played a significant role in shaping the decision (Harrison, 2010).

The implementation of the danish carbon tax was a result of a rare occurrence in carbon pricing implementation. In an unusual turn of events, it wasn't the governing cabinet that enacted the tax, but rather opposition parties, including one that had departed the cabinet due to disagreements over the tax's creation, proposed and endorsed the legislation in parliament. Initially, the governing cabinet, pressed by the same increase in environmental salience as in the case of Finland, and coupled with the will to reduce income or payroll taxes to lower the unemployment rate, supported the carbon tax's implementation to address both

concerns. However, faced with a strong opposition from the industrial sector, the government decided not to act and was subsequently defeated by the opposition parties (Harrison, 2010).

On the national level, Canada opted for a unique mechanism for its carbon tax. Its federal carbon tax functions as a backstop, activated when provinces lack their own form of carbon pricing. This way, the national government can ensure a minimum level of compliance, while allowing the provinces some room for flexibility (Winter, 2020). What was intended to be a backstop became the main policy, with ten out of the thirteen Canadian provinces currently subject to the federal carbon price in 2023. The federal carbon tax is designed to be revenue neutral[10], and its revenue can only be spent on the province it was originally collected[11].

The federal backstop was created and successfully defended by the governing party as a policy needed to achieve Canada's targets as set in the Paris Agreement. The government also benefited from an increase in environmental awareness due to natural disasters and heatwaves, coupled with worldwide student climate strikes that happened around the 2019 election (Macneil, 2020).

The Irish carbon tax provides a compelling lens through which to examine how the imperative to boost revenue, the influence of a green party in the cabinet, and other contextual factors can drive governments to adopt carbon pricing measures. Notably, Ireland transitioned from opposing an EU-wide carbon tax in the 1990s to instituting its own national version of the tax in 2010 (Convery; Dunne; Joyce, 2013).

The 2007 Irish election marked a pivotal moment with the inclusion of a green party in the governing coalition. For this party, environmental concerns held utmost importance, leading it to propose the reinstatement of a carbon tax as its contribution to the coalition agreement. Concurrently, the 2008 Global Financial Crisis and the requirements for the Irish bailout by the Troika[12] prompted the government to seek increased revenue. The wave of negative news during this period mitigated public opposition to the carbon tax (Convery; Dunne; Joyce, 2013).

The establishment of the carbon tax was facilitated by its non-impact on the largest industrial polluters in the country, as their carbon emissions were already priced under the EU ETS. Similarly, the agricultural sector, with the majority of its emissions exempt, faced a lower tax rate for the emissions that were subject to taxation (Convery; Dunne; Joyce, 2013).

---

[10] https://shorturl.at/glyL6
[11] https://shorturl.at/ablC2
[12] European Commission, European Central Bank, and the International Monetary Fund.

In sum, the success of the Irish carbon tax can be explained by the mounting fiscal pressure and the Green Party's presence in the cabinet (Bothner et al., 2022). By framing the discourse around the tax in terms of the imperative to raise revenue, the Irish carbon tax appears to have mirrored the early patterns of the first carbon taxes in the Nordic countries. These initial taxes similarly emerged as solutions for revenue generation (Skovgaard et al., 2019; Carl; Fedor, 2016).

Portugal's carbon tax was created in 2015 by a Right-wing cabinet and while the economy was the major issue to voters. At that time, the Portuguese government was facing a major austerity program in an attempt to revert its fiscal deficits (Bothner et al., 2022). The cabinet at the time had an average budget deficit of 5.77% per year, with the deficit reaching 7.4% in the year before the tax came into effect[13]. This was a worrying situation as European Union's regulations defined the ceiling for fiscal deficits at 3% per year.

In order to reduce taxes on labor income, in an attempt to incentivize the economy without adding more pressure to the government's coffers, the cabinet decided to implement the carbon tax (Bothner et al., 2022).

Utilizing revenue allocation strategically can serve as a tool to enhance public support for carbon taxes (Haites, 2018). As the public's perception on climate change may oscillate over the years, carbon revenues can offer a range of visible, yearly reportable, and politically immediate benefits (Carl; Fedor, 2016). This strategy was evident in two unsuccessful attempts to implement a carbon tax in the American state of Washington. The initial proposal in 2016 linked carbon tax revenue to rebates for working families and a reduction in other taxes. In contrast, the 2018 attempt allocated 95% of the revenue to green projects and the remaining 5% to local communities. The former approach garnered increased acceptance among conservatives, while the latter contributed to greater acceptance among liberals (Anderson; Marinescu; Shor, 2023).

In British Columbia, Canada, the utilization of the carbon tax's revenue was strategically designed to enhance its acceptability among voters. The government of the time linked the tax to rebates and reductions in other taxes. Notably, they included a provision in the legislation stipulating that if the tax yielded a surplus, the Finance Minister's salary would be reduced by 15% (Harrison, 2013). This provision served as a clear demonstration to voters that the tax burden would not increase with its implementation. Interestingly, the tax eventually turned out to be revenue negative, as the tax cuts and rebates exceeded the tax's generated revenue. The reasons for this outcome could be attributed to the threat to the

[13] https://tradingeconomics.com/portugal/government-budget

Finance Minister's salary, lower-than-expected revenue from the tax, or a combination of both (Harrison, 2013).

It is important to highlight that there is some contestation on the importance of revenue use for green spending in establishing and increasing carbon taxes. The taxes that generated the highest revenue per capita in 2013 tended to have their revenue sent either to the general funds or to revenue recycling initiatives (Carl; Fedor, 2016). However, this does not imply that as environmental concerns gained prominence in subsequent years, public perceptions regarding the utilization of carbon tax revenue remained static.

In the same way as political institutions are an important aspect to determine the strength of a country's environmental regulations (Congleton, 1992), they can be for carbon pricing in general. The rationale follows that strong liberal democratic institutions, which focus on the long term, tend to generate legislation with higher environmental stringency. Dolphin, Pollitt and Newbery (2019) have demonstrated in their research about carbon pricing implementation in the world that jurisdictions with high democratic standards and strong institutional capacity are positively correlated with the adoption of carbon pricing policies. It's worth noting that the authors did not test these variables to assert its relation with carbon pricing rate variation, nor did they differentiate between carbon taxes and emission trading systems.

In South America, the adoption of carbon taxes appears to be more associated with other goals rather than reducing carbon emissions, setting it in contrast to initiatives in Europe. For instance, in Argentina, the carbon tax introduction was seen as part of a broader reform of its fiscal system. In the case of Uruguay, the carbon tax served as a partial replacement for existing fuel taxes, in order to make it an explicit tax to the domestic and international public (Rabbia, 2023).

In Asia, Japan stands out as the sole country to have implemented a carbon tax. The Japanese government implemented this measure in 2012 in order to reduce the country's carbon emissions and comply with its internationally agreed emissions targets. Notably, this decision followed two decades of attempting voluntary programs for industries, including a voluntary Emissions Trading System, that resulted in a small 0.03% emissions reduction compared with 1990 levels. The Japanese resistance to implement a carbon tax was largely due to concerns about its potential impact on economic growth, international competitiveness, and price effects (Gokhale, 2021).

These concerns, associated with the country's high dependence on fossil fuels for its energy (84.4%, as of 2019[14]), lead the government to adopt a low carbon tax rate with several exemptions and rebates for industries. The tax rate has remained the same after the last increase in 2016, which severely limits the country's ability to achieve its carbon emissions reduction targets. On the revenue side, the tax money is spent on renewable energy projects and investments on energy efficiency programs (Gokhale, 2021).

South Africa is the only country in Africa to have enacted a carbon tax. Its experience highlights the difficulties that non-developed economies may face when considering implementing a carbon pricing mechanism. South Africa's carbon tax was considered as part of a larger process of environmental fiscal reform, serving as a strategy to diminish carbon emissions and align with internationally agreed-upon targets. The government preferred a carbon tax over an emissions trading system, because a tax was much easier to implement and the country's emissions were heavily concentrated: a single energy company represented more than 44% of the country's total emissions (Baker, 2022).

It is impressive that the government managed to push forward with the tax despite encountering resistance from well-organized energy and mining sectors. Although this opposition resulted in the tax taking nine years to be implemented, and upon creation, it was divided into two phases, accompanied by significant exemptions. Notably, certain sectors were granted a substantial 95% emissions exemption in their carbon tax obligations, with the majority of exemptions falling within the range of 60% to 75% (Qu et al., 2023).

2.4 Failed attempts at implementing or increasing carbon taxes

In 2012, the Australian government created one of the most ambitious carbon taxes in the world. This tax was the result of a coalition agreement between a center-Left and a green party. The Green Party, advocating for climate action, played a pivotal role by stipulating the carbon tax as a necessary condition for signing the coalition agreement. The tax introduction resulted in a takeover of the opposition Conservative Party by its climate skeptic section (Crowley, 2017).

The Australian carbon tax stood out by collecting the highest revenue globally, reaching nearly nine billion dollars annually, and bearing the highest per capita burden of 391 dollars annually. To put it into perspective, the second-highest in 2013 was the Swedish carbon tax, with about 3.7 billion dollars in revenue and a per capita burden of 381 dollars (Carl; Fedor, 2016). While the Swedish tax continues to exist, marking its twenty-second year

[14] https://www.enecho.meti.go.jp/en/category/special/article/detail_171.html

in 2023, the Australian tax was canceled two years after its implementation, making Australia the only country in the world to have abandoned its own carbon tax (Crowley, 2017).

Several factors could have unleashed this outcome, from the countries high utilization of coal to the tax rate not being implemented in a step by step fashion (Carl; Fedor, 2016), unlike the approaches taken in Ireland (Convery; Dunne; Joyce, 2013) and British Columbia (Harrison, 2013). These factors, associated with the climate skeptic section of the Conservative Party winning of the party's leadership context, led to stringent opposition not only to the tax but also to nearly any climate policy. After the Conservative Party won the 2013 election, the new cabinet made its priority to end the carbon tax and several of Australia's environmental agencies (Crowley, 2017). The new conservative prime minister even stated that "Coal is good for humanity, coal is good for prosperity […]"[15].

Crowley (2017) argues that this shift in Australia's climate policies could be explained by a combination of self-interest, given Australia's position as the world's largest coal exporter, and the government's conservatism and climate skepticism. The author also puts into doubt that the Labor Party would attempt again to introduce carbon pricing, since it was the Green Party's insistence on the mechanism that made it happen.

In the 1990s, there was a strong debate in Germany regarding the implementation of a carbon tax, which, in the end, proved unsuccessful, leading to the establishment of an energy tax as an alternative. Despite sharing similar circumstances with other nations that successfully implemented a carbon tax—such as heightened environmental awareness, a government seeking to reduce direct taxes, and the presence of a green party in parliament—Germany also possessed distinct features that impeded the policy's success (Harrison, 2010).

German reunification, in the same decade, produced an anti-risk sentiment in the government, which was not willing to approve grand policy innovations. The reunification also provided the country with a comfortable windfall emissions reduction that guaranteed it would achieve its near term emissions reduction targets. What made the government ultimately switch from a carbon tax to an energy tax was the strong anti-nuclear energy sentiment in Germany's environmental groups and in society in general, fueled by the Chernobyl nuclear accident in 1986. If a carbon tax was approved, it would benefit the nuclear energy producers, since nuclear energy does not produce carbon emissions. Ultimately, an energy tax that taxed nuclear energy, but exempted coal, was approved by the Green-Social Democrat coalition (Harrison, 2010).

[15] https://www.abc.net.au/news/2014-10-13/coal-is-good-for-humanity-pm-tony-abbott-says/5810244

The French carbon tax was successfully implemented in 2014 and its price rate increased in the following years. According to French law, the tax was set to reach 56 euros per ton of carbon in 2020 and 100 euros in 2030, with the government deciding on the periodical increases to attain these goals. In 2017, a new French government assumed power and proposed ambitious hikes, aiming for a 2022 tax rate of 86.2 euros per carbon ton (Douenne; Fabre, 2020). Which would have made the French carbon tax the highest in the world, with its Emissions-weighted carbon tax rate hovering around 60 dollars, leaving the Swedish tax (around 52 dollars) in second place.

The government's attempts to increase the tax were derailed by massive protests, known as the"gilets jeunes", resulting in the government indefinitely freezing the tax rate at 44.6 euros. These manifestations were fueled by the belief among protesters that the tax was an ineffective tool against climate change. They viewed the tax as unfair since the tax revenues largely went to the general budget, and they overestimated the negative impact of the tax on their incomes. The timing of the tax increases coincided with a period of rising oil prices, potentially amplifying the perceived impact of the tax (Douenne; Fabre, 2019).

Interestingly, the perception of the carbon tax among the French seems to become more favorable if the tax revenues were directed at investments in green infrastructure, providing enhanced commuting options, supporting renewable energy and energy efficiency initiatives, or facilitating other tax cuts and compensations for households constrained to consume petroleum products(Douenne; Fabre, 2020).

It is important to emphasize that this argument should be analyzed with caution. Tatham and Peters (2023) conducted a similar survey experiment in Norway, but instead of observing the general population's preference, the authors divided it into two groups: "urban elites" (high-educated urbanites); and "yellow vests" (low-educated ruralities). The authors found that earmarking the carbon tax revenues to green investments widens the gap between those two groups, which can lead to polarization. The contrary was true when the revenues were destined to low-income households and, interestingly, international commitments were mentioned to justify the tax (Tatham; Peters, 2023).

When Portugal established its carbon tax in 2015, it linked its price rate to the EU ETS rate from the previous year, with the expectation that the tax would likely increase at a gradual pace and peak at 35 euros per carbon ton in 2030. The commission responsible to advise the government on the carbon tax's establishment even suggested setting a minimum tax rate if the EU ETS price rate was lower than expected (Vasconcelos et al., 2014).

Contrary to the expectation of the commission, EU ETS prices have skyrocketed, with the certificate rate reaching the 100 euros mark in March 2023[16]. In response, the Portuguese government opted to freeze the carbon tax rate at approximately 23 euros since 2021[17]. This decision underscores that even when governments are not obligated to annually determine the carbon tax rate, whether to allow it to rise, decline, or remain unchanged remains, ultimately, a political decision.

The Liberal Party of Canada, situated in the center to center-Left political spectrum, observing an increase in environmental awareness and the ineffectiveness of prior voluntary emission reduction initiatives, attempted to implement a carbon tax in the country in the late 2000s. In the lead-up to the 2008 federal Canadian election, the party, then in opposition, made the carbon tax a campaign issue. In contrast, the Right-wing Conservative Party proposed, as a solution to reduce emissions, to introduce an emissions trading system and to increase public spending, rather than tax consumers and industries (Harrison, 2012).

When the election came, the public's attention to environmental issues had lowered, with the economy making the majority of the headlines. By the campaign's conclusion, the economy emerged as the primary focus in over 70% of all media articles, while environmental topics constituted approximately 16%[18]. In the end, the Liberal Party received its lowest share of the popular vote in Canadian history, and with this result the carbon tax proposal was defeated (Harrison, 2010).

Interestingly, a swift in the importance of the environment to voters that harmed the Liberal Party attempt to implement a federal carbon tax was what ended up saving British Columbia's carbon tax. The difference being that the Liberal Party proposed the tax amid the voters' worries about the state of the economy. In contrast, British Columbia's governing party had already enacted the tax and was trying to defend it in the 2009 provincial election. The shift of attention towards the economy also shifted voters' attention away from the provincial carbon tax (Harrison, 2012).

2.5 Final considerations

This chapter had the important function to present the value of carbon taxes as a central policy to reduce carbon emissions. It achieves this by making polluters internalize the cost of pollution and promoting environmental action by altering individual behaviors (Jagers;

[16] https://tradingeconomics.com/commodity/carbon
[17] http://bit.ly/4b2swtG
[18] https://bit.ly/3tWFfxa

Harring; Matti, 2017). The chapter also highlighted the main differences between carbon taxes and emission trading systems. In carbon taxes, the government defines the price for the emissions by considering the carbon content of fossil fuels and, the market determines the quantity of emissions. In contrast, in emission trading systems the government defines the quantity of emissions, based on verified emissions, with the market setting the price. Other important features are that while ETS are more flexible and complex to implement, carbon taxes produce more revenue and can be applied to individuals (Schaffer, 2021; Dolphin; Pollit; Newbery, 2019; Thisted; Thisted, 2020).

The chapter also explained the main criticisms around carbon taxes: its low rates and the possibility of carbon leakage. Carbon taxes with low rates have a limited potential to decarbonize an economy (Errendal; Ellis; Jeudy-Hugo, 2023). While carbon leakage, the relocation of polluting companies from environmentally stringent countries to those with more lenient environmental policies, is high on the political agenda, there is little to no evidence of its occurrence (Arlingahus, 2013; Venmans; Ellis; Nachtigall, 2019).

An overview of carbon taxes in the world was also presented in this chapter, highlighting Europe's central position in this policy area. The historical progression of carbon pricing was also divided into three periods: the first wave (1990-2000); the intermission (2000-2008); and the second wave (2008-2019). The first wave marked the creation of the first carbon taxes in Europe, the intermission period was characterized by the implementation of the EU ETS, and the second wave witnessed the support for carbon tax by international organizations and the expansion of the policy inside and outside Europe (Thisted; Thisted, 2020). Later on, the chapter presented the differences between carbon taxes and other environmental taxes. The main distinction being that carbon taxes impose a direct and explicit penalty on carbon emissions to promote behavioral change, which is transparent to the public and viewed through ideological lenses (Dolphin; Pollit; Newbery, 2019; Carl; Fedor, 2016).

The third topic of the chapter looks into what makes carbon taxes politically viable. The literature highlights three general reasons: climate mitigation; political considerations; and fiscal policy innovation (Rabbia, 2023). These motives, whether in isolation or manifested through various combinations resulting in push and pull effects, helped explain why some cabinets managed to introduce carbon taxes (Bothner et al., 2022). The cabinets that enacted the carbon tax in the Nordic countries and Ireland were concerned with climate change, observed the electoral growth of green parties, and were interested in tax reforms, either to reduce other taxes or to raise revenue (Thisted; Thisted, 2020; Convery; Dunne; Joyce, 2013). In contrast, governments in Canada, Japan, and South Africa were primarily

motivated by climate mitigation and the compliance with international climate agreements (Macneil, 2020; Gokhale, 2021; Baker, 2022).

The cabinets in Argentina, Portugal, and Uruguay implemented their carbon taxes as tax reforms, Argentina as a part of a broader reform to improve its tax system (Rabbia, 2023), Portugal to use the revenue to reduce taxes on labor income (Bothner et al., 2022). Uruguay, on the other hand, transformed some of its fuel excise taxes into carbon taxes in order to change it from an implicit to an explicit tax on carbon (Rabbia, 2023). Uruguay's example highlights the importance of using explicit carbon taxes in this research. Furthermore, this topic also demonstrated that strong political institutions and mandatory revenue use can help make carbon taxes politically viable.

This chapter's final topic covered unsuccessful attempts to implement or increase carbon taxes. Failures in these cases were often tied to specific country or time-related factors, such as Germany's strong negative view of nuclear power and its reunification process. For Canada, the global economic crises in the late 2000s shifted the voters' attention from the environment to the economy and made the public less willing to pay for a reduction in emissions (Harrison, 2010). Australia, France, and Portugal share the occurrence of either planned strong increases in their carbon taxes or the implementation of a carbon tax with a very high rate. Australia's case was further complicated by the take-over of its conservative party by its climate skeptic faction that not only rejected any form of carbon pricing but also undermined various government agencies responsible for environmental protection (Crowley, 2017). In France, the increase in oil prices and the carbon tax's revenue being sent to the general budget were also cited as reasons why the government at the time faced resistance to increase its tax (Douenne; Fabre, 2019).

Reviewing the carbon taxes' importance, what made them become politically viable in some countries, and the failed attempts to create or implement it in other countries, provided not only a strong foundation for the selection of this study's features, but also the theoretical tools to analyze the classification trees produced by this research.

3 IDEOLOGICAL POSITIONS

This chapter is divided into two topics. The first topic covers how the main European cleavages (Gal-Tan, Left-Right, and Anti-Pro EU) interact with one another, and the increased importance of issues that involve culture, nation, and integration. Additionally, it explores how the new cleavages can disrupt traditional party families, such as the conservatives, and how ideological cleavages can have different meanings in Western and Eastern Europe. Finally, this topic displays a plot with the cabinets, included in this research, in relation to their position across the three ideological cleavages.

The second topic explains the importance of including ideology when researching carbon taxes, and how the ideological cleavages interact with environmental policy. It also demonstrates the difference towards the environment, climate change, and international environmental targets in conservative and extreme-Tan parties. In the end, the topic outlines certain assumptions, based on the literature, about the three ideological cleavage positions on carbon taxes.

3.1 Ideological cleavages

Ideology can be broadly defined as how each political party believes and expects the country to be governed. Essentially, it constitutes a coherent system of belief that can justify the exercise of power, explain and judge historical events, identify politically what is right and wrong, and guide action (McClosky, 1964). Putting it in another perspective, ideology can be considered as a set of ideas by which a social group tries to make sense of the world (Jagers; Harring; Matti, 2017).

Ideological cleavages are a useful tool to understand the configuration of party systems. Cleavage theory argues that current parties are a product of the social and cultural divisions prevalent at the time of their foundation (Edwards, 2009). Parties remain relatively stable because they make programmatic commitments based on these divisions, rather than changing from within, party systems tend to change from shocks external to the party system. Although parties can be flexible on particular issues, they rarely shift position at the level of conflict dimension. This inflexibility means that even when faced with exogenous forces, the parties tend to maintain their current position. While voters will promote change by voting for new “challenging” parties. This is contrary to the Downsian model of issue competition, where parties are expected to respond to voter preferences by changing their policies (Hooghe; Marks, 2018).

The traditional cleavages were caused by national revolutions (center-periphery and church-state) and by the industrial revolution (landed-industrial interests and owners-workers). The center-periphery divide centers on the conflict between the elites which promote a central national culture, and the provincial elites that resist assimilation. While the church-state conflict revolves around the preference of religious and secular voters, often involving the privileges of the church. The landed-industrial interest represents a conflict between the industrial and agricultural sectors regarding trade policy. Finally, the owners-workers cleavage is tied to economic conflicts (Lipset; Rokkan, 1967).

Currently, there are three main ideological divides in Europe: Left-Right, Gal-Tan, and Anti-Pro EU (Buzogany; Cetkovic, 2021). While the Left-Right cleavage is the political expression of the traditional owners-workers conflict, the other two ideological cleavages are relatively more recent phenomena, which adds an interesting perspective, as the new cleavages are still evolving, and their social divisions have not yet solidified. Consequently, the newfound parties wield the capacity to shape the public discourse, impacting the social divisions and, in turn, the emerging cleavages. In contrast to the established parties, attached to the cleavages of their foundational era, these new political parties are both influenced by and influential in the shaping of contemporary cleavages (Hooghe; Marks, 2018).

The Left-Right divide is mainly characterized by the level of intervention in the economy, or a "conflict about who gets what" (Hooghe; Marks, 2018, p. 113). While the parties in the Left emphasize the need for income redistribution, social justice, and government regulation. The parties on the Right argue for property rights and the free market. Put differently, the Left promotes a non-neutral state, whereas the Right prefers a passive state (Jagers; Harring; Matti, 2017). To illustrate this dichotomy, Left-wing parties are more likely to implement market-based climate instruments, including environmental taxes (Schaffer, 2021). This occurs because Left-leaning parties are more skeptical toward the benefits of unregulated markets than their Right-wing counterparts (Neumayer, 2004).

The Gal-Tan divide (Green, Alternative, Liberal - Traditional, Authoritarian, Nationalist), as posited by Marks et al. (2021), represents a contemporary cleavage that has emerged with the waning influence of the traditional Left-Right conflict, marked by declines in church attendances, union memberships, and class distinctions. Since the 1990s, a series of institutional reforms lowered the cost of international trade and migration. Simultaneously, powers were being delegated from the central states to lower (regions and municipalities) or higher (international institutions) levels of governance. Examples of this are the enlargement

of the EU's competences, such as the common currency and an EU environmental policy, along with the establishment of the World Trade Organization (Hooghe; Marks, 2018).

Multilevel governance, the delegation of power from the central state to other institutions, can be more efficient in solving problems which are out of the reach of the central government (Maggetti; Trein, 2018). However, governance serves not only as a means to attain collective benefits through the coordination of human activity but also as an expression of community. The challenge in multilevel governance is that the function demand for regional authority almost never overlaps with the community's desire for self rule (Hooghe; Marks, 2009).

This novel division has surfaced in response to the ascendance of transnationalism, becoming characterized by divergent stances on cultural issues such as climate change, environmental protection, gender equality, human rights, and policies leaning towards nationalism or cosmopolitanism (Beramendi et al., 2015).

The economic repercussions of transnationalism further accentuate this cultural conflict by creating a rift within national societies. This division delineates those who can reap benefits from transnationalism due to possessing higher human and financial capital from those who cannot, consequently exposing the latter group to heightened competition for opportunities (Marks et al., 2021; Hooghe; Marks, 2018).

Although, it is important to note that anti-immigrant sentiments are often mobilized through identity-based frames rather than concerns about personal economic circumstances. The success of this mobilization is connected to the individual's level of education, since education has a liberalizing effect on social values (Beramendi et al., 2015). Conversely, individuals that value their national citizenship because they have few alternatives sources of self-worth are inclined to resent transnationalism, as "Nationalism has long been the refuge of those who are insecure, who sense they are losing status, and who seek to standing by identifying with the group" (Hooghe; Marks, 2018, p. 114).

The main goal of Tan parties is to protect the nation state, or at least what they see as the representation of the nation state and its national community. For them, immigration represents the corruption of the nation's culture and ethnic composition. While foreign influences, be as the cosmopolitan elites or international institutions, are agents attempting to limit the nation's sovereignty or transform its ideals and culture (Hooghe et al., 2002).

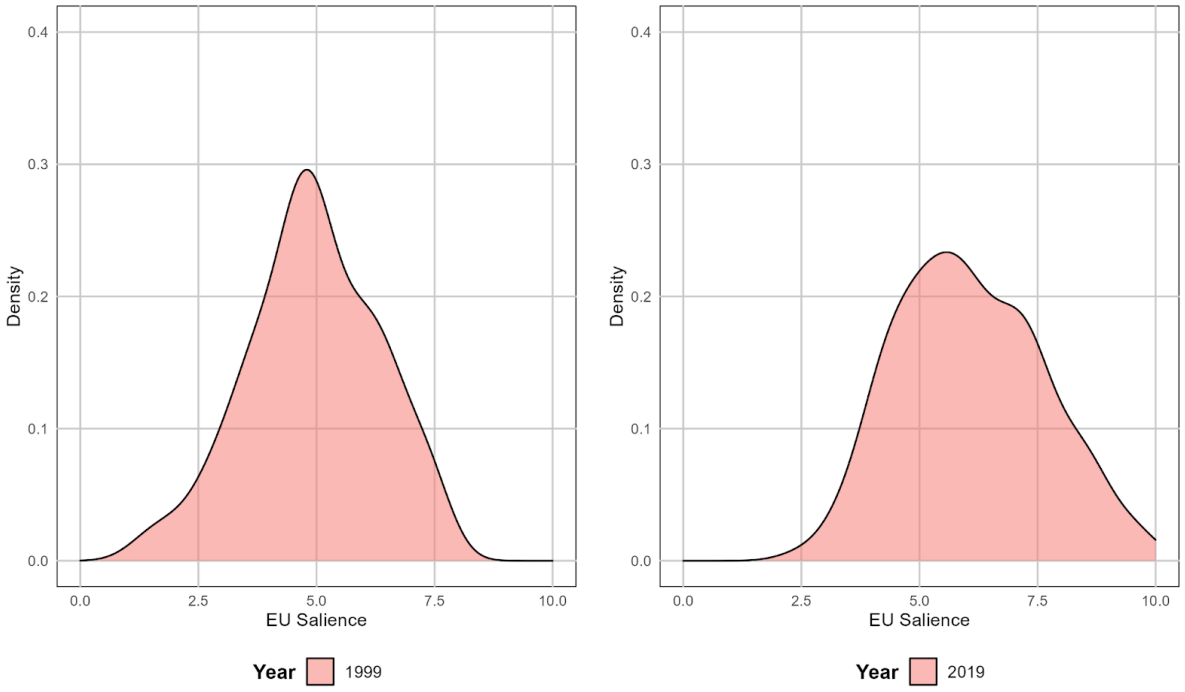
On the other hand, Gal parties can perceive the limitation of the national state and the delegation of some of its functions to international organization as a gain, particularly if these institutions uphold a politically cosmopolitan view (Beramendi et al., 2015). In essence, Gal

parties, with their cosmopolitan perspective, accept as legitimate the delegation of political regulation and decision-making to institutions beyond the nation state (Mau, 2010).

This emerging cleavage does not render the Left-Right divide irrelevant; rather, it posits that the structure of conflict is shaped by both cleavages, even though one is on the wane while the other is gaining prominence (Marks et al., 2021). As argued by Hooghe and Marks (2018, p. 113) "Cleavage theory is about the interaction of cleavages rather than the replacement of one alignment by another". This perspective emphasizes the dynamic nature of conflict and the cleavages stemming from it, suggesting that these elements can undergo restructuring over time (Marks et al., 2021).

The Pro-Anti European Integration spectrum is defined by the level of support or opposition for the European Union in political parties. This cleavage has been gaining importance over the years, as European politics have become more mainstream. Recent crisis that have hit the EU have resulted in an unprecedented polarization of the European integration (Schimmelfenning, 2018). This can be seen in the plot below:

Figure 1 - Density plot of the EU's salience in European national parties in 1999 and 2019[19]



Source: own elaboration, with data from CHES (Chapel Hill Expert Survey) database (Jolly et al., 2022).

[19] 0 = European Integration is of no importance, never mentioned; 10 = European Integration is the most important issue.

Examining the density plot from 1999 reveals that no European national party attributed a salience rating higher than 9 to European integration. Most parties hovered around the 5 mark. Compared with twenty years later, the situation clearly changed. Almost no parties scored lower than 2.5, the majority of the parties are now between the 5 and 7.5 mark, and new parties have emerged with European integration as their primary concern.

The three cleavages previously mentioned interact with each other, specialty the Gal-Tan and the Left-Right, in relation to the Anti-Pro European integration. As written by Hooghe et al. (2002, p.985) "European politics is domestic politics by other means." Parties on either the extreme Left and the extreme-Right end of the spectrum are more correlated with the rejection of the European project, when compared with center parties. Which should not come as a surprise considering that the EU is a product of the consensus politics of center-Right, center, and center-Left mainstream parties (Hoogle et al., 2002).

The extreme-Left European parties see the European Union as an inhospitable place for its policy objectives, a group of institutions that promote market liberalization and that prevent strong government interventionism in the economy (Edwards, 2009). While the extreme-Right is enthusiastic about market integration, it dislikes other EU policies such as regulations on the environment and on workers rights, which they see as a form of government intervention (Hooghe et al., 2002).

As for the Gal-Tan cleavage, Tan parties see the European project as the literal representation of everything they are trying to defend the nation state against: immigrants, foreign influences, cosmopolitan elites, and international institutions (Hooghe; Marks, 2009). The European Union is considered a threat that will weaken the authority of the nation state, a primal example of this is the Tan parties rejection of the EU law's supremacy over national law. As such, extreme-Tan parties are usually very eurosceptic parties, which does not mean they necessarily want to dissolve the EU, but they certainly want to see a Europe with intergovernmentalism at its core (Hooghe et al., 2002).

The Gal-Tan parties position on ending or reforming the European project is influenced by their position on the Left-Right economic spectrum. Gal-leaning parties are especially supportive of European integration if they do not share an extreme-Left ideology. These parties support the strengthening of the EU's environmental policy, the EU's initiatives to promote democracy and liberalize immigration law (Hooghe et al., 2002). Tan parties with Right-wing leanings may see the EU's market integration as an indispensable policy, while more Left-wing parties might perceive it as another tool for the erosion of the nation state. Many European conservative parties face an internal struggle between the factions which

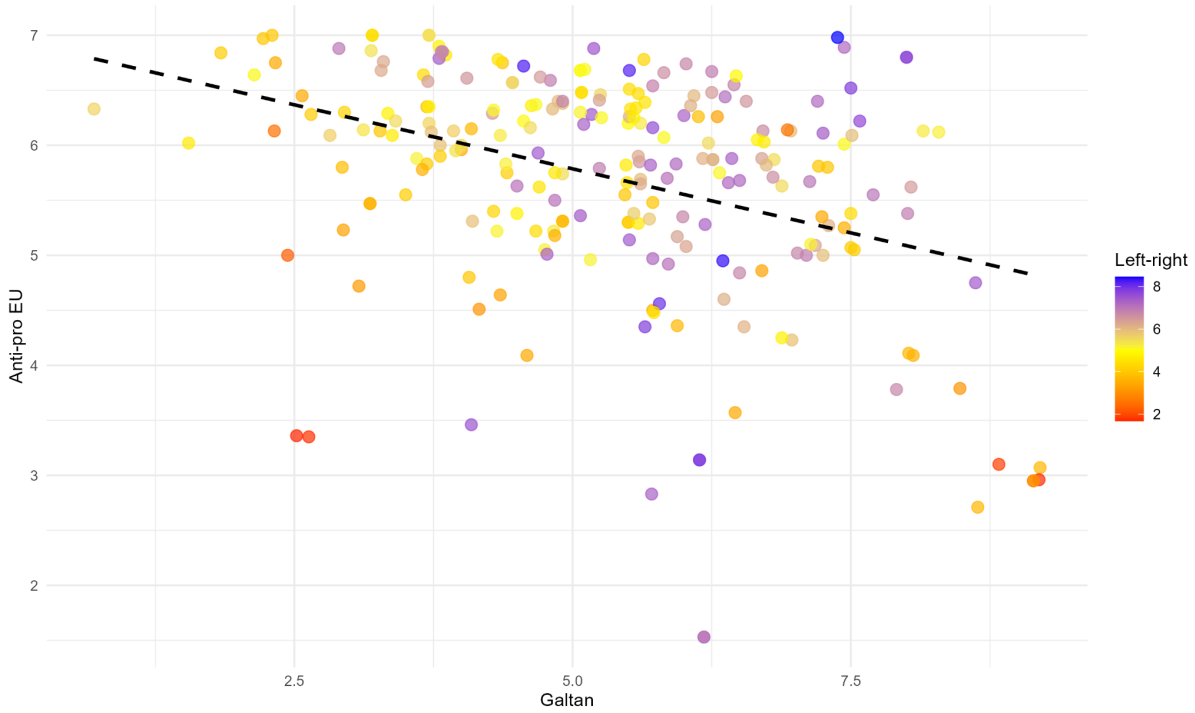
completely reject the European Union and the other which generally dislikes European integration, but sees the benefits of market integration (Edwards, 2009).

An example of this was the decades of infighting in the British Conservative Party between its “soft” eurosceptic faction, which wants to reform or limit the EU, and “hard” eurosceptic faction, that wants to leave the Union. The struggle to form a unified party position regarding European integration was so devastating that it profoundly affected conservative prime ministers. Margaret Thatcher's escalating euroscepticism culminated in her resignation, while John Major's premiership was marred by constant attacks from the Anti-European integration faction. David Cameron, facing pressure, ultimately accepted a referendum on EU membership, which would eventually end his premiership (Dorey, 2017). Even when the United Kingdom had already voted to leave the European Union, the internal discord within the British Conservative Party on the future relation with the bloc led to the resignation of Theresa May’s cabinet (Hickson; Page; Williams, 2020).

The correlational interaction among those three cleavages in the cabinets included in this study can be observed in the scatter plot below[20]:

[20] For plots where the correlation was harder to observe, a line was added.

Figure 2 - Scatter plot of the Gal-Tan[21], Left-Right[22], and Anti-Pro EU[23] cleavages in the researched cabinets



Source: own elaboration, with data from CHES (Jolly et al., 2022) and RepDem (Hellstrom et al., 2023) databases.

Observing the plot above, a discernible negative correlation emerges between being a Pro-European integration cabinet and being a Tan-leaning cabinet. This demonstrates that the expected relationship, in the literature (Hooghe; Marks, 2009), between these two cleavages is confirmed in this study. It also shows that this relationship not only exists in parties, but also in cabinet coalitions.

Furthermore, analyzing the relation between Left-Right and Anti-Pro EU, it is possible to observe that while some extreme-Right cabinets are Pro-EU, almost no extreme-Left cabinet presented the same attitude towards the European Integration. This also confirms the literature (Hooghe et al., 2002) argument that Right-wing parties can see the benefits of the EU's market integration and liberalization, whereas Left-wing parties may perceive the EU as a roadblock for more government intervention in the economy. This is accentuated by the decision to consider, in this study, the Left-Right cleavage only in economic terms.

[21] 0 = Libertarian/Postmaterialist; 10 = Traditional/Authoritarian.
[22] 0 = Extreme-left (red); 10 = Extreme-right (blue).
[23] 1 = Strongly opposed; 7 = Strongly in favor.

The relationship patterns between Gal-Tan and Left-Right cleavages are less clear to distinguish, since there is the occurrence of Right-wing and Left-wing cabinets which are also either Gal-leaning or Tan-leaning cabinets. This can be explained by past ideological divisions in Europe (McCright; Dunlap; Marquart-Pyatt, 2015). In the post communist European countries, party competition formed around Gal-Right parties, defending the free market and liberal democracy, and Tan-Left parties, promoting nationalism and government intervention (Hooghe; Marks, 2018).

The liberal party family also has some division in relation to the Left-Right cleavage. Some parties within this family prioritize economic liberalization, while others consider political liberalism as the paramount factor and are open to adopting certain Left-wing economic policies (Edwards, 2009). Furthermore, Piketty (2020) highlights the emergence of new ideological combinations in Western Europe when analyzing the French political system in 2017. The author identifies four main blocs: egalitarian internationalist (Gal-Left leaning); inegalitarian internationalist (Gal-Right leaning); inegalitarian nativist (Tan-Right leaning); and egalitarian nativists (Tan-Left leaning).

3.2 Ideology and carbon taxes

Carbon taxes do not emerge, persist, or undergo changes in a vacuum. The current lack of political will in many countries to price carbon, or implement other climate policies, poses a significant challenge to achieving the objectives set forth in the Paris Agreement (Levi; Flachsland; Jakob, 2020). Regardless of the assessments from economists, environmentalists, and other experts regarding the merits of the tax, ultimately, political actors play a decisive role in determining its implementation and tax rate. This holds particularly true in Europe, where all current carbon taxes have been enacted by national parliaments. This stands in contrast to two unsuccessful attempts in the American state of Washington to introduce a carbon tax through referendums (Anderson; Marinescu; Shor, 2023).

Ideology is especially important to understand the implementation and variation of carbon taxes rates, because, as seen in the last topic, it offers a guide to political parties about the climate crisis. Support for costly climate policies will only exist if climate change is recognized as a serious man-made problem, which can be reversed by mitigation measures. This is true specially for high visibility policies such as carbon taxes (Levi, 2021).

The significance of political actors, specifically political parties, in this process is exemplified in the case of Alberta. In this Canadian province, the Notley cabinet[24],

[24] Commonly recognized as the Notley ministry, in Canada, cabinets are typically referred to as ministries.

representing a center-Left party, introduced a provincial carbon tax in 2017. However, just two years later, following a change in government to a conservative party, Alberta terminated its carbon pricing initiative.

This does not imply that political actors operate without constraints when implementing and defending their ideological positions. Economic factors also play a pivotal role in shaping the public's support for carbon taxes, as exemplified by the case of British Columbia, a Canadian province. In response to the growing significance of environmental concerns, the Liberal (center-Right) cabinet in the province introduced a carbon tax. Unfortunately, the timing coincided with a spike in oil prices, fostering a perception that the tax significantly contributed to the surge in gas prices (Harrison, 2013).

The opposition party, the New Democratic Party, despite being ideologically positioned further to the Left than the Liberal Party and having advocated for a carbon tax that same year, initiated a campaign opposing the tax. This example underscores how external factors, such as oil prices, can influence voter perceptions of the tax and subsequently impact the stance of political parties, even those ideologically aligned with the environmental policy in question. To counter the negative perception, the Liberal Party asserted that the tax was revenue neutral. They emphasized that the government had offset the carbon tax by reducing other taxes, framing it not as a tax increase but as a shift from taxing income and business to discouraging undesirable activities like pollution. In doing so, the Liberal Party sought to garner support from ideologically center-Right voters (Criqui; Jaccard; Sterner, 2019).

Furthermore, several studies have found an association between the individual's ideology or party preference and its general position on climate change and climate policy (McCright; Dunlap; Marquart-Pyatt, 2015). In Poland, when comparing the acceptance of carbon taxes among voters of different parties, Yazar et al. (2022), found that voting for a Right-wing party rather than an extreme Right-wing party significantly correlates with support for carbon tax. Interestingly, the same was not true for Left-wing voters, who exhibit a preference for government subsidies for renewable energy. This trend appears to be consistent across Eastern Europe, where Right-leaning citizens are more willing to pay for climate policy than Left-leaning citizens, while the reverse is observed in Western Europe (McCright; Dunlap; Marquart-Pyatt, 2015).

While this difference can be attributed in part to a lower environmental awareness in Eastern Europe compared to Western Europe, it may also stem from studies measuring the Left-Right cleavage in its traditional sense without distinguishing between the cultural and economic components. Since the party divide in Eastern Europe is structured around

culturally Tan parties with Left-wing economic policies, and culturally Gal parties favoring Right-wing economic policies (Hooghe; Marks, 2018). In contrast, in Western Europe the parties traditionally organized around Tan parties with Right-wing economic policies and Gal parties with Left-wing economic policies (McCright; Dunlap; Marquart-Pyatt, 2015). This distinction could help explain the variation between Eastern and Western Europe.

Some authors recommend separating the cultural from the economical cleavage while researching environmental policy, as different political-cultural contexts may influence the traditional Left-Right ideological scale (Jagers; Harring; Matti, 2017). Another example that separating the Left-Right cleavage in Gal-Tan and Left-Right can be beneficial to the research comes from Tawiah (2022) article on environmental policy stringency and political ideology. The author reached the odd conclusion that Right-wing governments have higher environmental policy stringency than Left-wing governments. Tawiah (2022) defines Left-leaning as promoting social freedom and market regulation, while Right-wing parties prefer less social freedom and unregulated markets.

Tawiah's (2022) ideological definitions may overlook cabinets with a Gal-Right coalition. In the former, despite a preference for minimal government interference, parties may recognize the significance of climate change, leading them to support some degree of market regulation. Conversely, in the latter, where the coalition may not prioritize environmental concerns, it might not be inclined to introduce stringent environmental regulations, regardless of its stance on government regulations.

Regarding the Gal-Tan cleavage, it is anticipated that Tan-leaning parties are more likely to oppose climate policies due to their commitment to traditional values and national economies compared to their Gal-leaning counterparts (Buzogany; Cetkovic, 2021). The fact that climate change is a global problem which demands global cooperation, agreements, and commitments often framed in "far away" institutions, be it on the European Union or on the United Nations, further positions the Tan-leaning parties against climate policies.

Since these parties have a great distrust towards international institutions and binding agreements. For them, climate policy is an imposition from the liberal, cosmopolitan elites (Lockwood, 2018). In this context, Tan parties' position on climate change is more a reaction against what they perceive as a Gal/green/cosmopolitan plot than an alternative view of environmentalism (Gemenis et al., 2012).

As mentioned earlier, European conservative parties exhibit a potential lack of unity regarding European integration. However, these parties not only tend to be more supportive of climate policies in general, but also endorse the EU's climate policies more than extreme-Tan

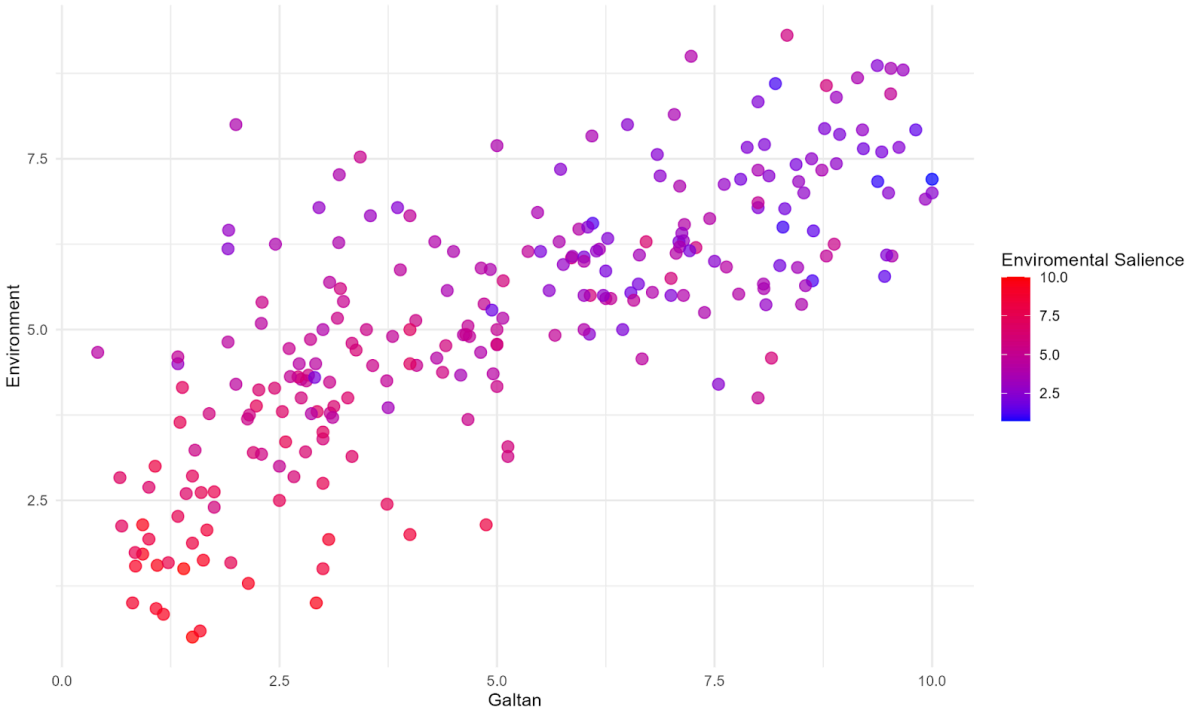
parties. Comparing conservative parties with extreme-Tan parties in France, Germany, the Netherlands, Poland, and Spain has shown that the majority of the former support emissions reduction measures, while all the latter either outright reject climate change or are silent about it. For instance, the Alternative for Germany Party, an extreme-Tan party, went as far as proposing in its 2017 electoral manifesto that an increase in carbon dioxide in the atmosphere should be incentivized (Hess; Renner, 2019).

All the conservative parties in the countries mentioned above highlighted their commitment to international agreements and European emissions' reduction targets. In France, The Republicans party's candidate, for the 2017 French presidential election, even called for an EU wide carbon price floor. While the Polish Civic Platform, although noting that Poland had other priorities, guaranteed it would comply with EU climate policy. In contrast, all the extreme-Tan parties rejected a European climate policy and international cooperation on climate change. The Polish Law and Justice Party accused the Paris Agreement of being the product of political corruption and a way for other European nations to interfere with Poland's interests (Hess; Renner, 2019). The emergence of a stronger energy and climate EU policy in the last decades only increased the disputes between those which believe these are prerogative of the national governments and those which see the merit of a European-wide policy (Herranz-Surrallés, 2015).

It is noteworthy that extreme-Tan parties are not against every environmental policy. Since their nationalistic ideology romanticizes the national landscapes, they tend to promote conservationist measures at the local level (Lockwood, 2018). Gemenis et al. (2012) corroborate with this argument, they researched the party manifestos of 13 extreme-Tan parties, and found that although all of them defended that their country should be free of pollution, most parties denied that climate change was man-made, and only the Swedish Democrats were in favor of environmental taxes.

A central point of Gemenis et al. (2012) argument was that there is only a consensus on the environment, when the issue is framed as a yes/no issue. When the environmental question is understood as a trade-off with economic growth, this consensus vanishes as Tan-leaning parties adopt an anti-environmentalism position. To illustrate the Gal-Tan relationship with the environmental sustainability issue and their environmental salience in European national parties during the 2019 wave, refer to the scatter plot below:

Figure 3 - Scatter plot of the Gal-Tan[25], environmental sustainability issue [26], and environmental salience[27] in European national parties in 2019



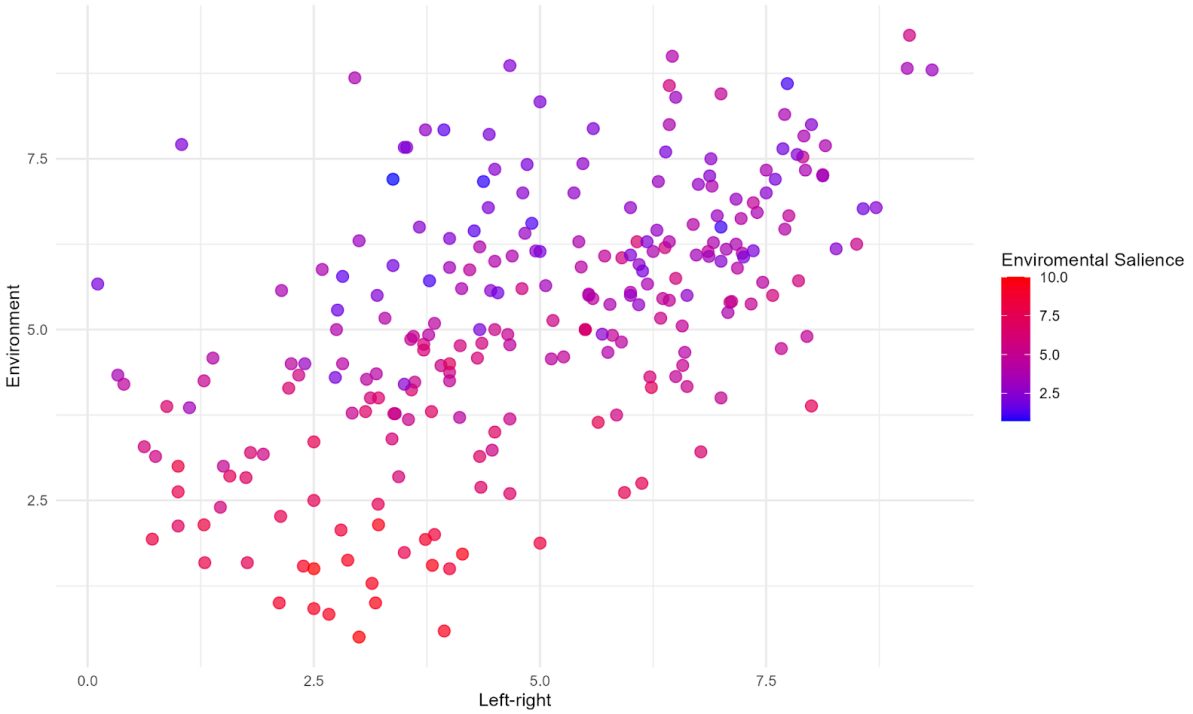
Source: own elaboration, with data from CHES (Jolly et al., 2022).

Examining the scatter plot above reveals a robust positive correlation between supporting economic growth even at the cost of environmental protection and being a Tan-leaning party. This graph suggests that the literature assumptions about Gal parties, support for the environment and post-materialist issues, are, in general, valid. Another indication of this is that the Gal parties have a higher environmental salience when compared with Tan parties.

Although the other two cleavages, Left-Right and Anti-Pro EU, do not present a correlation with the environmental sustainability issue as strong as the Gal-Tan divide, they nonetheless indicate a correlation pattern. The following scatter plots illustrate the connection between the Left-Right/Anti-Pro EU cleavage and the environmental sustainability issue, along with their environmental salience in European national parties during the 2019 wave.

[25] 0 = Libertarian/Postmaterialist; 10 = Traditional/Authoritarian.
[26] 0 = Strongly supports environmental protection even at the cost of economic growth; 10 = Strongly supports economic growth even at the cost of environmental protection.
[27] 0 = Not important at all; 10 = Extremely important.

Figure 4 - Scatter plot of the Left-Right[28], environmental sustainability issue, and environmental salience in European national parties in 2019



Source: own elaboration, with data from CHES (Jolly et al., 2022).

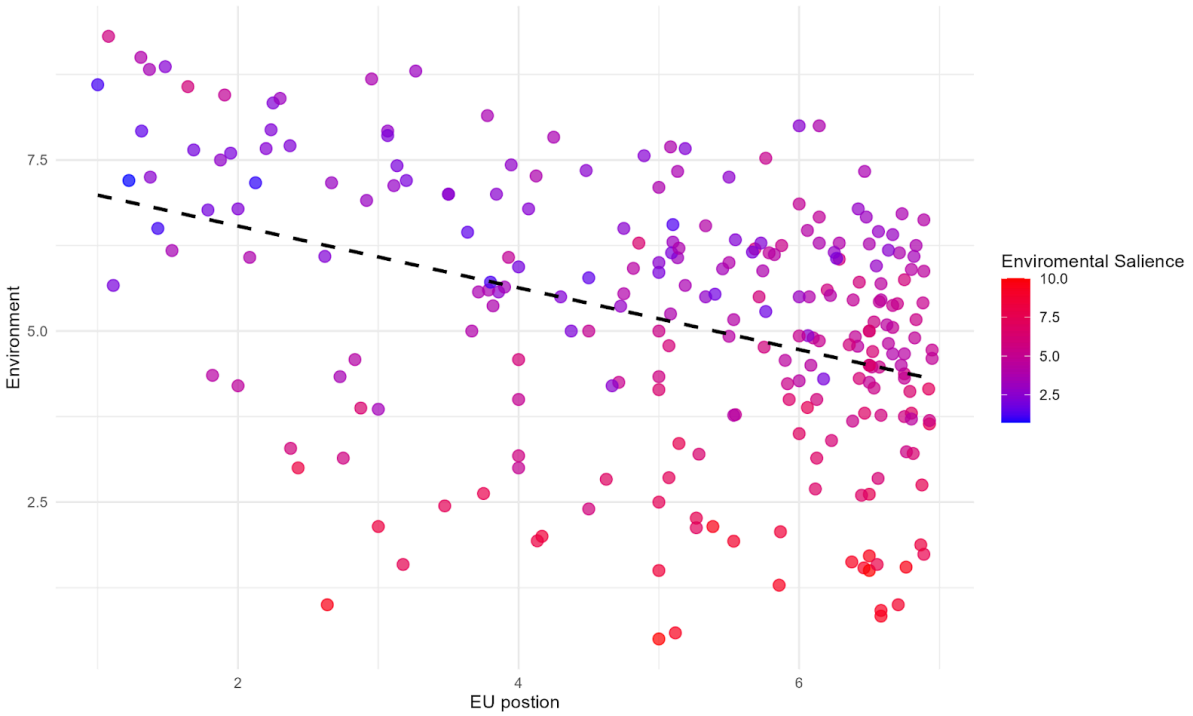
This scatter plot indicates that Right-leaning parties are more inclined to prioritize economic growth over environmental concerns. This fits their ideological position, since Right-wing parties are, in general, against government intervention in the economy, it is only to be expected that this translates into their environmental policy. Conversely, Left-leaning parties, less worried about government action, would also be more open to government regulations to deal with climate change (McCright; Dunlap; Marquart-Pyatt, 2015; Jagers; Harring; Matti, 2017). It is important to note that the cases are much more sparsely located when compared with the Gal-Tan relation with the environment, which indicates that this presents a weaker correlation. Notably, Left-leaning parties have a stronger environmental salience than their Right-wing counterparts.

This plot specifically illustrates the relationship between the Left-Right cleavage and the general stance on environmental protection versus economic growth. It does not directly capture the Left-Right positions on specific climate policies. As argued by Levi (2021) individuals that strongly oppose or advocate free markets may be less likely to support carbon

[28] 0 = Extreme-left; 10 = Extreme-right.

taxes. While the former see the tax as an illegitimate government intervention, the later may regard the tax as an inappropriate market instrument.

Figure 5 - Scatter plot of the Anti-Pro EU[29], environmental sustainability issue, and environmental salience in European national parties in 2019



Source: own elaboration, with data from CHES (Jolly et al., 2022).

Examining the presented scatter plot, it becomes apparent that parties supportive of European Integration tend to adopt a less extreme stance. Although there are parties that highly favor environmental protection and dislike the European Union, the majority of parties that favor the environment have a neutral or favorable position on the EU. Additionally, the plot reveals that parties expressing Anti-EU sentiments generally exhibit lower environmental salience compared to those favoring European integration. A concrete example is the Identity and Democracy group, a hard eurosceptic faction within the European Parliament, which did not even mention the environment or climate change as a priority in their 2019 EP election manifesto (Nur, 2023).

In relation to climate policy, the Anti-Pro EU debate is even more prominent, as Eurosceptic parties regard climate change as an issue created by the European elites. These parties also criticize the delegation of decision-making authority from the nation states to the

[29] 1 = Strongly opposed; 7 = Strongly in favor.

European Union (Buzogany; Cetkovic, 2021). This position puts these parties at odds with the global nature of climate change and the need for international collective action to stop it. For instance, members of the European Parliament (EP) who are less Pro-EU are less likely to vote in favor of the EU's environmental and climate policies, and vice versa (Buzogany; Cetkovic, 2021). Supporting this observation, nearly all speeches in the EP advocating for a reduction in the ambition of the EU's climate policy were delivered by members of Anti-EU European Parliament political groups (Petri; Biendenkopf, 2021).

The Anti-Pro EU divide becomes more apparent when EP members debate the actual implementation of EU climate targets. The majority of Pro-European integration parliamentarians tend to support the implementation measures, while the majority of Anti-EU members express opposition (Kinski; Servent, 2022). This pattern seems to extend to the national level, where Anti-EU parties have been associated with an increase in carbon emissions when they assume power in European states (Jahn, 2021).

Reviewing the literature, this study posits that parties on the Left, Gal, and Pro-EU end of the spectrum are more likely to propose and increase carbon taxes when compared to more Right, Tan, Anti EU-leaning parties. The parties on the Left would be more willing to intervene in the economy and raise taxes to fulfill a societal goal. While the parties closer to the Gal end of the spectrum are more sensible to the environmental cause, thus more willing to create and raise carbon taxes to reduce emissions. Pro-EU parties attempting to comply with the EU's climate goals are more inclined to create and raise carbon taxes. Conversely, parties positioned on the Right, leaning towards Tan, and harboring Anti-EU sentiments would be less likely to endorse or support increased carbon taxes.

3.3 Final considerations

This chapter had the crucial role of presenting the importance of ideology in the study of carbon taxes. It began by defining ideology for the political parties as how each party believes and expects the country to be governed (McClosky, 1964). It then proceeds to highlight the usefulness of the concept of ideological cleavages, drawing from cleavage theory, which posits that the present party system is a relatively stable outcome shaped by the social and cultural divisions present at the time of its establishment (Edwards, 2009). After a brief explanation of the traditional cleavages, the chapter introduces the current ones: Left-Right; Gal-Tan; and Pro-Anti EU.

The Left-Right divide is described as being the conflict about the level of support for government intervention in the economy and income redistribution in a society (Hooghe;

Marks, 2018). On the other hand, the Gal-Tan cleavage involves cultural issues such as climate change, immigration, human rights and the preference for nationalist or cosmopolitan policies (Marks et al., 2021). Meanwhile, the Anti-Pro EU division is marked by the level of support or opposition to the European integration process.

The chapter also explores the interaction between those cleavages, as they co-exist in the European party system. Extreme-Left and Extreme-Right parties tend to reject European integration, and thus be more Anti-EU, because those in the Left see the EU as a market liberalizing project and those in the Right dislike the EU's social and environmental policies (Edwards, 2009; Hooghe et al., 2002). Gal parties have a higher association with supporting European integration, while the Tan-leaning parties tend to reject it. This happens because Tan parties see the EU as a threat to the authority of the state, a project controlled by the cosmopolitan/ foreign elites. Gal parties are generally more receptive to the expansion of the EU's authority, viewing it as an advocate for their core cultural values, such as climate change policy and the promotion of democracy (Hooghe; Marks, 2009).

It is noteworthy that Extreme-Left Gal parties will be less inclined to support the EU because it also limits the national governments' ability to intervene in the economy and promote income redistribution (Hooghe et al., 2002). Parties with mixed Left and Tan ideologies will also be more likely to reject European integration, since they advance different cultural and economic policies. Conversely, Right and Tan parties can be more inclined to support European integration because of its market liberalization policies, albeit with a preference for a more restricted and intergovernmental EU. The chapter also demonstrates that this difference in support for the EU can promote infighting, especially in conservative parties, between the party's "soft" eurosceptic and the "hard" eurosceptic factions (Edwards, 2009).

Later on, a plot was presented illustrating the interaction of these three ideological cleavages in the cabinets included in this research. Upon observing the plot, it becomes apparent that the literature's assumptions on the interaction between the ideological cleavages is reflected in this study's cabinets.

The second topic discussed the relation between ideology and carbon taxes. It commenced by acknowledging that carbon taxes do not exist in a political vacuum, but are deeply embedded in political contexts, with political actors ultimately wielding significant influence. To illustrate this, it presented the case of Canada's province of Alberta, where the change in the ruling party resulted in the end of its carbon tax. The chapter also highlights the importance of dividing the Gal-Tan cleavage from a more general Left-Right division, noting

the historical distinction between Western and Eastern Europe in terms of ideological alignments. Traditionally, Western Europe features Gal-Left and Tan-Right parties, while Eastern Europe exhibits Gal-Right and Tan-Left parties (Hooghe; Marks, 2018). Moreover, there is a recent emergence of Gal-Right and Tan-Left parties in Western Europe (Piketty, 2020).

These differences impact the assumptions relating to these parties' climate policy preference. Left-wing parties are more inclined to accept government intervention to societal goals, such as protecting the environment. On the other hand, Right-wing parties are either more skeptical or more resistant to government intervention (Levi, 2021). Gal-leaning parties have the environmental and climate policy in the center of their ideology, whereas Tan-leaning parties tend to reject the urgency of climate change and prioritize economic growth (Buzogany; Cetkovic, 2021).

Extreme-Tan parties, in particular, view climate change as a conspiracy orchestrated by cosmopolitan, foreign, and corrupt elites to undermine the authority of the state. This interpretation differentiates conservative parties from extreme-Tan parties, as the former, at least in Europe, accept the need to reduce carbon emissions, EU-wide reduction targets, and international agreements (Hess; Renner, 2019).

Regarding the Anti-Pro EU cleavage, the eurosceptic parties tend to reject any European-wide climate policy that may represent the delegation of decision-making authority from the nation states to the Union (Buzogany; Cetkovic, 2021). Those parties also tend to prioritize economic growth over the environment and are generally skeptical of climate international agreements. On the other hand, the Pro-EU parties tend to have a less extreme stance towards favoring economic growth in detriment of the environment.

This dynamic can be observed on the European Parliament, where Anti-EU parliamentarians are more likely to vote and speak against the EU's climate policy, while their Pro-European counterparts exhibit the opposite behavior (Petri; Biendenkopf, 2021; Kinski; Servent, 2022). Importantly, this tendency seems to extend to the national level, as Anti-EU parties have been linked to an increase in carbon emissions when they come into power in European states (Jahn, 2021). Additionally, three plots were utilized to demonstrate the interaction between the three ideological cleavages, the environment's importance in relation to economic growth, and the environmental salience of national European parties in 2019.

The chapter concluded, based on the literature reviewed, by establishing assumptions about the ideological divides in relation to carbon taxes. Parties on the Left, Gal, and Pro-EU

side of the spectrum would be more likely to create and increase carbon taxes than the parties on the Right, Tan, and Anti-EU side.

4 METHODOLOGY

The primary aim of this research is to develop a classification tree capable of predicting the decisions made by European governments concerning the implementation and rate of carbon taxes. The time frame is between 1995 and 2023, this limit was selected due to data limitations in the main database, CHES (Jolly et al., 2022).

A decision tree was chosen as the statistical model based on the assumption that decisions regarding carbon taxes in various political entities have been made using a similar rationale (Skovgaard et al., 2019). This choice stems from the belief that the model can effectively sift through the data and discern patterns underlying these decisions. It is crucial to emphasize that decision tree models, akin to many machine learning models, are unable to establish causality. Therefore, their outcomes should be interpreted as correlational (Levi, 2021) and associated with the literature's assumptions. Nevertheless, it remains relevant to conduct this research as it contributes to the understanding of patterns and associations within the complex landscape of carbon tax implementation and variation in Europe. The decision tree models help identify variables that are statistically associated with certain outcomes, providing insights into potential influencing factors. This holds particularly true for the ideological features, which, unlike economic or structural factors, have not been thoroughly investigated.

Table 3 - Methodology overview

Hypotheses	H1a: Leaning Left/Gal/Pro-Eu cabinets are expected to be associated with the creation and an increase in carbon taxes. H1b: Leaning Right/Tan/Anti-Eu cabinets are expected to be associated with a decrease in carbon taxes and with "No tax" scenarios. H2a: The inclusion of a Green party in the coalition and/or a strong electoral performance of green parties is expected to be associated with the creation and an increase in carbon taxes. H2b: The absence of a Green party in the coalition, weak electoral performance of green parties is expected to be associated with a decrease in carbon taxes and with "No tax" scenarios.
Target Variable	The implementation and variation of the averaged Emission-weighted carbon tax rate by cabinet.
Features	● Ideological position of the governing coalition in the cleavages: Left-Right, Gal-Tan, Pro-Anti EU.

	• Occurrence of anti tax policy change protests. • Carbon tax's revenue destination. • Presence of a green party in cabinet. • Share of votes to green parties in the previous election. • GDP per capita (PPP). • Brent price. • Environmental disasters. • Environmental pressure. • Caretaker government. • Decade. • Paris Agreement. • European regions. • Bond yield. • Share of fossil fuels in energy consumption. • Liberal democracy score. • Government debt to GDP.
Statistical Model	Decision tree model.
Robustness Technique	Leave-one-out cross validation.

Source: own elaboration.

The remaining topics of this chapter are subdivided into three topics. The first topic provides an overview of decision tree models, its advantages and limitations. It also covers always to identify *overfitting* and *underfitting*[30], such as observing the accuracy rate and p-value, as well as methods as Holdout Validation and Leave-One-Out Cross Validation. Within this topic, various techniques for mitigating *overfitting* and *underfitting* were presented, such as pre-pruning, post-pruning, and data pre-processing. Additionally, It contains information on the different splitting criteria available to obtain the highest information gain.

The second topic describes how the target variable and features were coded and where their information was retrieved from. This topic also explains the rationale behind the selection of certain features and the exclusion of others. Furthermore, it describes the temporal and geographical constraints inherent in this research. The third topic presents an overview of the main datasets used in this study.

[30] *Overfitting* happens when the model is too complex, failing to generalize effectively to unseen data. On the other hand, *underfitting* occurs when the model is overly simplistic, resulting in suboptimal performance both in the training data and with unseen data.

4.1 Decision trees

Utilizing the decision tree method offers numerous advantages. One noteworthy benefit is the inherent simplicity and interpretability of decision trees, facilitating the dissemination of academic knowledge to a broader audience without an extensive background in statistics or machine learning (Grus, 2021). This is particularly important given the policy relevance of carbon taxes as a research area. The ease of understanding decision trees is further enhanced by their structure, which consists of a sequence of simple tests compared against a threshold value or a set of possible values. This characteristic makes decision trees more straightforward to understand, compared to the opaque nature of "black-box" neural networks (Kotsiantis, 2011).

Unlike certain statistical methods, decision trees do not assume linearity between dependent and independent variables, nor do they presume a linear relationship between the *logit* of the outcome and each predictor variable. Furthermore, decision trees operate without relying on the assumption of normal distribution in variables, and can identify relationships that are conditional on the specific values of other features. In contrast to qualitative methods, which predominate in the existing climate policy literature, decision tree models can explicitly rank the importance of different features (Levi, 2021).

Additionally, they adeptly handle heavily skewed data without necessitating data transformation, and exhibit robustness in the face of outliers (Song; Lu, 2015). By leveraging insights from historical data and undergoing training to discern patterns and relationships between the target variable and features within the training dataset, the decision trees model becomes adept at making predictions on novel, unseen data.

The decision to employ a machine learning method, such as decision trees, stemmed from a careful examination of the dataset utilized in this research. The descriptive statistics annex reveals that the features in the data frame violate the assumptions of several conventional statistical methods. Notably, certain variables exhibit non-normal distributions (as depicted in the annex's Figure fifteen), while others manifest the presence of outliers (as illustrated in the annex's Figures sixteen and seventeen). Additionally, a lack of a linear relationship between variables further complicates adherence to traditional statistical assumptions.

A significant challenge arises from the disparate occurrences among the categories of the target variable, as evident in Figure thirteen. The decision tree method offers a pragmatic solution to this issue by accommodating varying weights for categories. Conforming the data frame to meet the assumptions of traditional statistical methods would necessitate extensive

data transformations, introducing the risk of *overfitting* and exacerbating the complexity of result interpretation.

Moreover, employing a non-linear model offers an alternative lens through which to analyze climate policy issues. While linear statistical models expect a “straight-line” relationship between the dependent variable and the independent variables. The models’ results are explained by observing the magnitude and sign of its coefficients. The magnitude of a coefficient signifies the extent to which a one-unit change in the predictor variable affects the dependent variable, with larger coefficients indicating a stronger impact. Positive coefficients imply that an increase in the predictor variable leads to an increase in the dependent variable, whereas negative coefficients suggest an inverse relationship. On the other hand, non-linear statistical models, such as decision trees, are capable of capturing complex, "non-straight-line" relationships present in the data. These models learn the data patters and attempt to predict or classify the data points.

This difference in results interpretation can be observed in concrete cases, as exemplified by the following citations: For the linear models, “The associated estimated coefficients suggest that an increase of 10% in the share of electricity generated from coal would lead to a 0.6–1.2USD/tCO2e decrease in the average carbon price” (Dolphin et al., 2019, p. 21). In contrast, for non-linear models, “If the Final energy consumption is between 24.6 and 34.2 million TOE, and the Average years of activity of the policy mix is higher than 6 years, the mean value predicted to be achieved is 34.4%, compared to a 25.3% if lower than 6 years” (Ortiz et al., 2022, p.10). As mentioned before and demonstrated in the previous example, non-linear models excel at identifying relationships contingent on specific values of other features. This stands in sharp contrast to linear models, which assess each predictable variable while maintaining the others at constant values.

Decision trees are structured with nodes and branches, encompassing three types: root nodes, internal nodes, and leaf nodes. The root node serves as the inception point, initiating subsequent subdivisions. Internal nodes house questions, altering the tree's direction based on the answers. Meanwhile, leaf nodes symbolize the ultimate outcomes (Grus, 2021). The branches signify the consequences stemming from the divisions at each node, akin to "if-then" rules, where the occurrence of conditions A and B leads to outcome C (Song; Lu, 2015).

In essence, decision trees endeavor to classify data by discerning its patterns. These trees come in two types: classification trees, which yield categorical outcomes, and regression trees, which produce numeric outcomes (Kotsiantis, 2011). To partition the data into more manageable segments, the model seeks to identify the test that most effectively diminishes the

impurity or uncertainty of the data under scrutiny. A prevalent method involves striving to minimize Entropy. Higher information gain with the split results in lower Entropy for the remaining data (Grus, 2021).

Beyond Entropy, decision tree models can be configured to utilize alternative metrics such as the Gini index, Towing criteria, and Chi-square (Song; Lu, 2015). These metrics share a common objective of minimizing impurity in the data. The Gini index, a popular alternative to Entropy, is particularly advantageous for larger datasets due to its computational efficiency. Moreover, it exhibits lower sensitivity to outliers compared to Entropy.

Towing criteria is well-suited for highly dispersed data with numerous local patterns (Aning; Przybyla-Kasperek, 2022). On the other hand, Chi-square focuses on the statistical significance of differences between the parent node and the child nodes. While Entropy and the Gini index can accommodate both categorical and continuous target variables, Towing criteria and Chi-square exclusively work with categorical target variables. Notably, all these metrics can handle both categorical and continuous features (Song; Lu, 2015).

When assessing a decision tree model, two crucial metrics to consider are accuracy and probability estimates. Accuracy gauges how frequently the model's predictions are correct, calculated by dividing the number of accurate predictions by the total number of predictions. This metric can be compared with the no information rate, representing the model's accuracy if it did not consider any features. On the other hand, probability estimates reflect the model's confidence in its predictions. In summary, accuracy evaluates the overall correctness of predictions, while probability estimates measure the level of certainty associated with each instance.

When dealing with an imbalanced data frame, characterized by a substantial difference in the number of cases in the categories within the target variable, decision tree models can undergo modified split calculations to address this challenge. It becomes possible to introduce varied weights for different categories, typically based on their frequency in the data frame. Additionally, preferences can be specified for metrics such as false negatives and false positives.

In instances where there are rare classes in the data frame, the model may disregard patterns in the data, as it learns that predicting the majority class would result in a high accuracy rate anyway. Concerning false positives and false negatives, as illustrated by Wang et al. (2010), for a bank, it is preferable not to grant a mortgage to a client who is likely to repay it than to lend the sum to a higher-risk client. Consequently, decision trees can be

tailored to accommodate similar scenarios. It's essential to note that these adjustments can potentially lead to *overfitting*.

To enhance the model's adaptability to unseen data and generate more concise decision trees, three strategies—pre-pruning, post-pruning, and data pre-processing—can be employed. Pre-pruning involves establishing termination conditions to limit the tree's size before its formation. These stopping rules may include specifying a minimum number of cases in a leaf node, a minimum number of cases in a node for it to split, or defining a maximum depth for the tree (Song; Lu, 2015). Post-pruning involves constraining the size of the tree after its formation by removing non-significant branches. In contrast, data pre-processing aims to mitigate *overfitting* by carefully selecting features. This process helps reduce irrelevant correlations that might otherwise confound the model's classification process (Wang et al., 2010).

A primary strategy to assess if a model is overly specific, meaning it may not perform well with new data, involves setting aside a portion of the data frame that the model has not encountered for later testing. Adjustments, such as adding weights and setting preferences, are typically made during the training phase to ensure that the test set remains representative of real-world data. Subsequently, the model's performance can be estimated by evaluating the generalization error. Various methods can be employed for this purpose, including Holdout Validation, K-Fold Cross-Validation, Leave-One-Out Cross-Validation, and Bootstrap Aggregating.

In Holdout Validation, the data frame is split into two parts: a training set, typically comprising between 70% and 90% of the data, and a test set containing the remaining cases. The model is trained with the majority of the data and subsequently tested against the remaining cases. The better the model performs, the smaller the generalization error, indicating that the model is better prepared to handle unseen data.

For K-Fold Cross-Validation, the data frame is divided into k folds. The decision tree is trained k times, with each iteration leaving one case as a test case. Average metrics are then calculated across all folds to obtain an estimated generalization error. Following a similar logic, Leave-One-Out Cross-Validation sets k to the number of samples in the dataset. In each iteration, the decision tree is trained on all data except one sample, and the test occurs on the left-out sample (Wong, 2015). Although computationally more intensive, it is a less biased method for assessing generalization error compared to K-Fold Cross-Validation, as one cannot choose the number of folds. Finally, the Bootstrap Aggregating technique generates random

samples with replacement from the data frame, training a decision tree in each sample. The results of all trees are then aggregated.

The size of the data frame plays a crucial role in choosing an appropriate validation technique. While Holdout Validation is effective with larger data frames, it may inadvertently exclude crucial information from the training phase when applied to smaller datasets. For smaller data frames, K-Fold Cross-Validation, Leave-One-Out Cross-Validation, and Bootstrap Aggregating are more suitable, allowing for a more robust utilization of the limited available information.

While the recommendation is to keep the construction of the decision tree as simple as possible, its size and shape can vary depending on the dataset. It may have numerous levels or be a shallow tree; it can exhibit symmetry or be skewed in one direction (Kotsiantis, 2011).

4.2 Target variable and features

As mentioned before, given that decision trees employ the terminology of target variable and features rather than dependent, independent, or control variables, this study will adopt these nomenclatures. The target variable in question is designated as Label10, representing the variation (or lack thereof) in the averaged Emissions-weighted carbon tax price rate within a government cabinet. The variable categories are encoded as follows: "No tax," "Tax created," "Increased," "Decreased," and "Same."

To provide specificity, the label "No tax" is assigned when there is no existing tax in that cabinet; "Tax created" is assigned if the cabinet initiated the tax. For cases where a variation occurred, it is considered significant only if the tax changed by more than 10%. If the tax decreased, it is coded as "Decreased"; if it increased, it is coded as "Increased"; otherwise, it is labeled as "Same."

The choice of a 10% threshold stems from the calculation of the averaged Emission-weighted carbon tax price rate, which considers both the tax rate and the percentage of carbon emissions taxed. Given that the impact of the tax is not uniform across the entire economy and certain sectors may fare better than others, some variation in carbon emissions per sector is anticipated. To isolate these "natural" oscillations and exclusively capture international variations in the tax rate, the 10% threshold was implemented. This threshold serves as a filter to discern significant changes in the tax rate that go beyond the expected sectoral fluctuations.

To construct the target variable, the cabinets were transformed into a yearly format. Given that governments may come into power or exit without strict adherence to the calendar

year, a compromise was reached. If a cabinet governed for the majority of a year, it was considered to have governed for the entire year. For instance, if Cabinet A governed from February 1, 2008, until the end of October 2010, it is coded in the data frame as having governed from 2008 to 2010. This approach was adopted to align the cabinet duration with other data. Once the cabinets were standardized into a yearly format, the average of the Emission-weighted carbon tax price rate during their governance was calculated. This method of aggregation not only integrates cabinet duration into the dataset but also helps mitigate the "natural" oscillations mentioned earlier. It provides a more stable representation of the carbon tax price rate throughout each government's tenure.

Regarding the features, binary factors were encoded with 0s and 1s, where 0 signifies the absence of the occurrence, and 1 indicates the presence of the occurrence. For instance, data on the presence of a green party in the cabinet was collected and coded with 0 denoting no green party in government and 1 denoting the presence of at least one green party in the cabinet. The other binary factor features include whether the tax was revenue-neutral, if the revenues were directed towards green projects, whether the cabinet was in session or post the Paris Agreement, whether it was a caretaker cabinet, whether it presided over environmental disasters or faced environmental pressures from international agreements, and whether the country's cabinet is located in Western Europe. The presence of anti-tax policy protests with over 5 thousand attendees was not coded in a binary form. This decision was made due to the dataset's limitation, which only extends to 2020. In this context, 0s signify uncertainty regarding protest occurrences, 1s indicate the absence of protests, and 2s denote the presence of protests.

Numeric features encompass the ideological position of the coalition in the Gal-Tan, Left-Right, and Anti-Pro EU cleavages; the aggregated percentage of votes received by all national green parties in the last election of each cabinet; GDP per capita (PPP); Brent price; the government debt to GDP; bond yield; share of fossil fuels in energy consumption; and the score of its liberal democratic system. All the numeric features, except for the green parties share of the previous election results and the ideological features, were coded with the average for each cabinet.

The features related to the ideological cleavages are in different scales. The Gal-Tan and the Left-Right divisions are in a scale from 0 to 10, while the Anti-Pro EU is in a 1-7 scale:

Table 4 - Ideological features' scales

Scale	Gal-Tan	Left-Right	Anti-Pro EU
0	Libertarian/Postmaterialist	Extreme-left	X
1	X	X	Strongly opposed
4	X	X	Neutral
5	Center	Center	X
7	X	X	Strongly in favor
10	Traditional/Authoritarian	Extreme-right	X

Source: own elaboration, with data from CHES (Jolly et al., 2022) database.

To obtain the ideological position of each cabinet in the three ideological cleavages, it was first necessary to obtain the cabinet compositions. Using data from RepDem (Hellstrom et al., 2023) each cabinet was constructed by identifying the constituent parties and assigning weights based on their participation. The parties' participation was calculated considering the total number of the seats the coalition had in parliament (lower chamber). For instance, if party A had 80 seats and party B had 20 seats, party A would receive a weight of 0.8, while party B would receive a weight of 0.2.

Next, to acquire the parties' ideologies, the CHES database (Jolly et al., 2022) was utilized. The ideological position of each party on each scale was multiplied by their respective coalition participation weights. Subsequently, the parties' ideological scores were aggregated to determine the coalition's overall ideological position. For example, if party A had a Gal-Tan score of 10 and party B had a Gal-Tan score of 5, considering their respective coalition weights (0.8 and 0.2), the coalition score on the Gal-Tan scale would be 9.

Since the CHES (Jolly et al., 2022) data is available in waves (1999, 2002, 2006, 2010, 2014, and 2019), the ideological position of parties was coded using the wave closest in proximity to the year of the cabinet's formation. Considering that party ideology is relatively stable in the short term (Edwards, 2009), each wave was considered to be valid for 4 years, aligning with a conventional electoral cycle. This approach allowed for the inclusion of cabinets commencing between 1995 and 1998 and those concluding until 2023.

While the majority of European parties are covered in the CHES dataset (Jolly et al., 2022), certain short-lived parties that existed between waves may not be included. Considering this, a 10% threshold was adopted, where if the missing parties accounted for

10% or more of the cabinet seats, the cabinet would be excluded from the analysis. If it was less than 10%, the party would be excluded from the coalition. For instance, since the SOP party[31] from Slovakia was not on CHES (Jolly et al., 2022), and represented about 13% of the "Dzurinda I" cabinet; the whole cabinet was excluded from the research. The SOP party only existed from 1998 to 2003 and did not win any seats in Slovakia's 2002 parliamentary election.

Not all the researched countries were included in all the CHES (Jolly et al., 2022) waves. The main difference was between the 1999 and the 2002 surveys. In 1999, all the EU-15[32] countries were included, except for Luxembourg. While in 2002, those 14 countries were jointed by 9 Eastern European countries[33], that would later join the European Union. The 2010 wave included Croatia, while Norway and Luxembourg were included from the 2014 survey onwards. The countries were included in the research as they were available on CHES (Jolly et al., 2022), and on RepDem (Hellstrom et al., 2023). Since Cyprus and Malta were never included in the latter, they were excluded from the research.

Table 5 - Target variable and features sources

Category	Description	Source
Target variable	Label10 = Is there a carbon tax? (No = No tax). Was the carbon tax created? (Yes = Tax created). Was there a variation in the carbon tax price? (Up 10% or more = Increased; Down 10% or more = Decreased; Less than 10% = Same) **Categorical**.	Cabinets: RepDem database (Hellstrom et al., 2023). Tax rate from 1995 to 2020: World Carbon Pricing database (Dolphin; Xiahou, 2022). Tax rate from 2021 to 2023: Carbon Pricing Dashboard (World Bank, 2023).
Political	Ideological position in cleavages = the ideological scores of the cabinets in the cleavages: Left-Right, Gal-Tan, Pro-Anti EU. **Numeric**.	CHES database (Jolly et al., 2022).
Political	Occurrence of anti tax policy change protests = Have protests been recorded? (Uncertain = 0; No = 1; Yes = 2). **Categorical**.	Mass Mobilization Protest Data (Clark; Regan, 2016).

[31] Party of Civic Understanding.
[32] Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Portugal, Spain, Sweden, the United Kingdom.
[33] Bulgaria, the Czech Republic, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia.

Political	Presence of a green party in cabinet = Was a green party part of the cabinet? (No = 0; Yes = 1). **Binary**.	RepDem database (Hellstrom et al., 2023).
Political	Share of votes to green parties in the previous election. **Numeric.**	ParlGov database (Doring; Huber; Manow, 2022).
Political	Liberal democracy score. Scale (0 = least democratic; 10 = most democratic). **Numeric**.	V-Dem (2023).
Environmental	Environmental disasters = Have environmental disasters related to climate change been recorded? (No = 0; Yes = 1). **Binary**.	Center for Research on Epidemiology of Disasters (2023).
Environmental	Environmental pressure = Was the cabinet **not** on track to comply with Kyoto Protocol for the majority of its tenure? (No = 0; Yes = 1). **Binary**.	Global Carbon Budget (2023) and European Commission (2023).
Fiscal policy	Neutral tax = Was the carbon tax earmarked to reduce other taxes? (No = 0; Yes = 1). **Binary**.	Denmark, Finland, France, Ireland, Latvia, Poland, Portugal, Slovenia, Sweden, UK, and Norway: (Marten; Dender, 2019). Estonia: (Riigi Teateja, 2014). Germany: (Wettengel, 2024). Luxembourg: (Morgan, 2019).
Fiscal policy	Green revenue = Was the carbon tax earmarked for green investments? (No = 0; Yes = 1). **Binary**.	
Fiscal policy	Bond yield = average 10-year maturity bond. **Numeric**.	OECD (2023).
Fiscal policy	Government debt to GDP = average Government debt to GDP. **Numeric**.	Eurostat (2023).
Structural	Caretaker government = Was the cabinet considered a caretaker government? (No = 0; Yes = 1)	RepDem database (Hellstrom et al., 2023).
Structural	Decade = The cabinets were classified by the decade of their first year in government. (1990; 2000; 2010; 2020). **Categorical**.	**X**

Structural	Paris Agreement = Was the Paris Agreement (2015) signed after the cabinet's tenure? (No = 0; Yes = 1). **Binary**.	**X**
Structural	Western Europe = Was the cabinet's country in Western Europe? (No = 0; Yes = 1). **Binary**.	EuroVoc.
Structural	European subregions = The cabinets were classified by their sub-European region. (Central and Eastern Europe; Northern Europe; Southern Europe; Western Europe). **Categorical**.	EuroVoc.
Structural	Share of fossil fuels in energy consumption = average share of fossil fuels in energy consumption. **Numeric**.	Energy Institute Statistical Review of World Energy (2023).
Structural	GDP per capita (PPP) = average GDP per capita (PPP). **Numeric**.	IMF (2023).
Structural	Brent price = average Brent price. **Numeric**.	Statista (2023).

Source: own elaboration.

The inclusion of the green parties in the cabinet feature aims to capture the potential influence exerted by green parties within the coalition, signaling potential pressure for an increase in the carbon tax or, at the very least, resistance against its reduction. The feature related to protests takes into account the challenges a government might face in raising taxes amidst protests concerning tax policy, especially evident in instances like the "gilets jaunes" movement in France. The cabinet was designated as having experienced anti-tax policy change protests if such protests were categorized under price increases or tax policy in the Mass Mobilization Protest Data (Clark; Regan, 2016). Only protests with more than 5,000 attendees were considered, as this would characterize as a large number of people protesting (Wouters; Walgrave, 2017).

Two features concerning the destination of carbon tax revenue were incorporated to account for the distinct implications of a change in carbon tax depending on its revenue allocation. If a government opts to increase the tax with the revenue directed to the general budget, it might be perceived as an increase in the overall tax burden. However, if the carbon tax increase is offset by other tax decreases, it would be viewed as a mere shift in taxation.

Similarly, if the revenue is earmarked for green projects, any variation in the tax would be analyzed considering its impact on these specific projects. It is important to acknowledge that while some authors have argued for the importance of the carbon tax's revenue use (Haites, 2018; Carl; Fedor, 2016), others have only found a moderate effect on carbon tax acceptance (Levi, 2021).

Regarding the caretaker cabinet feature, given that caretaker cabinets typically lack the mandate to enact substantial policy changes, they are markedly less likely to alter the carbon tax rate significantly. The features related to ideological positioning were introduced to illustrate the ways in which political considerations, rather than purely economic factors, influence decisions regarding the carbon tax. To assess the potential influence of geographical position, two features were added: one regarding the cabinet's location in Western Europe; and another more detailed with the four European regions, according to EuroVoc[34]: Central and Eastern Europe; Northern Europe; Southern Europe; and Western Europe.

Since polling data on environmental awareness or relevance was only available from 2008 onwards, the election results of green parties were utilized as a proxy feature. The underlying logic is that the more salient or important the environmental question becomes, the more voters are inclined to support parties that prioritize this issue. Building upon the approach of Bothner et al. (2022), this research also added features related to environmental pressure and environmental disasters. The first was coded by checking if the cabinet's country is complying with internationally agreed emissions' reduction, more specifically the targets set for the Kyoto's Protocol first and second commitment periods. If the country was complying with the emission reduction targets for the majority of the cabinet's tenure, the cabinet was coded as having no environmental pressure, and vice versa. The environmental disasters feature was included with the assumption that if during the cabinet's tern a major environmental disaster related to climate change happened, there would be increased pressure on the cabinet to take action to reduce emissions. The keywords to filter the environmental disasters related to climate change were: "Drought"; "Wildfire"; "Extreme Temperature"; and "Flood".

To incorporate a more systemic measure of environmental awareness, the GDP per capita (PPP) feature was introduced, considering the observed correlation between higher GDP per capita and increased environmental taxation per capita (Castiglione et al., 2014). This feature uses the purchasing power parity because it considers the cost of living, is more

[34] https://eur-lex.europa.eu/browse/eurovoc.html?locale=pt

stable, and less dependent on currency exchange rates. Making it more suitable for international comparisons (Callen, 2023).

The inclusion of the level of liberal democracy in the analysis accounts for the assumption that more autocratic governments produce weaker environmental regulations when compared with more democratic ones (Congleton, 1992; Levi; Flachsland; Jakob, 2020). Additionally, other authors have also argued that countries with well-working institutions have a greater legitimacy to introduce carbon taxes as they are seen by their citizens as less corrupt and more trustworthy (Levi, 2021).

The inclusion of the Brent price feature aims to acknowledge that governments might be less inclined to raise the carbon tax rate when oil prices are higher, given the economic strain already imposed on the public and businesses. The feature related to the share of fossil fuels in energy consumption aims to address two contrasting assumptions. On one hand, the higher the dependence on fossil fuels, the more costly and bigger the opposition to a carbon tax. On the other hand, a high use of fossil fuels may result in more pressure for the cabinet to implement a carbon tax to reduce emissions.

Lastly, the government debt-to-GDP ratio and the bond yield features were included to capture the challenges faced by cabinets in heavily indebted countries or in financial crises, both in terms of potential pressure to not lower taxes and the incentive to raise taxes to generate additional revenue. In most cases, the metric used for the bond yield feature was the 10-year maturity bond yield; in instances where this information was unavailable, the short-term bond yield was utilized. The preference for 10-year bonds is due to their increased responsiveness to changes in both monetary policy and economic conditions.

This study omits structural economic features, such as the energy intensity of the economy, CO2 emissions per capita or per GDP unit, and CO2 emissions from industrial sources. This choice is informed by insights from Skovgaard et al.'s (2019) cluster analysis study, which found no evidence that these factors influence the adoption of carbon pricing mechanisms. Additionally, their research guided the decision to employ the Left-Right spectrum, focusing solely on the level of support for government intervention in the economy. The authors' analysis concluded that the Left-Right cleavage, in its general form, played a minor role in identifying patterns.

In the same way, variables about industry as a percentage of the GDP and trade openness were not included because Dolphin, Pollitt, and Newbery (2019) did not find their relation to be significant to the implementation of carbon pricing. The authors also found no statistical evidence suggesting that Left-wing governments are more predisposed to adopt

carbon pricing policies. This aligns with the research's design choice to utilize the Left-Right divide, emphasizing government intervention.

A feature for proportional/majoritarian electoral systems was not added because the features relating to the percentage of votes for green parties and the presence of green parties in cabinet already captures the possible effects of the electoral systems on the ecological parties. Regulatory control and public belief in climate change were excluded from the research because they are highly correlated with the level of democracy (Levi; Flachsland; Jakob, 2020). Additionally, polls containing information on the importance of climate change to citizens or their awareness of the climate crisis were also not incorporated because of their patchy and often inconsistent nature (Bothner et al., 2022).

4.3 Datasets

The main databases used in this research were: RemDem (Hellstrom et al., 2023); ParlGov (Doring; Huber; Manow, 2022); World Carbon Pricing (Dolphin; Xiahou, 2022); Carbon Pricing Dashboard (World Bank, 2023); Mass Mobilization Protest Data (Clark; Regan, 2016); and CHES (Jolly et al., 2022).

The RepDem database (Hellstrom et al., 2023) is a project hosted by the Swedish University of Umeå. It contains information about, mainly European, parliamentary democracies from 1945 to 2023. It contains information on governments, parliaments and political parties. Similarly, the ParlGov database (Doring; Huber; Manow, 2022) also contains information about European political parties and cabinets in parliamentary democracies, with the difference that it also records the election results.

The World Carbon Pricing database (Dolphin; Xiahou, 2022) compiles information related to carbon pricing in 198 jurisdictions and 94 subnational jurisdictions, from 1990 to 2020. It focuses on pricing instruments whose design is directly related to the carbon content. Hence, it excludes energy taxes and duties, as well as taxes on other greenhouse gasses. Consequently, Spain is not included, since its taxation on greenhouse gasses only covers fluorinated gasses (Dolphin; Xiahou, 2022).

All pricing data is standardized to US dollars and adjusted to have 2019 as the base year. As the database segregates data to sectors according to the IPCC 2006 sectorial desegregation, it pays special attention to sectorial rebates and exemptions (Dolphin; Xiahou, 2022). The measurement of carbon price stringency utilized in this database is the Emissions-weighted carbon price (ECP). This metric is obtained by combining sector or sector-fuel-level coverage and price information to calculate the economy-wide ECP

(Dolphin; Pollitt; Newbery, 2019).

The ECP is an important metric as it addresses the potential discrepancy between a jurisdiction's high carbon price and limited coverage, or vice versa, providing a more accurate representation of a country's actual efforts related to carbon pricing (Dolphin; Pollitt; Newbery, 2019). For instance, Ukraine, not included in this research, had a carbon tax in 2020 with over 80% coverage but priced at only 0.38 dollars per carbon ton, resulting in an ECP of 0.26 dollars per carbon ton. In contrast, Switzerland, also excluded from this research had a high carbon tax rate of 99.44 dollars per carbon ton, but a coverage of around 20%, yielding an ECP of 19.88 dollars per carbon ton. Meanwhile, also in 2020, France had a carbon tax rate half of the Swiss, but three times the coverage, resulting in an ECP of 30.13 dollars per carbon ton.

The Carbon Pricing Dashboard (World Bank, 2023) aggregates the information from the “State and Trends of Carbon Pricing" reports from the World Bank. This database displays the price, coverage, and revenue of emission trading systems and carbon taxes around the world. Contrary to the World Carbon Pricing database (Dolphin; Xiahou, 2022), it shows the information around carbon pricing mechanism and not jurisdiction, and it does not offer sectoral information.

The Mass Mobilization Protest Data (Clark; Regan, 2016) covers 162 countries between 1990 and 2020. For each protest event, the project records protester demands, the scale of protests, their locations, and protester identities. The database's four primary sources are: New York Times; Washington Post; Christian Science Monitor; and Times of London.

The CHES database (Jolly et al., 2022) estimates party positioning on European integration, ideology and policy issues for national parties in a variety of European countries. It relies on expert opinions surveyed about their respective countries' political parties. The first survey was conducted in 1999, with subsequent waves in 2002, 2006, 2010, 2014, 2019. The number of countries increased from 14 Western European countries in 1999 to 24 current or prospective EU members in 2006 to 31 countries in 2019.

4.4 Final considerations

This chapter had the important task to present the methodology employed in this study. It commenced with a methodological overview, introducing the hypothesis, target variable, features, and the chosen method. A dedicated topic delved into the decision tree model, it showed its advantages such as having an easy interpretability, being more flexible with its data assumptions, the possibility of adding weights to different categories to correct

imbalances in the data frame, and having the ability to predict on unseen data. The topic also explains the risks of *overfitting*, where the model is excessively complex, leading to poor generalization on unseen data, and *underfitting*, characterized by a low accuracy rate.

The general structure of decision tree models and different metrics for the model to split the data were also discussed, with the more common metrics being the Gini index and minimizing Entropy. Subsequently, the topic explored techniques aimed at enhancing the model's adaptability to unseen data. Pre-pruning, post-pruning, data pre-processing being the main techniques to improve the model's accuracy and p-value. The discussion also touched upon different techniques for splitting training and testing data, the Leave-One-Out Cross-Validation appeared the best and most useful for small datasets.

The next topic presented the target variable and the features in more detail. It provides insights into the rationale behind the selection of each feature, how they were constructed, and justifies the chosen approach. Additionally, it discusses the exclusion of certain cabinets or entire countries based on geographic and timeframe limitations inherent in the primary datasets. This topic concludes with an explanation on the methodological reasons to exclude some potential features from the research. Finally, the chapter ends with a brief overview of the main dataset used.

5 A DECISION TREE FOR CARBON TAXATION IN EUROPE

Several decision tree configurations were attempted to produce the classification tree with the highest accuracy rate and the lowest p-value, while avoiding *overfitting*. The sensitivity of the model to each individual category was also considered. This analysis was done using the RStudio program and the language R. The following packages were used: *tidyverse*; *ggplot2*; *DataExplorer*; *rpart*; *caret*; *rpart.plot*; *and DMwR*. To ensure transparency and replicability, all the code scripts files and datasets used to create the models, as well as, all the confusion matrices, decision tree plots, and feature importance plots, are available in this study's GitHub repository[35].

Due to the small size of the data frame, 241 cases, to divide the training set from the test set, following the example of Li and Wong (2002), it was used the Leave-One-Out Cross-Validation. Pruning conditions were defined as a maximum tree depth, the length of the longest path from the root to a leaf, of 5 and the minimum number of observations for a terminal node of 1. These criteria were defined after several attempts to find a balance between a model with good accuracy and p-value, without making the classification tree overly complex and possibly overfitted. Due to the unbalance between the categories of the target variable[36], weights were added to the model. The weights for each category were based on the frequency of each category in the data frame[37].

Cabinets with Emissions-weighted carbon taxes lower than one dollar were considered as if they did not have a carbon tax. This was done for two reasons, first an Emissions-weighted carbon tax of less than one dollar is largely a symbolic tax, and because the value is so low one cent variations could pass the 10% threshold. To illustrate, if Estonia's carbon tax increased from 0.02 dollars to 0.03 dollars, this would be a 50% increase. This criteria affected cabinets in Poland, Estonia, and Latvia, with the highest Emissions-Weighted carbon tax in this group being Latvia's at 0.44 dollars.

All successful decision tree models, defined as those with an accuracy rate higher than the no information rate and a p-value lower or equal to 0.01, were displayed. Each model was presented along with their corresponding accuracy rate and p-value, accompanied by visual representations of the decision tree and the feature importance plot.

The first classification tree constructed included all the categories and all the features mentioned in the "Target variable and features" topic. Regrettably, the model exhibited an

[35] https://github.com/ChristianAlmBran/A-Decision-Tree-model-for-Carbon-Taxation-in-Europe
[36] Decreased: 9 cases. Increased: 20 cases. No tax: 173. Same: 30. Tax created: 8.
[37] Decreased: 0.1111. Increased: 0.05. No tax: 0.00578. Same: 0.03333. Tax created: 0.125.

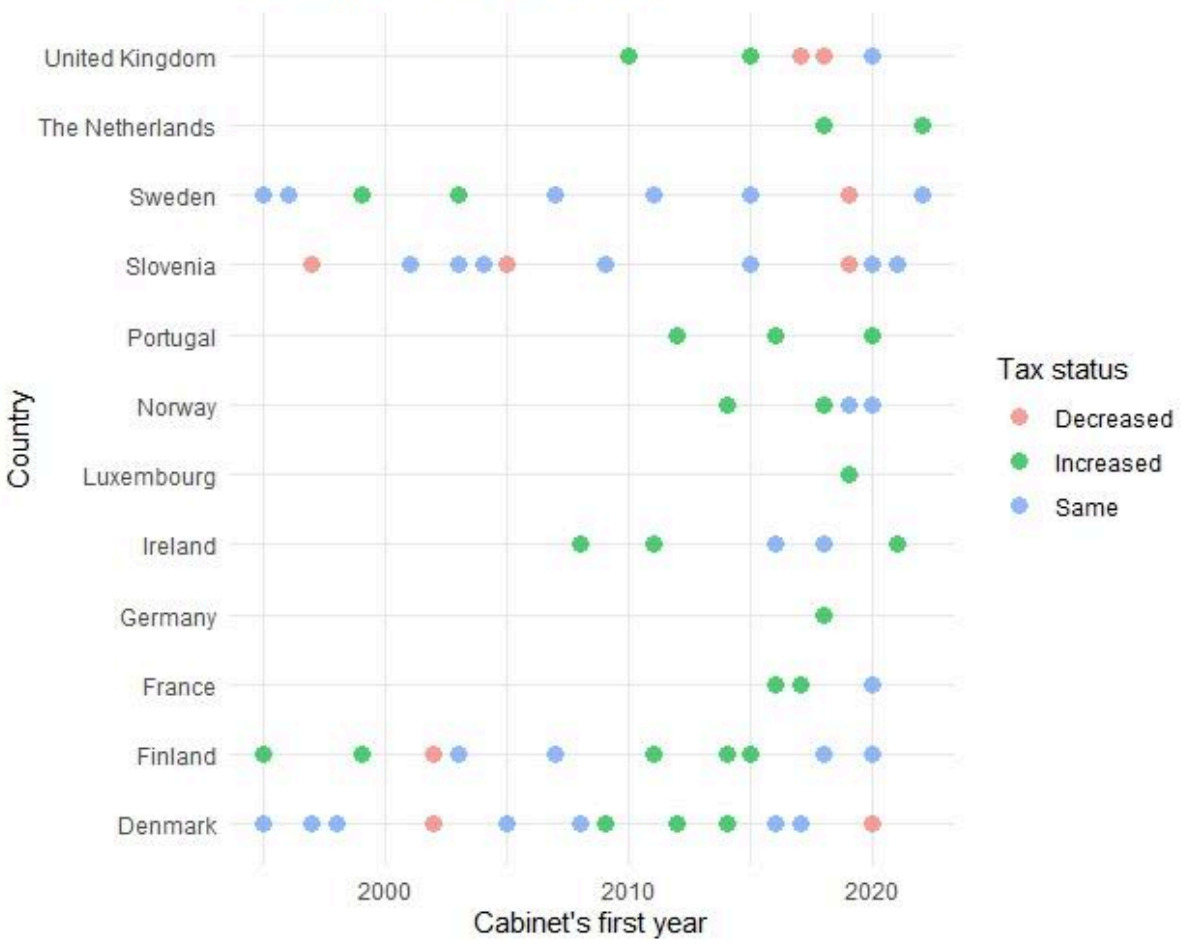
accuracy rate of 0.5917, falling below the no information rate of 0.7208. This implies that the model would have been more accurate if it had always chosen the majority class. The p-value was very high, 1. Despite correctly classifying over 87% of the "Decreased" and "Tax created" categories, its predictions were less reliable for the "Increased" class (35%), "No tax" (approximately 56%), and "Same" (about 76%) categories.

In an attempt to improve the model, a feature selection was done by testing various combinations of features to assess potential improvements in metrics. Unfortunately, this was unsuccessful as in the majority of the attempts the accuracy rate actually decreased. In both cases, the models were done one time with Entropy and another with Gini Index as the impurity measure, yet no discernible improvement in performance was observed.

To circumvent this challenge, the analysis was divided in two. One classification tree model for cabinets with a carbon tax already in place, with the categories: “Increased”; “Decreased”; and “Same”. The second classification tree model was dedicated to cabinets without the tax and those which created the tax, with the categories: “No tax”, and “Tax created”. On forward, the first classification tree will be referred to as the tax variation tree, and the second, the tax creation tree.

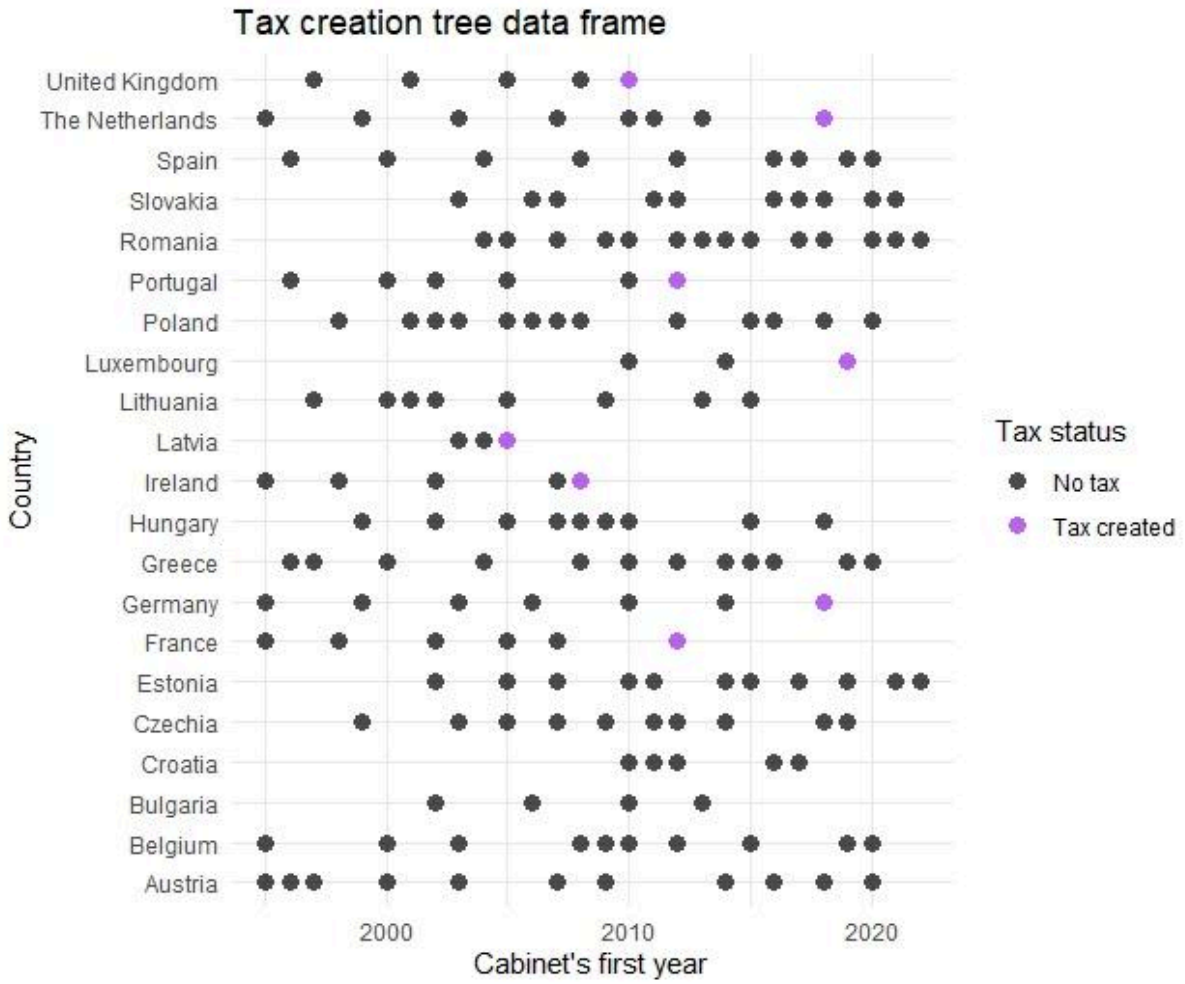
The tax variation trees data frame encompasses 12 countries, predominantly from Western Europe. Conversely, the tax creation trees data frame includes 21 countries, with notable exclusions such as the Nordic countries due to the research’s temporal constraints. Both datasets are visualized in the scatter plots below:

Figure 6 - Tax variation trees data frame



Source: own elaboration.

Figure 7 - Tax creation trees data frame



Source: own elaboration.

The last topic of this chapter presents classification trees with alternative parameters, such as changing the variation threshold from 10% to 5%, or including Emissions-weighted carbon taxes with rates lower than one dollar. These models, including their decision tree plots and feature importance plots, were also analyzed and compared with the main decision tree model of the previous topic. To summarize, a table detailing the key statistical metrics of all the models was provided.

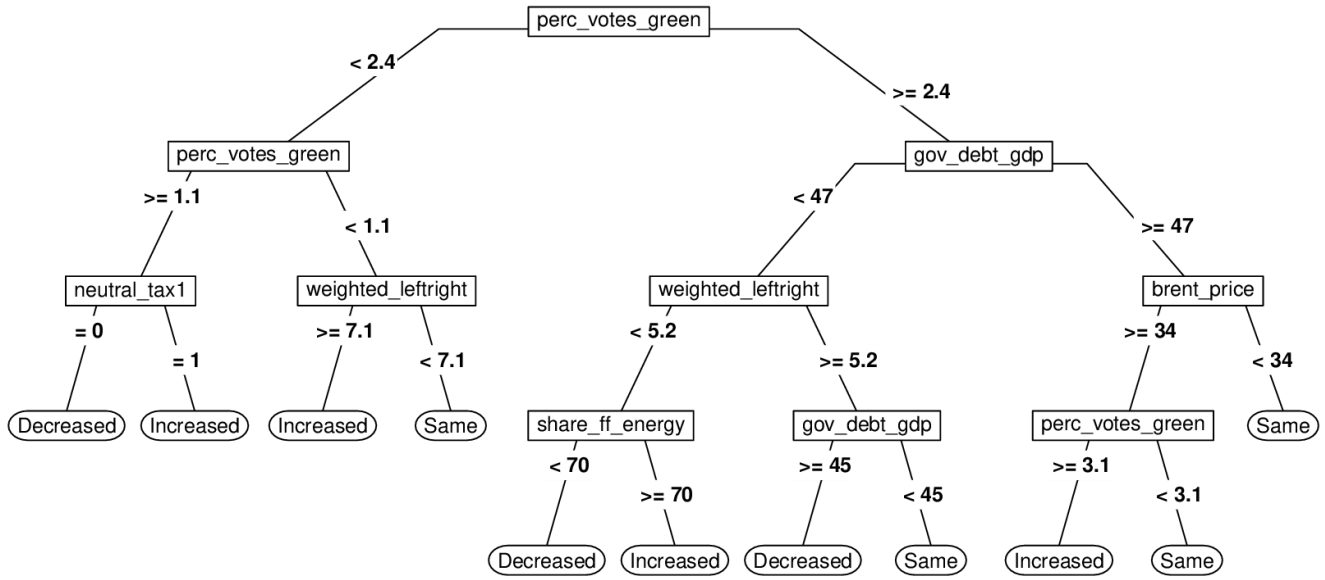
5.1 Tax variation tree

First, it was performed a tax variation tree containing all the features[38]. The weights were modified to account for the new frequency[39] of the categories[40]. This model's accuracy

[38] Referred on table 6 as: TV-AF.
[39] Decreased: 0.1111. Increased: 0.0385. Same: 0.03333.
[40] Decreased: 9 cases. Increased: 28 cases. Same: 30 cases.

rate was 0.8308, which was much higher than the no information rate of 0.4615. Additionally, the p-value was remarkably low, measuring 8.741e-10. The model's sensitivity for each category was high, with the "Decreased" class rating at 1 and the other two classes with scores higher than 0.80.

Figure 8 - Tax variation tree with all features



Source: own elaboration.

This decision tree provides intriguing insights. The selection of the percentage of votes for the green party as the feature for the root node emphasizes its significance. The root node, serving as the initial condition deemed most informative by the model's algorithm, underscores the importance of this feature in distinguishing between various classes or outcomes.

It can also be observed that in cabinets where the green parties had a low share of the previous election votes, the revenue destination of the carbon tax played an important role. If the revenues were sent to the general budget or green projects, the tax would be decreased. However, if the revenues were earmarked for tax cuts or rebates, the tax would increase. This highlights the difficulty for a cabinet to reverse the tax cuts or end the rebates if it wished to reduce the carbon tax. A similar situation happened in Australia when it abolished its carbon tax and the government had to maintain the rebates and tax cuts as if the tax was still in place (Crowley, 2017).

Continuing on the left side of the tree. In cabinets, where the green parties had a low share of the previous election votes, being Right-wing—cabinets advocating for a reduced

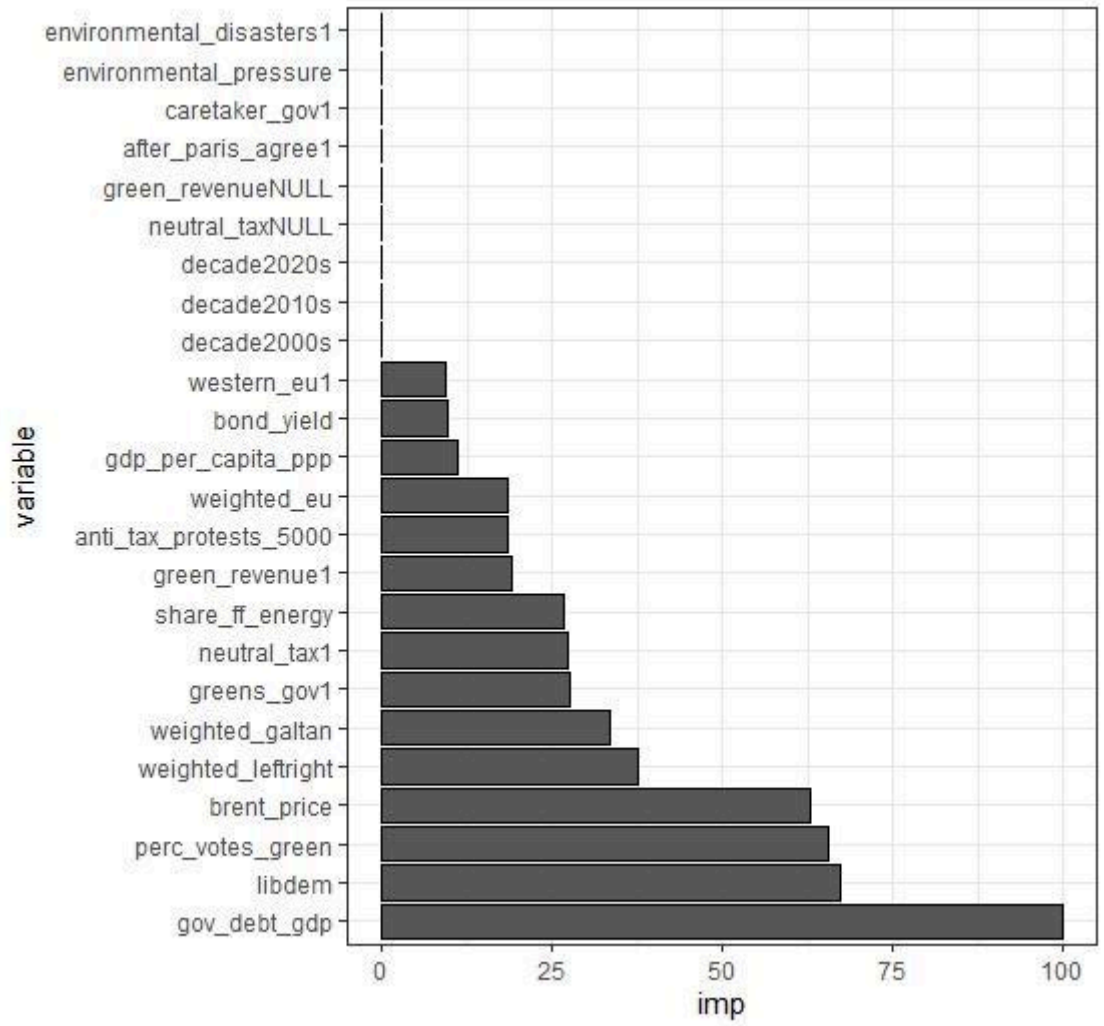
government role—does not prevent the increase of carbon taxes rates. This situation can be illustrated by the "Passos Coelho I" cabinet, which was the second most Right-wing cabinet to rule Portugal since 1995, and created the Portuguese carbon tax. This cabinet was marked by austerity, and the carbon tax was seen as a way to decrease taxes on labor income without adversely affecting the national budget (Bothner et al., 2022).

On the right side of the tree, cabinets presiding over countries with higher than 47% government debt by GDP[41], have not decreased their carbon taxes, which may be an indication of these taxes' significance to government budgets. Corroborating with this assessment, the majority of the decreases appeared in cabinets with a low government debt by GDP. The share of fossil fuels in energy consumption also appears to play a role when the green parties had a stronger presence in the last election, the government debt by GDP is low, and the cabinet is center or Left-wing. The inclination to increase the tax rate when fossil fuels in energy consumption surpass 70% may indicate a government's commitment to drive the decarbonization of its economy. A stronger electoral performance of green parties[42] also appears to lead to an increase on the carbon tax rate, when the government debt by GDP is higher than 47%, even if the Brent price is higher than or equal to 34 dollars.

[41] As a reference, the European Union's Stability and Growth Pact Agreement establishes the ceiling for public debt at 60% by GDP. Although the general government gross debt to GDP ratio in the EU was 84% in 2022: https://ec.europa.eu/eurostat/documents/2995521/16349859/2-21042023-BP-EN.pdf/282de4e3-e6f2-0571-a5da-6eb8391788f5

[42] As a reference, the highest share of the vote for green parties in the data frame was 14.8%, while the mean was 3.25%. More information can be found in the descriptive statistics annex.

Figure 9 - Feature importance plot: tax variation with all features



Source: own elaboration.

This plot illustrates the significance of each feature in influencing the model's decisions and predictions. The feature importance plots were generated using the Mean Decrease in Gini (MDG) metric. MDG measures the average change in the Gini impurity before and after randomly shuffling a feature's values. Features with higher MDG scores contribute more significantly to the model's ability to make accurate predictions, making them more important for the overall model performance.

Interestingly, environmental disasters and environmental pressure did not seem to influence the model. On the other hand, all the ideological variables played a role in the model's performance, specially the Gal-Tan and the Left-Right cleavages. Although they were not as important for the model as the level of debt, the score of liberal democracy, the percentage of votes for green parties in the last election, and the price of the Brent.

Curiously, GDP per capita (PPP) had a limited relevance in the model's prediction,

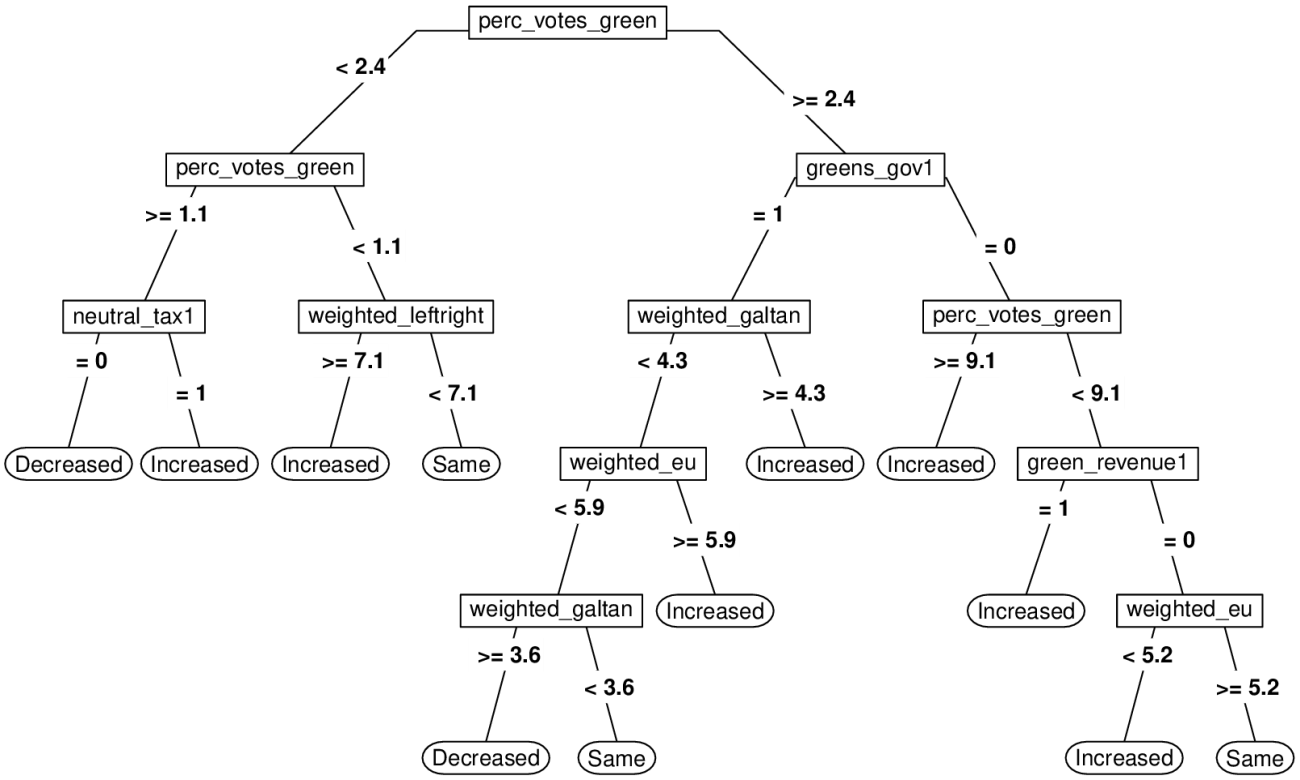
despite existing studies suggesting a correlation between GDP per capita and environmental protection (Castiglione et al., 2014). This divergence may be caused by the other ways available to fight climate change and protect the environment, such as the introduction of subsidies, that do not have to be implemented with a carbon tax.

It is noteworthy that the protest feature did not significantly impact the model. This may indicate that protests like the "gilets jeunes", capable of halting carbon price increases, might be a phenomenon restricted to France. In this research's data frame, while France only represented 3.6% of the total number of cabinets, it accounted for 16% of the recorded protests against tax policy changes. Eight out of the nine French cabinets experienced such protests.

To improve the model's prediction capabilities, it was performed a feature selection, where several combinations of features were tested[43]. In this second decision tree focusing on price variation, only features related to ideological cleavages, green parties' participation in the government, their vote shares in the last election, and the revenue use of the carbon tax were utilized. The accuracy rate of this tree improved to 0.8615, while the no information rate was 0.4615, and the p-value was 2.201e-11. Although the sensitivity for the "Decreased" class decreased to 0.7778, the sensitivity for the other two classes improved.

[43] Referred on table 6 as: TV-SF.

Figure 10 - Tax variation tree with selected features



Source: own elaboration.

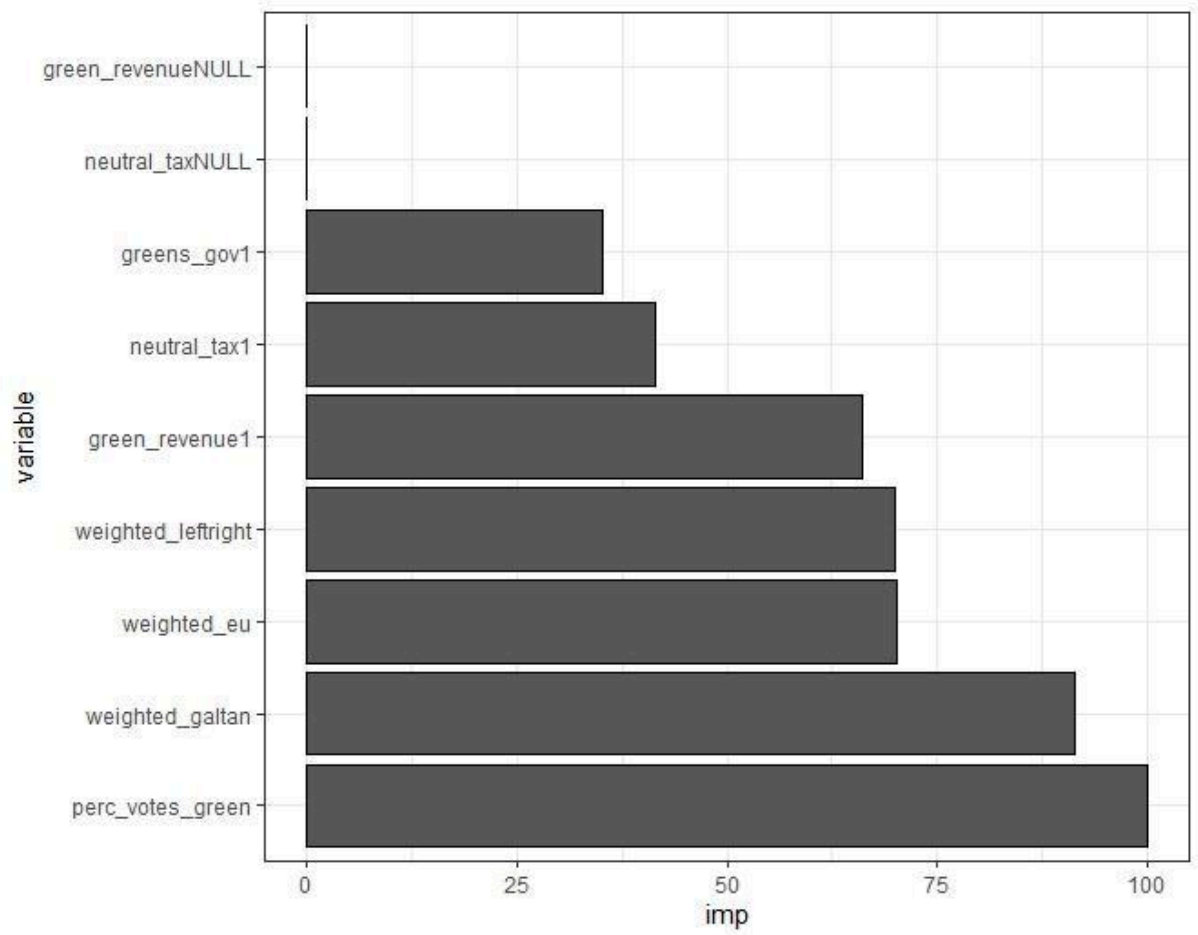
It is interesting to note that, even after the feature selection, the Left side of the tree remains the same. On the right side, the existence of a green party in the cabinet further branches the tree. The presence of a green party in the cabinet seems to influence the center and more on the Tan side of the ideological spectrum to increase the carbon tax rate. A possible example of this is the “Cowen I” cabinet in Ireland. This cabinet had a Gal-Tan score of 6.71 and had a green party in its composition. It introduced the carbon tax not solely to boost government revenue, but also in response to the green party's ultimatum to exit the coalition if the tax was not introduced (Bothner et al., 2022).

Conversely, the presence of a green party in cabinet does not seem to prevent decreases in carbon taxes if the cabinet is more inclined to the Gal side and does not fully support the European Union. However, it's important to note that these reductions occurred during the COVID-19 pandemic. Whether these changes are related to the pandemic, and the extent to which the green parties in the coalition were constrained, require further investigation. More research on the effects of the pandemic on carbon taxes prices is necessary before conclusions can be drawn.

A high percentage of votes received by green parties in the last election seems to

promote an increase in the tax rate, even if the green parties are not in the governing coalition. This suggests that the cabinet parties are responding to the electoral success of green parties. Furthermore, directing the revenues towards green investments seems to lead to an increase in the tax rate, even without a green party in government, and a lower electoral performance of green parties. Interestingly, cabinets that do not fully support the European Union and are not particularly affected by the green parties, still increased the carbon tax. Indicating that none of those two factors are a necessary condition for carbon tax rates to increase.

Figure 11 - Feature importance plot: tax variation tree with selected features



Source: own elaboration.

As expected from the feature selection, the feature importance plot shows that all features had an impact on the model's performance. Notably, while the percentage of green parties share of the vote in the last election was the most relevant feature for the model, the green parties' participation in the cabinet was the least important. The same difference in relevance can be observed in figure 7. All the ideological features were among the most relevant for the model, with the Gal-Tan cleavage being the most influential of the three.

5.2 Tax creation tree

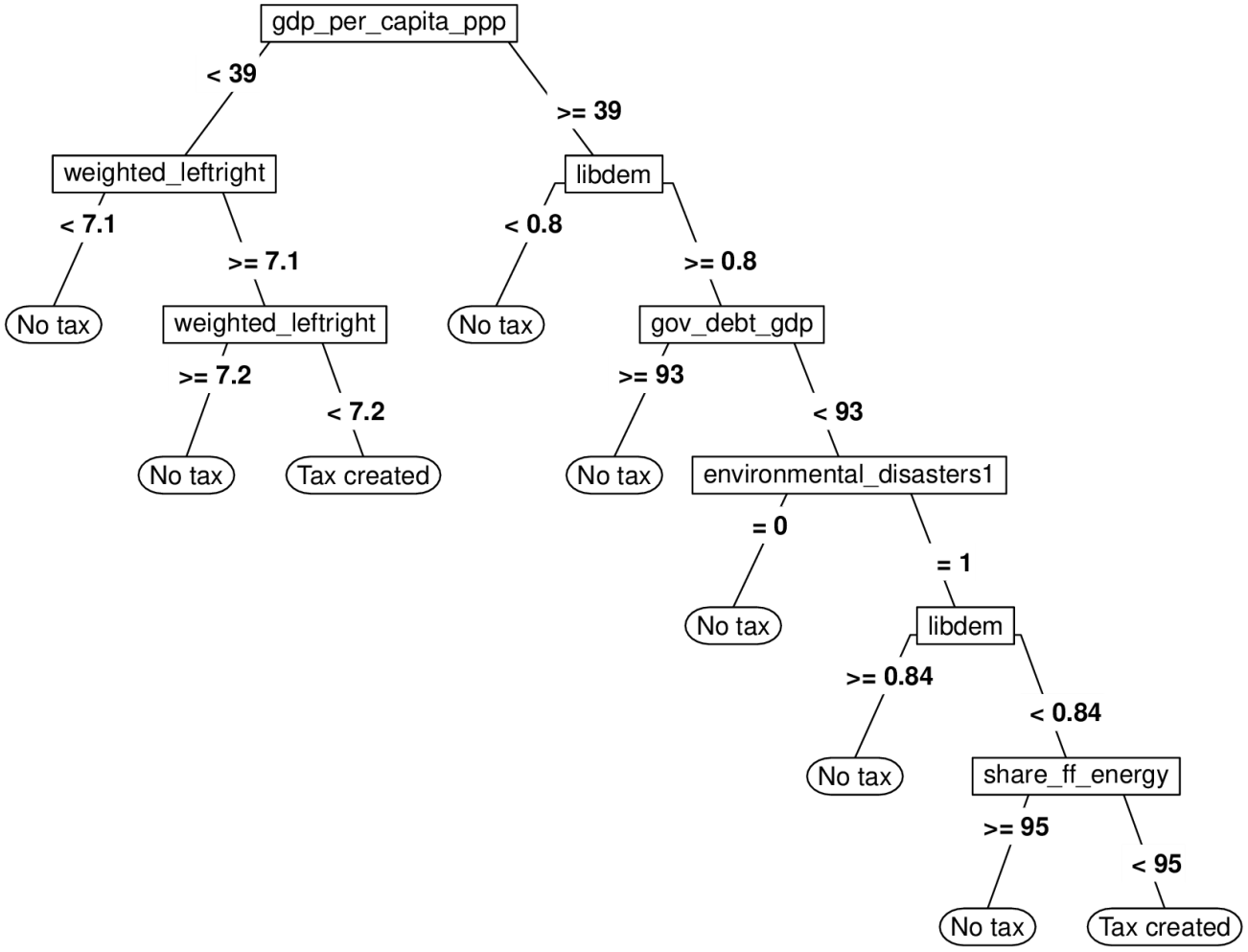
The first tax creation tree was constructed with all the features. The weights were adjusted to the new frequency[44] of the categories[45]. This model's accuracy rate was 0.9834, which was higher than the no information rate of 0.9558, and had a relatively high p-value of 0.03923. Although the accuracy rate was higher than no information rate, the confidence interval (95%) lower band (0.9523) fell below the no information rate.

To improve this model, three strategies were deployed: feature selection, oversampling, and relaxing the tree depth criteria. Feature selection, previously applied in the decision tree models, involves evaluating and choosing feature subsets based on model performance. Oversampling, attempted through the SMOTE method, aims to artificially boost the minority class by generating synthetic data points. Lastly, the relaxation of the depth criteria allowed the three to reach the depth 6. While the first two strategies proved ineffective, the third succeeded in improving the model's performance.

The tax creation tree, using all features and a depth of 6[46], had an accuracy rate of 0.9945. This was higher than the no information rate of 0.9558, even when taking into account the confidence intervals. The p-value was 0.00262, which meets the 0.01 criteria.

[44] No tax: 0.00578. Tax created: 0.125.
[45] No tax: 173. Tax created: 8.
[46] Referred on table 6 as: TV-AF-D6.

Figure 12 - Tax creation tree plot with all features and depth of 6



Source: own elaboration.

At first sight, it's noteworthy that the root node does not feature the percentage of votes for green parties in the last election, unlike the previous decision tree models. The GDP per capita (PPP) demonstrates the different dynamics of carbon tax creation in countries with different economic conditions. In countries with a GDP per capita (PPP) lower than 39 thousand dollars, the cabinet being Right-wing seems to promote the creation of a carbon tax. Two countries exemplify this phenomenon, Portugal with the “Passos Coelho I” cabinet, and the United Kingdom with the “Cameron I” cabinet. Both cabinets were marked by austerity measures, with their respective governments committed to reducing the public debt. This may be an indication that under such conditions, Right-wing cabinets, unless extreme, may be willing to create a carbon tax.

On the right side of the decision tree, it seems that, for wealthier countries, the conditions for the creation of a carbon tax are to have a strong liberal democratic system in place, not have a crippling amount of debt, experience a natural disaster occur during the

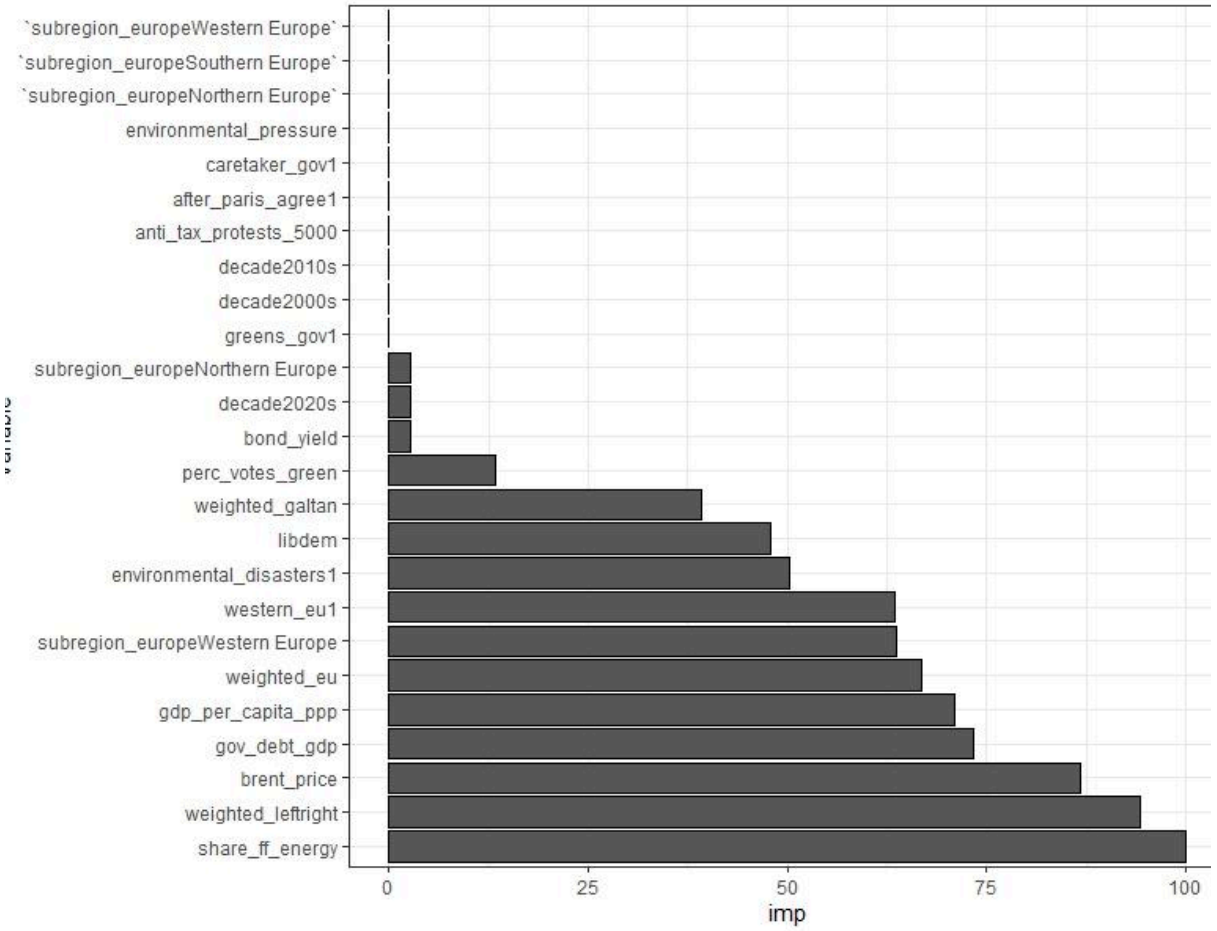
cabinet's tenure, and not being completely relying on fossil fuels for energy consumption. The apparent restriction for cabinets in countries with a "libdem" score higher than or equal to 84% can be exemplified by the case of Germany. Almost all of Germany's cabinets, with one exception, scored higher or equal to than 84%, and interestingly, the one cabinet that scored lower, "Merkel IV", was the cabinet that created the German carbon tax.

The implementation of the tax maybe less correlated with the state of the liberal democracy in Germany, and more associated with a concealed, country specific factor: the German public's resistance to nuclear energy. One of the main arguments against a carbon tax in Germany was that it would benefit the nuclear energy sector (Harrison, 2010), since it does not produce carbon emissions. However, by the "Merkel IV" cabinet, the shut-down of the remaining nuclear power plants in Germany was a given[47]. In sum, the end of nuclear power, rather than a decline in the liberal democratic system, could have paved the way for the creation of a German carbon tax.

Decision tree models are programmed to find patterns in the data and attempt to make predictions based on those patterns. The correlations the model identifies may be spurious and must be interpreted with the literature assumptions in mind. Decision tree models can also provide interesting insights to be further researched and later confirmed or dismissed by researchers.

[47] The shut-down of all nuclear reactors in Germany was scheduled to the end of 2022, this was extended in one year due to the energy crisis caused by Russia's war of aggression against Ukraine: https://bit.ly/3HlPRJd.

Figure 13 - Feature importance plot: tax creation tree with all features and depth of 6



Source: own elaboration.

The feature importance plot shows that although all the ideological features were relevant for the model, with the Left-Right cleavage standing out as the second most influential. Notably the feature relating to greens in government was not relevant for the model, showing that although in some cases the green party was essential to the tax implementation, as in the Irish case (Bothner et al., 2022), it certainly is not a necessary condition for the creation of a carbon tax. Additionally, the protest feature was not considered very relevant for the model, as was the case in the tax variation trees. This indicates that either public opposition in the form of protests is ineffective or is a rare occurrence.

It is also interesting that the occurrence of environmental disasters are related with the implementation of a carbon tax, but the environmental pressure is not. As the environmental pressure feature was constructed using the compliance, or lack of compliance, to internationally agreed emissions' reduction targets, it may indicate that European countries are achieving their emissions targets. This can be, either because of a lack of ambition for the targets, or because countries are implementing other policies, such as renewable energy

subsidies or investments in energy efficiency to reduce their emissions. It can also be the case that lower than expected economic growth led European countries to more easily achieve their climate objectives.

It is important to highlight that in the research's data frame, only eight cabinets are recorded as having created a carbon tax. All the cabinets that implemented carbon taxes on the first wave, as well as, cabinets in countries like Iceland and Ukraine, were not included due to the temporal and scope limitations of the CHES (Jolly et al., 2022) and RepDem (Hellstrom et al., 2023) datasets. In summary, out of the 18 current carbon taxes in Europe as of 2023, only the implementation of 8 of them was captured in this research.

5.3 Robustness

A tax variation tree with all the features, using a 5% variation threshold was also tested. The categories' weights[48] were changed to reflect their new frequency[49] in the model. This model had a low accuracy of 0.6, with a no information rate of 0.5077, and a p-value of 0.08588. Interestingly, it predicted correctly all the cabinets in the "Increased" class, but got wrong all cases in the "Same" category. The decision tree generated by the model with a 5% threshold had only the root node, featuring the "western_eu" attribute. It then split the tree into two branches, predicting that if a cabinet was in Western Europe, the tax would increase, and if it was in Eastern Europe, it would decrease. Though the feature importance plot it was possible to observe that the model used other four features, none of them were the ideological-related features.

A tax variation tree with all features, including carbon taxes with Emission-weighted rates lower than one dollar, and using the 10% threshold was also tested. The categories' weights[50] were changed to reflect their new frequency[51] in the model. The model presented a good accuracy rate (0.8416) in comparison with its no information rate (0.4851), and a very small p-value (9.386e-14). It also performed well in the "Decreased" and "Same" classes, while the sensitivity for the "Increased" category was 0.75.

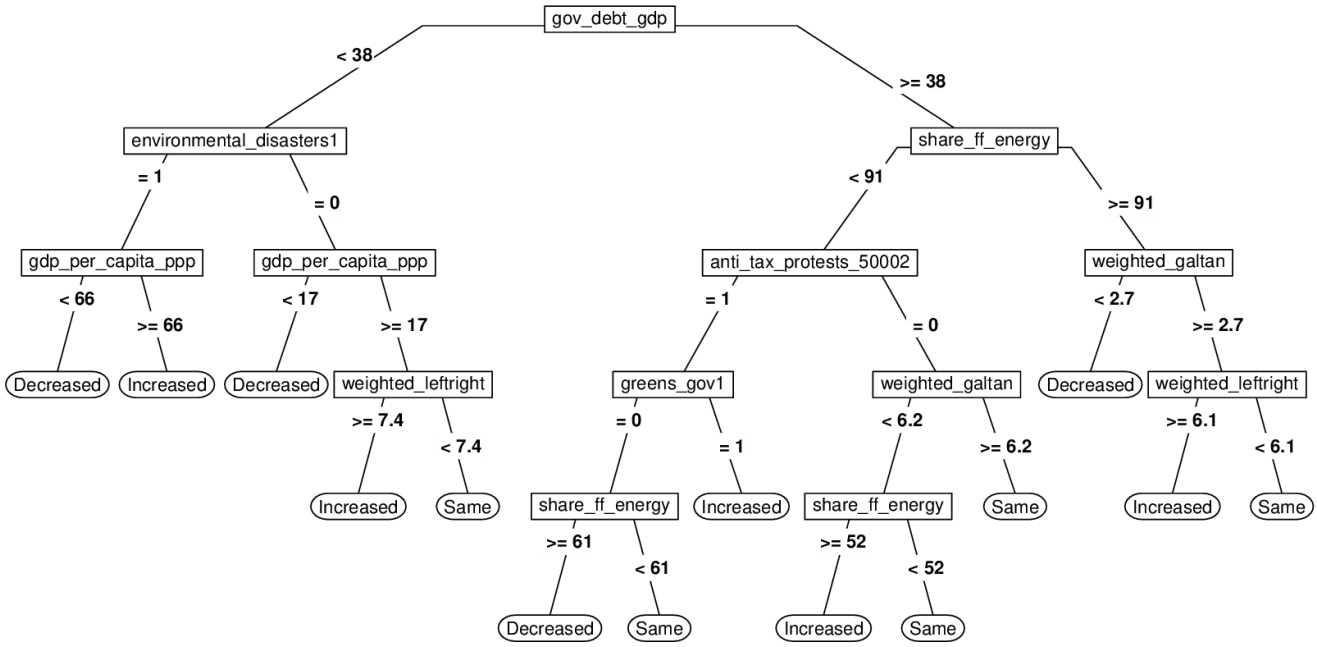
While the statistical metrics appeared promising, a closer examination of the decision tree plot revealed indications that the model likely overfitted to the data. The decision tree plot was so complex that, even using the whole A4 page in the vertical position, it was not possible to adequately visualize its information. Furthermore, the tree structure included 20

[48] Decreased: 0.0667. Increased: 0.0303. Same: 0.0588.
[49] Decreased: 15 cases. Increased: 33 cases. Same: 17 cases.
[50] Decreased: 0.0625. Increased: 0.0278. Same: 0.0204.
[51] Decreased: 16 cases. Increased: 36 cases. Same: 49 cases.

leaf nodes, whereas, for reference, the decision tree plots presented thus far in this research had 9, 11, and 12 leaf nodes. Although a decision tree with 20 leaf nodes may not be uncommon on big data frames, on small samples as in this research, it is an indication of *overfitting*. To ensure transparency, this plot, together with the feature importance plot and the model's confusion matrix, are available in this study's GitHub repository[52]

Attempting to solve this overfitting issue, a similar decision tree model was constructed, with the sole modification being that the minimum number of observations for a terminal node was increased to 2[53]. This change, although, reduced the model performance, made it less prone to *overfitting*. The accuracy rate for this decision tree model was 0.7525, higher than its no information rate of 0.4851. The model's p-value was 3.813e-08. It achieved perfect sensitivity in the "Decreased" class, a 0.7551 in the "Same" category, but exhibited a comparatively lower performance in the "Increased" category (0.6389).

Figure 14 - Tax variation tree plot with all features, including carbon taxes with Emission-weighted rates lower than one dollar, and minimum number of observations of a terminal node of 2



Source: own elaboration.

Observing the left side of the decision tree, in cabinets with a government debt to GDP lower than 38%, the occurrence of environmental disasters coupled with the country's GDP per capita (PPP) seems to predict the cabinet's actions towards the carbon tax. On the right

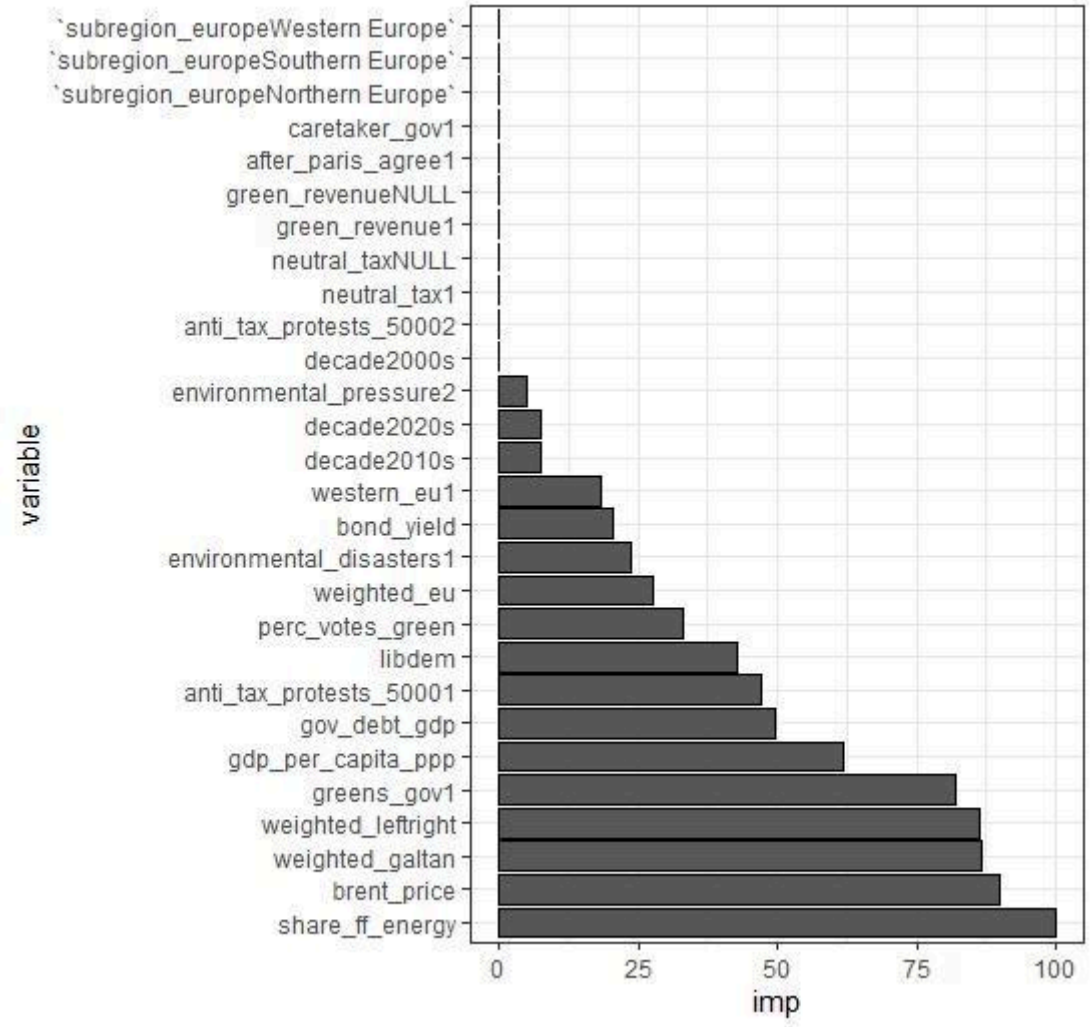
[52] https://bit.ly/3HpQykw
[53] Referred on table 6 as: TV-AF->1-M2.

side, in countries with a very high fossil fuels share in the energy consumption, the Gal ideology of the cabinets does not prevent it from decreasing the carbon tax. This can be illustrated by the "Belka" cabinet in Poland, which had a very low Gal-Tan score (1.55), and still decreased the Polish carbon tax. Although this should be taken with a grain of salt, as the tax was reduced from 0.01 to 0.00[54].

Further down this branch of the tree, the prediction that Right-wing cabinets would raise the tax, while other cabinets would maintain it, aligns with the findings from the initial decision tree model presented in this study (tax variation tree with all features). In cabinets where the government debt-to-GDP ratio exceeds 38%, fossil fuel share in energy consumption is below 91%, and no anti-tax policy change protests have been recorded, the participation of the green party in the cabinet appears to influence the cabinet to increase the tax rate. When the lack of protests can not be confirmed, the Gal-Tan ideological position and the proportion of fossil fuels in energy consumption seems to play a bigger role. This can indicate governments that care about the environment and are trying to diminish the reliance on fossil fuels in their economies.

[54] The Polish emission-weighted carbon price, while not precisely zero, was in proximity to zero, leaning more towards zero than one cent. As part of the rounding procedure, it was ultimately rounded down to zero.

Figure 15 - Feature importance plot: tax variation tree with all features, including carbon taxes with Emission-weighted rates lower than one dollar, and minimum number of observations of a terminal node of 2



Source: own elaboration.

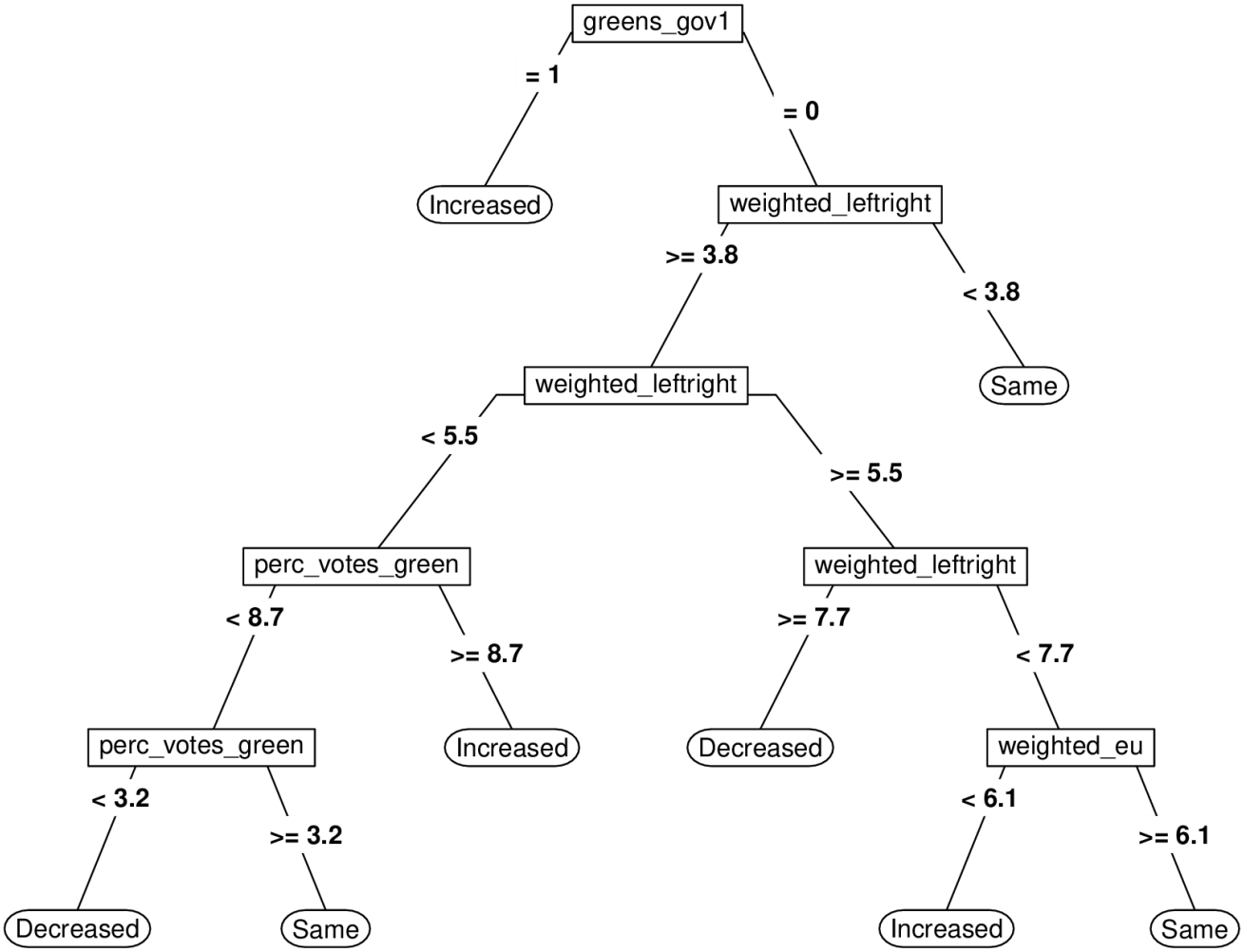
Examining the feature importance plot revels that all ideological variables were relevant to the model, although the Gal-Tan and the Left-Right cleavages were more important than the Anti-Pro EU divide. Notable differences between this plot and the feature importance plot for the tax variation tree with all features are a higher importance for the share of fossil fuels in energy consumption, and the presence of green parties in cabinet. On the other hand, this model attributed less relevance for the features related to the score of liberal democracy, the share of green parties votes in the last election, and the tax revenue's destination.

The last model implemented was a tax variation tree with selected features, including carbon taxes with Emission-weighted rates lower than one dollar[55], using the 10% threshold.

[55] Referred on table 6 as: TV-SF->1.

This model had a lower accuracy rate (0.6535) than the last two presented models, but it was higher than the no information rate (0.4851). Its p-value was at 0.0004791. The model had a good sensitivity for the “Increased” class, more than 0.80, but performed poorly for the other two categories, less than 0.60.

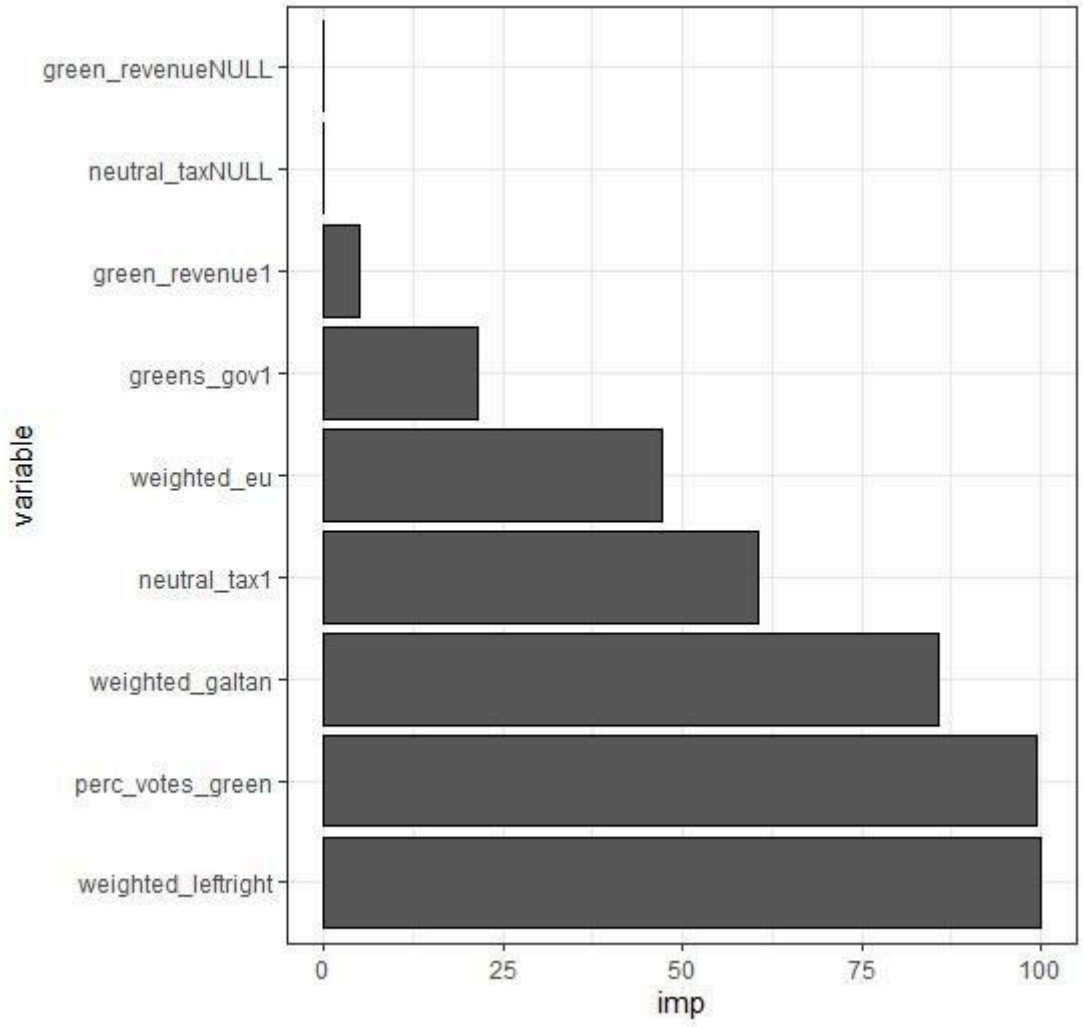
Figure 16 - Tax variation tree plot with selected features, including carbon taxes with Emission-weighted rates lower than one dollar



Source: own elaboration.

In this decision tree plot, the presence of a green party in the cabinet seems to predict an increase in carbon tax rates. Progressing down the tree, when cabinets are not Right-wing, the performance of green parties in elections is the predictor for variations in the tax. On the other hand, a high score in the Left-Right cleavage predicts that the cabinet will decrease the tax, while a Right-wing, but not extreme, cabinet would only increase taxes if it did not strongly support the European Union.

Figure 17 - Feature importance plot: tax variation tree with selected features, including carbon taxes with Emission-weighted rates lower than one dollar



Source: own elaboration.

Observing this plot, it is interesting to note that, following the same patterns as the tax variation tree with selected features, the green parties' presence in cabinets is less relevant than their share of the votes in the previous election. Additionally, it's noteworthy that in this model, the tax's revenue-neutral nature holds more significance for predictions compared to the allocation of revenue to green investments.

In the table below, a statistical summary of the decision tree models presented in this research is provided:

Table 6 - Statistical summary

Statistic	TV-AF[56]	TV-SF[57]	TC-AF-D6[58]	TV-AF->1-M2[59]	TV-SF->1[60]
Accuracy rate	0.8380	0.8615	0.9945	0.7525	0.6535
No Information rate	0.4615	0.4615	0.9558	0.4851	0.4851
P-value	8.741e-10	2.201e-11	0.00262	3.813e-08	0.0004791
Sensitivity - Decreased	1	0.7778	X	1	0.56250
Sensitivity - Increased	0.8077	0.8846	X	0.6389	0.8056
Sensitivity - Same	0.800	0.8667	X	0.7551	0.5714
Sensitivity - No tax	X	X	0.9942	X	X
Sensitivity - Tax created	X	X	1	X	X

Source: own elaboration.

The table below summarizes the findings of the three main classification trees and indicates whether they support or contradict the research hypotheses:

Table 7 - Main findings and hypotheses.

Tree model	**Relation with carbon tax**	**Conditions**	**Relation with the hypotheses**
TV-AF and TV-SF.	Increased.	Very low green parties electoral performance + Right-wing cabinet.	Supports: Contradicts: H1b; H2b.
TV-AF and TV-SF.	Same.	Very low green parties electoral performance + Center or Left leaning cabinet.	Supports: Contradicts: H1a; H2b.

[56] Model with tax variation and all features.
[57] Model with tax variation and selected features.
[58] Model with tax creation, all features, and a maximum tree depth of 6.
[59] Model with tax variation, all features, less than one dollar carbon taxes included, and a minimum observation in a terminal node of 2.
[60] Model with tax variation, selected features, and less than one dollar carbon taxes included.

TV-AF.	Decreased.	**Not** very low green parties electoral performance + low debt-to GDP + Center or Left leaning cabinet + **not** high share of energy consumption by fossil fuels.	Supports: Contradicts: H1a.
TV-AF.	Increased.	**Not** very low green parties electoral performance + low debt-to GDP + Center or Left leaning cabinet + high share of energy consumption by fossil fuels.	Supports: H1a. Contradicts:
TV-AF.	Decreased or Same.	**Not** very low green parties electoral performance + low debt-to GDP + Center or Right leaning cabinet.	Supports: H1b. Contradicts:
TV-AF.	Increased.	Low debt-to GDP + **not** low Brent price + **not** low green parties electoral performance.	Supports: H2a. Contradicts:
TV-AF.	Decreased.	Low debt-to GDP + **not** low Brent price + low green parties electoral performance.	Supports: H2b. Contradicts:
TV-SF.	Decreased or Same.	**Not** very low green parties electoral performance + Green party in cabinet + Gal leaning cabinet + **not** Extreme Pro-EU.	Supports: Contradicts: H1a; H2a.
TV-SF.	Increased.	**Not** very low green parties electoral performance + Green party in cabinet + Center or Tan leaning cabinet.	Supports: H2a. Contradicts: H1b.
TV-SF.	Increased.	**No** Green party in cabinet + strong green parties electoral performance.	Supports: H2a Contradicts: H2a
TC-AF-D6	Tax created.	Lower GDP per capita (PPP) + Center-Right cabinet.	Supports: Contradicts: H1b.
TC-AF-D6	No tax.	Lower GDP per capita (PPP) + Center or Left cabinet.	Supports: Contradicts: H1a.

Source: own elaboration.

5.4 Final considerations

This chapter had the central task to present the classification trees produced in this study and interpret them in light of the other chapters. It began demonstrating the general configurations for the models, as well as the software and packages used. The established configurations encompassed the utilization of Leave-One-Out Cross-Validation for splitting

the training set from the test set, a maximum tree depth of 5, a minimum number of observations on a terminal node set of 1, exclusion of carbon taxes with an Emissions-weighted rate lower than 1 dollar, and the incorporation of weights to address imbalances in the data frame.

The first decision tree model, which included all the categories and features, failed to produce good results. It had an accuracy rate lower than the no information rate, and a high p-value. To remedy this situation, the models were divided into models with categories related to price variation (“Increased”, “Decreased”, and “Same”) and models without price variation (“No tax”, and “Tax created”).

The tax variation tree with all features had a good accuracy rate, in relation to its no information rate, and a very small p-value. From this model, it was possible to identify the importance of green parties vote share, as it was in the root node, to determine the variation of the carbon tax. The revenue destination also played a role, with cabinets that have a neutral tax being more associated with tax increases, even in cases of a low vote share for green parties. The model also indicated that even when the green parties vote share was low and the cabinet in government was Right-wing, the tax could still be increased. It was possible to observe that when the green parties vote share was not low and the government debt to GDP was higher or equal to 47%, no cabinet decreased its carbon taxes.

The model also demonstrated that the combination of a center or Left-wing cabinet, low government debt to GDP, a significant vote share for green parties (≥ 2.4%), and high share of fossil fuels in energy consumption indicate an increase in carbon taxes. Notably, a robust vote share for green parties and a higher government debt-to-GDP ratio were linked to carbon tax increases, even in the absence of low Brent prices. In this model, the ideological features were considered relevant, although not as important as the government debt, liberal democracy score, share of votes for green parties in the previous election, and Brent price.

The tax variation tree with selected features had a higher accuracy rate than the previous model, and also presented a very small p-value. The green parties’ vote share in the last election remained an important feature, as it continued to be in the root node. Tax increases were associated with when green parties received a high share of the votes in the last election, even if they are not in the cabinet. Additionally, the tax revenue being spent on green projects was associated with tax increases, when the vote share of green parties was significant (>= 2.4%). Cabinets raised the carbon tax even if they did not fully support European integration, and were not pressured by green parties either in government or with a high vote share.

The association between revenue destination, Right-wing cabinets, a low performance of green parties in the last election, and the tax variation remained the same as in the previous model. Interestingly, the presence of a green party in cabinet when related to center or Tan-leaning cabinets produced an increase in the carbon tax. Although it is important to note that a green party being in cabinet does not prevent a decrease in the tax rate. The two most important features for this model were the electoral performance of green parties and the cabinet's Gal-Tan position. The other two ideological features came in third and fourth.

A tax creation tree using the same general configurations was not successful as part of its accuracy rate's confidence intervals was lower than the no information rate, and the p-value was relatively high. Techniques to improve the model's performance (feature selection and SMOTE) were unsuccessful. A new model with a more relaxed depth criteria, up to depth 6, was able to improve the model without over complicating the classification tree.

In this new tax creation tree including all the features, and a maximum depth of 6, the accuracy rate was higher than the no information rate, and the p-value was low. GDP per Capita (PPP) is in the root note in this model, which demonstrates the different dynamics between implementing a carbon tax and its price variation. Interestingly, this decision tree model indicated that the carbon taxes created in countries with a GDP per Capita (PPP) lower than 39 thousand dollars were done so by Right-wing cabinets. On the other hand, in wealthier countries, the implementation of a carbon tax was associated with a strong liberal democratic system, the absence of a crippling debt burden, the occurrence of a natural disaster during the cabinet's tenure, and not being completely relying on fossil fuels for energy consumption.

As for the features' importance to the model, all the ideological features were relevant, with the Left-Right cleavage being the second most influential. Although the occurrence of environmental disasters was relevant for the model, green parties being in government and the environmental pressure feature were not. This model's main limitation is that it was only able to analyze the implementation of 8 of the current 18 European carbon taxes, due to scope limitation on the CHES (Jolly et al., 2022) and RepDem (Hellstrom et al., 2023) datasets.

Later in this chapter, for increased robustness, alternative classification trees were introduced. The modifications involved lowering the 10% variation threshold to 5%, and the inclusion of carbon taxes lower than one dollar. Feature selection was performed in one of these models, while the minimum number of observations for a terminal note was set to 2 for another model. However, all the alternative models either were suspected of *overfitting* or

presented a lower accuracy rate than the main models; this can be observed in the table with the models' main statistical information on page 77. Another table has been included, on pages 77-78, to consolidate the findings of the three main trees, indicating whether they align with or oppose the research hypotheses.

6 CONCLUSION AND LIMITATIONS

As stated before, the main objective of this research was to construct a decision tree model incorporating ideological aspects capable of predicting the implementation and variation of carbon taxes in Europe. By including ideological features and recognizing the political dimensions of carbon pricing, this research aimed at contributing to fill the Political Science literature gap on carbon taxes (Schaffer, 2021; Skovgaard et al., 2019; Harrison, 2010). From the model, insights would be dawned and analyzed to enhance the understanding of the relationships between various features and the initiation and changes in carbon taxes across Europe.

This study commenced by reviewing the literature regarding carbon taxes. It explained the importance of carbon taxes to reduce emissions, the main differences between emissions trading systems and carbon taxes, as well as between carbon taxes and other environmental taxes. It continued by covering the general rationale behind implementing a carbon tax, its historical and current deployment globally, and the main criticisms directed at this policy.

The “Carbon tax” chapter also mapped what made carbon taxes viable in Europe, but also in Argentina, Uruguay, Japan, South Africa, and the Canadian province of British Columbia. This review pointed that the main reasons can be found around the globe: climate mitigation; political considerations; and fiscal policy (Rabbia, 2023). The majority of the European countries implemented the tax for a combination of these motives, in push and pull effects (Bothner et al., 2022). On the other hand, most countries outside Europe created the tax either to comply with international agreements, or as part of broad tax reforms.

Interestingly, many cabinets implemented a carbon tax either amidst an increase in environmental awareness, pressured by green parties in the coalition, or an increase in the electoral vote share of green parties. The importance of strong and well functioning democratic institutions was also demonstrated, as well as the possibility to earmark the carbon taxes' revenue to increase the acceptability of the tax. Unsuccessful attempts at implementing or increasing the carbon tax rate were also analyzed. Such failures were often associated with specific country or time-related factors. If any generalization could be made, it would be that strong or abrupt increases in the carbon tax rate tended to diminish its prospects for enduring and escalating in the future.

Later on, the research elucidated on the definition and importance of ideology in the study of carbon taxes. This was done by firstly introducing the concept of ideological cleavages and presenting the current ideological divides in Europe: Left-Right; Gal-Tan; and Pro-Anti EU. The Left-Right discourse is distinguished by varying degrees of endorsement

for governmental intervention and income redistribution (Hooghe; Marks, 2018). Conversely, the Gal-Tan cleavage centers on cultural considerations, such as climate change, and the leaning toward nationalist or cosmopolitan policies (Marks et al., 2021). In contradistinction, the Anti-Pro EU divide hinges on the degree of support or opposition to the European integration process.

This study explained the literature's assumptions on the interaction between these cleavages in parties, and also demonstrated this interaction on the cabinets selected for this research, concluding that these assumptions largely transpose to the governing coalitions in question. Additionally, the study underscored the practicality of dissecting the conventional Left-Right continuum into cultural (Gal-Tan) and purely economic (Left-Right) cleavages, taking into consideration the different party cultures in Eastern and Western Europe (Hooghe; Marks, 2018). Moreover, it was detailed what the positions in the ideological cleavages meant for environmental policy preferences.

Left-wing parties generally favor robust governmental intervention to achieve societal goals, including environmental protection. Conversely, Right-leaning parties tend to be more skeptical of extensive government involvement (Levi, 2021). Gal-oriented parties place environmental and climate policies at the core of their ideology, while Tan-leaning parties often downplay the urgency of climate change, emphasizing economic growth. Extreme-Tan parties typically adopt a radical stance against the necessity to reduce carbon emissions (Buzogany; Cetkovic, 2021). Anti-EU parties consistently prioritize economic growth, reject EU-wide climate policies, and have been linked to an increase in carbon emissions (Jahn, 2021). Moreover, they exhibit skepticism toward global climate agreements. In contrast, Pro-EU parties tend to adopt a less extreme position, striking a balance between economic growth and environmental concerns, and expressing support for EU climate policies (Petri; Biendenkopf, 2021; Kinski; Servent, 2022).

This research employed the decision trees, a machine learning method, for its numerous advantages, including easy interpretability, flexibility in data assumptions, the option to assign weights to different categories for correcting imbalances in the data frame, and the ability to make predictions on unseen data. It was highlighted the importance to use the Emissions-weighted carbon price to capture the variations in the tax rate, since it combines price with coverage.

To construct the target variable, the parties that participated in each coalition were identified and had their proportional participation calculated using the RemDem (Hellstrom et al., 2023) dataset. Subsequently, the ideological position of these parties in the tree main

cleavages was retrieved from the CHES (Jolly et al., 2022) dataset. The general cabinet position on the ideological scales considered the number of seats of each party had in relation to the total number of seats of the coalition in parliament.

Due to the small size of this study's data frame, the Leave-One-Out Cross-Validation was used to split the training set from the test set. The general configuration for the models were a maximum tree depth of 5, and a minimum number of observations for a terminal node of 1. The weights were added according to the frequency of the categories of the target variable in the data frame. To capture only intentional changes in the Emissions-weighted carbon price, a 10% variation threshold was adopted. Carbon taxes lower than one dollar were excluded from the models since they are largely symbolic and the smallest change in price would pass the established variation threshold.

The models were considered successful if their accuracy rate was higher than the no information rate, the p-value was equal to or lower than 0.01, and there was no indication of *overfitting*. Due to performance issues, the model had to be divided into two: one classification tree for categories with price variation ("Increased", "Decreased", "Same"); and another for categories without price variation ("No tax", "Tax created").

The tax variation tree with all features demonstrated the importance of the green parties vote share to determine the variation of the carbon tax. The model indicated that in cabinets with a revenue neutral tax, as well as Right-wing cabinets carbon taxes were increased, even when these cabinets were not pressured by the green parties electoral success. On the other hand, the classification tree predicted that the tax would decrease if its revenue was not earmarked to reduce other taxes. No cabinets with a government debt-to-GDP ratio above 47% and that experienced a substantial vote share in the last election going to green parties reduced its carbon tax rate (>= 2.4%).

The model also demonstrated that the combination of a center or Left-wing cabinet, a very low government debt to GDP (< 47%), a significant vote share for green parties (≥ 2.4%), and high share of fossil fuels in energy consumption (>= 70%), indicated an increase in carbon taxes. Conversely, if the share of fossil fuels in energy consumption was lower than 70%, and the other conditions maintained the same, the carbon tax would decrease. In the scenario where the cabinet leans towards the center or Right-wing, maintains a low government debt to GDP ratio (< 47%), and the green parties receive a significant share of the vote (≥ 2.4%), the prediction was for a decrease in taxes. Notably, a higher vote share for green parties (>= 3.1%) and a higher government debt-to-GDP ratio were linked to carbon tax increases, even in the absence of very low Brent prices (>= 34).

A second tax variation tree was developed using feature selection. Interestingly, this model maintained the same associations between tax rate variation and having a neutral tax, Right-wing cabinets, and a low electoral performance of green parties. The model corroborated with the importance of the share of votes received by green parties by maintaining it at the root note. Notably, a very strong electoral performance of green parties (>= 9.1%) was associated with tax increases, even if they were not in cabinet. On the other hand, tax revenue being earmarked to green projects was associated with tax increases, when the vote share of green parties was significant (>= 2.4%).

It is noteworthy that cabinets were predicted to raise the carbon tax even if they did not fully support the EU, and were not pressured by green parties either in government or with a high vote share (>= 9.1%). Although the presence of green parties in the cabinet, when related to center or Tan-leaning parties, was associated with an increase in the carbon tax, their presence in the cabinet did not prevent reductions in the price rate. Interestingly, the classification tree predicted that even when the greens had a significant (>= 2.4%) share of the vote, participated in the coalition, and the cabinet was Gal-leaning, the carbon tax would decrease.

The third model created was a tax creation tree using a maximum depth criteria of 6. Interestingly, this classification tree indicated that carbon taxes created in countries with a GDP per Capita (PPP) lower than 39 thousand dollars were implemented by Right-wing cabinets. However, it is important to note that the model predicted that extreme-Right cabinets would not create the tax. On the other hand, in wealthier countries, the implementation of a carbon tax was associated with a strong liberal democratic system, the absence of a crippling debt burden, the occurrence of a natural disaster during the cabinet's tenure, and not being completely relying on fossil fuels for energy consumption.

All the ideological features were deemed important for the models' predictions. However, these features were not considered the most influential. In the first tax variation model, the most relevant features were the government debt to GDP, liberal democracy score, the electoral performance of green parties, and the Brent price. The second tax variation model considered the most the electoral performance of green parties and the Gal-Tan ideological position. Interestingly, for the tax creation tree, the most influential feature was the fossil fuels share in energy consumption, followed by the Left-Right ideological position, and the Brent price.

It is noteworthy that none of the models presented the features related to protests, the Paris Agreement, and environmental pressure as highly influential for the models predictions.

It is also interesting that the greens in cabinet feature did not have a strong relevance for the tax creation tree. These findings suggest that either the research failed to fully capture the nuances of these features, or their significance has been exaggerated by qualitative case studies. In either scenario, it underscores the need for further research to comprehensively assess the impact of these features.

Other models were constructed to entrance the research's robustness. The modifications involved lowering the 10% variation threshold to 5%, and the inclusion of carbon taxes lower than one dollar. Feature selection was performed in one of these models, while the minimum number of observations for a terminal note was set to 2 for another model.

Upon analyzing the main findings of the three primary classification tree models in this study, it becomes apparent that none of the hypotheses can be definitively confirmed. As illustrated in the table on pages 77-78, no hypotheses garnered overwhelming evidence in their favor. For the first hypothesis, H1a received support from 2 findings but faced contradiction from 3. Similarly, H1b was supported by 1 finding but contradicted by 3. In the second hypothesis, H2a found support from 3 findings but was contradicted by 2, while H2b had 1 supporting finding and 2 contradicting ones.

This research has some limitations. Firstly, it couldn't include the first five years of carbon tax policies, as well as the carbon taxes in Iceland, Ukraine, and Switzerland due to limitations on the CHES (Jolly et al., 2022) and RepDem (Hellstrom et al., 2023) dataset. As a result of these constraints, the tax creation trees data frame contains only eight observations labeled as "Tax created," despite the current existence of 18 carbon taxes in Europe. Another limitation was that the study did not consider the upper camber of parliament in countries that do not have a unicameral parliament. Although some upper chambers are considerably less powerful than their lower chamber counterparts, in some countries they have a veto power over legislation and that could significantly influence the cabinets' actions toward carbon pricing. Furthermore, the research also did not consider the possible influence of presidents for the countries which have them, neither their possible power to veto legislation.

As the research focused on cabinets as the unit of analysis, it necessitated the transformation of yearly data into averages to align with the multi-year tenure of cabinets. This may have resulted in the lost of "more extreme data", such as bond yield or Bent price spikes, that could have positively or negatively influenced the carbon tax. Additionally, the decision to exclude the Emissions-weighted carbon taxes lower than one dollar reduced the representation of Eastern Europe in the study. In fact, the only Eastern European country in

the tax variation trees was Slovenia, since the criteria resulted in the exclusion of Poland, Latvia, and Estonia. The research also did not include a feature related to the diffusion of carbon taxes throughout Europe and its potential impact through policy learning.

Future research could address the limitations of this research and attempt to include surveys on climate awareness, and the upper chamber ideological position. Additionally, it may delve into the potential impact of presidential influence and the information loss resulting from the averaging of yearly data. Expanding the scope beyond Europe has the potential to yield valuable insights. A promising starting point could be Latin America, as the region is encompassed in the CHES (Jolly et al., 2022) dataset, and some countries within the region have already instituted carbon taxes.

REFERENCES

ANDERSON, Soren; MARINESCU, Ioana; SHOR, Boris. Can Pigou at the Polls Stop Us Melting the Poles? Journal Of The Association Of Environmental And Resource Economists, [S.L.], v. 10, n. 4, p. 903-945, 1 jul. 2023. University of Chicago Press. http://dx.doi.org/10.1086/722970.

ANDERSSON, J. J. Carbon Taxes and CO2 Emissions: Sweden as a Case Study. **American Economic Journal: Economic Policy**, v. 11, n. 4, p. 1–30, 1 nov. 2019.

ANING, S.; PRZYBYŁA-KASPEREK, M. Comparative Study of Twoing and Entropy Criterion for Decision Tree Classification of Dispersed Data. **Procedia Computer Science**, v. 207, p. 2434–2443, 2022.

ARLINGAHUS. **Impacts of Carbon Prices on Indicators of Competitiveness: A Review of Empirical Findings**: OECD Environment Working Papers. [s.l: s.n.]. Disponível em: <https://www.oecd-ilibrary.org/environment/impacts-of-carbon-prices-on-indicators-of-competitiveness_5js37p21grzq-en>. Acesso em: 27 nov. 2023.

BAKER, L. **The Political Economy of South Africa's Carbon Tax**. [s.l.] Institute of Development Studies, 10 nov. 2022. Disponível em: <https://opendocs.ids.ac.uk/opendocs/handle/20.500.12413/17745>. Acesso em: 25 dez. 2023.

BERAMENDI, P. et al. (EDS.). **The Politics of Advanced Capitalism**. 1. ed. [s.l.] Cambridge University Press, 2015.

BOTHNER, F. et al. Never let a serious crisis go to waste: the introduction of supplemental carbon taxes in Europe. **Journal of Public Policy**, v. 42, n. 2, p. 343–363, jun. 2022.

BUZOGÁNY, A.; ĆETKOVIĆ, S. Fractionalized but ambitious? Voting on energy and climate policy in the European Parliament. **Journal of European Public Policy**, v. 28, n. 7, p. 1038–1056, 3 jul. 2021.

CALLEN, Tim. PURCHASING POWER PARITY: weights matter. WEIGHTS MATTER. Disponível em: https://www.imf.org/en/Publications/fandd/issues/Series/Back-to-Basics/Purchasing-Power-Parity-PPP. Acesso em: 01 dez. 2023.

CARL, J.; FEDOR, D. Tracking global carbon revenues: A survey of carbon taxes versus cap-and-trade in the real world. **Energy Policy**, v. 96, p. 50–77, set. 2016.

CASTIGLIONE, C. et al. Environmental taxation in Europe: What does it depend on? **Cogent Economics & Finance**, v. 2, n. 1, p. 967362, 31 dez. 2014.

CONGLETON, R. D. Political Institutions and Pollution Control. **The Review of Economics and Statistics**, v. 74, n. 3, p. 412, ago. 1992.

CONVERY; DUNNE; JOYCE. **Ireland's Carbon Tax and the Fiscal Crisis: Issues in Fiscal Adjustment, Environmental Effectiveness, Competitiveness, Leakage and Equity Implications**: OECD Environment Working Papers. [s.l: s.n.]. Disponível em: <https://www.oecd-ilibrary.org/environment-and-sustainable-development/ireland-s-carbon-tax-and-the-fiscal-crisis_5k3z11j3w0bw-en>. Acesso em: 26 nov. 2023.

CRIQUI, P.; JACCARD, M.; STERNER, T. Carbon Taxation: A Tale of Three Countries. Sustainability, v. 11, n. 22, p. 6280, 8 nov. 2019.

CROWLEY, K. Up and down with climate politics 2013–2016: the repeal of carbon pricing in Australia. **WIREs Climate Change**, v. 8, n. 3, p. e458, maio 2017.

DECHEZLEPRÊTRE, A. et al. Searching for carbon leaks in multinational companies. **Journal of Environmental Economics and Management**, v. 112, p. 102601, mar. 2019.

DOLPHIN, G.; POLLITT, M. G.; NEWBERY, D. M. The political economy of carbon pricing: a panel analysis. **Oxford Economic Papers**, p. gpz042, 10 jul. 2019.

DOLPHIN, Geoffroy; XIAHOU, Qinrui. World carbon pricing database: sources and methods. Scientific Data, [S.L.], v. 9, n. 1, p. 1-7, 17 set. 2022. Springer Science and Business Media LLC. http://dx.doi.org/10.1038/s41597-022-01659-x.

DOREY, P. Towards Exit from the EU: The Conservative Party's Increasing Euroscepticism since the 1980s. **Politics and Governance**, v. 5, n. 2, p. 27–40, 5 abr. 2017.

DOUENNE, T.; FABRE, A. French attitudes on climate change, carbon taxation and other climate policies. **Ecological Economics**, v. 169, p. 106496, mar. 2020.

DUSSAUX. **The joint effects of energy prices and carbon taxes on environmental and economic performance: Evidence from the French sector**: OECD Environment Working Papers. [s.l: s.n.]. Disponível em: <https://www.oecd-ilibrary.org/environment/the-joint-effects-of-energy-prices-and-carbon-taxes-on-environmental-and-economic-performance-evidence-from-the-french-sector_b84b1b7d-en>. Acesso em: 27 nov. 2023.

EDWARDS. Institut für Höhere Studien (IHS), Wien. **Reihe Politikwissenschaft**, 2009.

ERRENDAL; ELLIS; JEUDY-HUGO. **The role of carbon pricing in transforming pathways to reach net zero emissions: Insights from current experiences and potential application to food systems**: OECD Environment Working Papers. [s.l: s.n.]. Disponível em: <https://www.oecd-ilibrary.org/environment/the-role-of-carbon-pricing-in-transforming-pathways-to-reach-net-zero-emissions_5cefdf8c-en>. Acesso em: 27 nov. 2023.

GEMENIS, K.; KATSANIDOU, A.; VASILOPOULOU, S. The politics of anti-environmentalism: positional issue framing by the European radical right. 2012.

GHAZOUANI, A. et al. Exploring the Role of Carbon Taxation Policies on CO2 Emissions: Contextual Evidence from Tax Implementation and Non-Implementation European Countries. **Sustainability**, v. 12, n. 20, p. 8680, 20 out. 2020.

GOKHALE, H. Japan's carbon tax policy: Limitations and policy suggestions. **Current Research in Environmental Sustainability**, v. 3, p. 100082, 2021.

GREEN, J. F. Does carbon pricing reduce emissions? A review of ex-post analyses. **Environmental Research Letters**, v. 16, n. 4, p. 043004, 1 abr. 2021.

GRUS, Joel. Data Science do Zero. Rio de Janeiro: Alta Books, 2021.

HAITES, E. Carbon taxes and greenhouse gas emissions trading systems: what have we learned? **Climate Policy**, v. 18, n. 8, p. 955–966, 14 set. 2018.

HARRISON. **The Political Economy of British Columbia's Carbon Tax**: OECD Environment Working Papers. [s.l: s.n.]. Disponível em: <https://www.oecd-ilibrary.org/environment-and-sustainable-development/the-political-economy-of-british-columbia-s-carbon-tax_5k3z04gkkhkg-en>. Acesso em: 12 jan. 2024.

HARRISON, K. The Comparative Politics of Carbon Taxation. **Annual Review of Law and Social Science**, v. 6, n. 1, p. 507–529, 1 dez. 2010.

HARRISON, K. A Tale of Two Taxes: The Fate of Environmental Tax Reform in Canada. **Review of Policy Research**, v. 29, n. 3, p. 383–407, maio 2012.

HERRANZ-SURRALLÉS, A. An emerging EU energy diplomacy? Discursive shifts, enduring practices. **Journal of European Public Policy**, v. 23, n. 9, p. 1386–1405, 20 out. 2015.

HESS, D. J.; RENNER, M. Conservative political parties and energy transitions in Europe: Opposition to climate mitigation policies. **Renewable and Sustainable Energy Reviews**, v. 104, p. 419–428, abr. 2019.

HICKSON, K.; PAGE, R.; WILLIAMS, B. Strangled at birth: the One Nation ideology of Theresa May. **Journal of Political Ideologies**, v. 25, n. 3, p. 334–350, 1 set. 2020.

HOOGHE, L.; MARKS, G. A Postfunctionalist Theory of European Integration: From Permissive Consensus to Constraining Dissensus. British Journal of Political Science, v. 39, n. 1, p. 1–23, jan. 2009.

HOOGHE, L.; MARKS, G. Cleavage theory meets Europe's crises: Lipset, Rokkan, and the transnational cleavage. **Journal of European Public Policy**, v. 25, n. 1, p. 109–135, 2 jan. 2018.

HOOGHE, L.; MARKS, G.; WILSON, C. J. Does Left/Right Structure Party Positions on European Integration? **Comparative Political Studies**, v. 35, n. 8, p. 965–989, out. 2002.

JAGERS, S. C.; HARRING, N.; MATTI, S. Environmental management from left to right – on ideology, policy-specific beliefs and pro-environmental policy support. **Journal of Environmental Planning and Management**, v. 61, n. 1, p. 86–104, 2 jan. 2017.

JAHN, D. Quick and dirty: how populist parties in government affect greenhouse gas emissions in EU member states. **Journal of European Public Policy**, v. 28, n. 7, p. 980–997, 3 jul. 2021.

JINYAN LI; LIMSOON WONG. **Solving the fragmentation problem of decision trees by discovering boundary emerging patterns**. 2002 IEEE International Conference on Data Mining, 2002. Proceedings. **Anais**... Em: 2002 IEEE INTERNATIONAL CONFERENCE ON DATA MINING. ICDM 2002. Maebashi City, Japan: IEEE Comput. Soc, 2002. Disponível em: <http://ieeexplore.ieee.org/document/1184021/>. Acesso em: 8 jan. 2024

KAUFMAN, N. et al. A near-term to net zero alternative to the social cost of carbon for setting carbon prices. **Nature Climate Change**, v. 10, n. 11, p. 1010–1014, nov. 2020.

KINSKI, L.; RIPOLL SERVENT, A. Framing Climate Policy Ambition in the European Parliament. **Politics and Governance**, v. 10, n. 3, 12 ago. 2022.

KOTSIANTIS, S. B. Decision trees: a recent overview. **Artificial Intelligence Review**, v. 39, n. 4, p. 261–283, abr. 2011.

LANZI et al. **Addressing Competitiveness and Carbon Leakage Impacts Arising from Multiple Carbon Markets: A Modelling Assessment**: OECD Environment Working Papers. [s.l: s.n.]. Disponível em: <https://www.oecd-ilibrary.org/environment-and-sustainable-development/addressing-competitiveness-and-carbon-leakage-impacts-arising-from-multiple-carbon-markets_5k40ggjj7z8v-en>. Acesso em: 27 nov. 2023.

LEVI, S. Why hate carbon taxes? Machine learning evidence on the roles of personal responsibility, trust, revenue recycling, and other factors across 23 European countries. **Energy Research & Social Science**, v. 73, p. 101883, mar. 2021.

LEVI, S.; FLACHSLAND, C.; JAKOB, M. Political Economy Determinants of Carbon Pricing. **Global Environmental Politics**, v. 20, n. 2, p. 128–156, maio 2020.

LIPSET, Seymour Martin; ROKKAN, Stein. Cleavage Structures, Party Systems and Voter Alignments: an introduction. In: LIPSET, Seymour Martin; ROKKAN, Stein (ed.). Cleavage Structures, Party Systems and Voter Alignments: cross-national perspectives. New York: Free Press, 1967. p. 1-64.

LOCKWOOD, M. Right-wing populism and the climate change agenda: exploring the linkages. **Environmental Politics**, v. 27, n. 4, p. 712–732, 4 jul. 2018.

MACNEIL, R. Is Canadian carbon pricing here to stay? The outlook after 14 elections. **Environmental Politics**, v. 29, n. 2, p. 354–359, 23 fev. 2020.

MAGGETTI, M.; TREIN, P. Multilevel governance and problem‐solving: Towards a dynamic theory of multilevel policy‐making? **Public Administration**, v. 97, n. 2, p. 355–369, jun. 2018.

MARKS, G. et al. Cleavage Theory. Em: RIDDERVOLD, M.; TRONDAL, J.; NEWSOME, A. (Eds.). **The Palgrave Handbook of EU Crises**. Palgrave Studies in European Union Politics. Cham: Springer International Publishing, 2021. p. 173–193.

MARTEN; DENDER. **The use of revenues from carbon pricing**: OECD Taxation Working Papers. [s.l: s.n.]. Disponível em: <https://www.oecd-ilibrary.org/taxation/the-use-of-revenues-from-carbon-pricing_3cb265e4-en>. Acesso em: 12 jan. 2024.

MAU, S. Social Transnationalism: Lifeworlds Beyond the Nation-State. 2010.

MCCLOSKY, H. Consensus and Ideology in American Politics. **American Political Science Review**, v. 58, n. 2, p. 361–382, jun. 1964.

MCCRIGHT, A. M.; DUNLAP, R. E.; MARQUART-PYATT, S. T. Political ideology and views about climate change in the European Union. **Environmental Politics**, v. 25, n. 2, p. 338–358, 3 mar. 2015.

MORGAN, Sam. Luxembourg to deploy carbon tax from 2021. EURACTIV, 10 Dec. 2019. Available at: <https://www.euractiv.com/section/climate-environment/news/luxembourg-to-deploy-carbon-tax-from-2021/>. Accessed on: 10 Dec. 2023.

NEUMAYER, E. The environment, left-wing political orientation and ecological economics. **Ecological Economics**, v. 51, n. 3–4, p. 167–175, dez. 2004.

NUR, A. I. Understanding European Union Climate Change Governance through Political Parties Euromanifesto. **Mulawarman Law Review**, v. 8, n. 1, 2023.

ORTIZ, D. et al. Analysis of Renewable Energy Policies through Decision Trees. Sustainability, v. 14, n. 13, p. 7720, 24 jun. 2022.

PEREIRA, A. M.; PEREIRA, R. M.; RODRIGUES, P. G. A new carbon tax in Portugal: A missed opportunity to achieve the triple dividend? **Energy Policy**, v. 93, p. 110–118, jun. 2016.

PETRI, F.; BIEDENKOPF, K. Weathering growing polarization? The European Parliament and EU foreign climate policy ambitions. Journal of European Public Policy, v. 28, n. 7, p. 1057–1075, 3 jul. 2021.

PIGOU, Arthur Cecil. The Economics of welfare. Indianapolis: Macmillan And Co, 1932. Disponível em: https://edisciplinas.usp.br/pluginfile.php/4154221/mod_resource/content/0/Pigou-The_Economic_of_Welfare_1920.pdf. Acesso em: 01 dez. 2023.

PIKETTY, Thomas. Capital and ideology. Cambridge: Harvard University Press, 2020.

QU, H. South Africa Carbon Pricing and Climate Mitigation Policy. Selected Issues Papers, v. 2023, n. 040, p. 1, jun. 2023.

RABBIA, M. Why did Argentina and Uruguay decide to pursue a carbon tax? Fiscal reforms and explicit carbon prices. **Review of Policy Research**, v. 40, n. 2, p. 230–259, mar. 2023.

RABE, B. G.; BORICK, C. P. Carbon Taxation and Policy Labeling: Experience from American States and Canadian Provinces. **Review of Policy Research**, v. 29, n. 3, p. 358–382, maio 2012.

RIIGI TEATEJA. Environmental Charges Act. 2014. Available at: <https://www.riigiteataja.ee/en/eli/513012014001/consolide>. Accessed on: 01 Dec. 2023.

SCHAFFER, L. M. The politics of green taxation. Em: HAKELBERG, L.; SEELKOPF, L. (Eds.). Handbook on the Politics of Taxation. [s.l.] Edward Elgar Publishing, 2021.

SCHIMMELFENNIG, F. European integration (theory) in times of crisis. A comparison of the euro and Schengen crises. **Journal of European Public Policy**, v. 25, n. 7, p. 969–989, 3 jul. 2018.

SEN, S.; VOLLEBERGH, H. R. J. The Effectiveness of Taxing Carbon Content of Energy Consumption. **SSRN Electronic Journal**, 2018.

SÉNIT, C.-A. The politics of carbon taxation in France: preferences, institutions, and ideologies. 2012.

SKOVGAARD, J.; FERRARI, S. S.; KNAGGÅRD, Å. Mapping and clustering the adoption of carbon pricing policies: what polities price carbon and why? **Climate Policy**, v. 19, n. 9, p. 1173–1185, 21 out. 2019.

SONG, Y.; LU, Y. Decision tree methods: applications for classification and prediction. v. 27, n. 2, 2015.

STERNER, T. Environmental tax reform: The Swedish experience. **European Environment**, v. 4, n. 6, p. 20–25, dez. 1994.

TATHAM, M.; PETERS, Y. Fueling opposition? Yellow vests, urban elites, and fuel taxation. **Journal of European Public Policy**, v. 30, n. 3, p. 574–598, 4 mar. 2023.

TAWIAH, V. Does political ideology affect the stringency of environmental policy? **Politics & Policy**, v. 50, n. 3, p. 631–653, jun. 2022.

THISTED, E. V.; THISTED, R. V. The diffusion of carbon taxes and emission trading schemes: the emerging norm of carbon pricing. **Environmental Politics**, v. 29, n. 5, p. 804–824, 28 jul. 2019.

VASCONCELOS, Jorge et al. PROJETO DE REFORMA DA FISCALIDADE VERDE. 2014. Disponível em: https://www.historico.portugal.gov.pt/pt/o-governo/arquivo-historico/governos-constitucionais/gc19/os-ministerios/maote/quero-saber-mais/sobre-o-ministerio/consulta-publica-fiscalidade-verde/relatorio-comissao-reforma.aspx. Acesso em: 02 dez. 2023.

VENMANS, F.; ELLIS, J.; NACHTIGALL, D. Carbon pricing and competitiveness: are they at odds? **Climate Policy**, v. 20, n. 9, p. 1070–1091, 20 out. 2019.

WANG, T. et al. Handling over-fitting in test cost-sensitive decision tree learning by feature selection, smoothing and pruning. **Journal of Systems and Software**, v. 83, n. 7, p. 1137–1147, jul. 2010.

WETTENGEL, Julian. Germany's carbon pricing system for transport and buildings. Journalism for the just transition, 08 Jan. 2024. Available at: <https://www.cleanenergywire.org/factsheets/germanys-planned-carbon-pricing-system-transport-and-buildings>. Accessed on: 08 jan. 2024.

WINTER, J. Carbon Pricing in a Federal State: The Case of Canada. 2020.

WONG, T.-T. Performance evaluation of classification algorithms by k-fold and leave-one-out cross validation. **Pattern Recognition**, v. 48, n. 9, p. 2839–2846, set. 2015.

WOUTERS, R.; WALGRAVE, S. Demonstrating Power: How Protest Persuades Political Representatives. American Sociological Review, v. 82, n. 2, p. 361–383, abr. 2017.

YAZAR, M.; HERMWILLE, L.; HAARSTAD, H. Right-wing and populist support for climate mitigation policies: Evidence from Poland and its carbon-intensive Silesia region. **Regional Sustainability**, v. 3, n. 4, p. 281–293, dez. 2022.

ANNEX A - Descriptive Statistics

To delve deeper into the data frame, target variable and features in this research, the data was organized into two tables and seventeen distinct figures. Table one outlines the fundamental structure of the data frame, while Table two provides insights into measures of central tendency, dispersion, and position. Figure one offers a geographical representation of the number of cabinets by country, complemented by Figure two, which provides frequency graphs for six key features. Turning attention to environmental aspects, Figure three portrays the frequency plots for these features, while Figure four shows the frequency distribution for the European regions feature. The fifth figure demonstrates the variations in Brent oil prices across diverse cabinets.

Figure six exhibits the cabinets' GDP per capita (PPP), while Figure seven shows the cabinets' government debt to GDP. Figure eight demonstrates the cabinets' liberal democracy score, and Figure nine shows the cabinets' share of fossil fuels in energy consumption. The bond yield feature is displayed on Figure ten.

Moving forward, Figure eleven presents a scatter plot detailing the electoral performance of green parties, while Figure twelve exhibits a frequency graph highlighting the presence of green parties in government coalitions. Moreover, Figure thirteen presents features' graphs related to the tax price and the 10% variation threshold. Figure fourteen displays the 5% variation threshold. Meanwhile, Figures fifteen, sixteen, and seventeen showcase density plots, scatter plots with box plots, and box plots of the "ideological cleavages" features categorized respectively.

Table 1 - Basic structure of the database.

Variable Name	Variable Type	Sample Number	Missing Count	Percentage of Missing	Number of distinct values
country	character	240	0	0	26
cabinet	character	240	0	0	240
adjusted_tax_average[61]	numeric	240	0	0	77
tax_created	factor	240	0	0	2

[61] Referred in the research as "Averaged Emission-weighted carbon tax".

greens_gov	factor	240	0	0	2
weighted_galtan	numeric	240	0	0	180
weighted_leftright	numeric	240	0	0	188
weighted_leftright	numeric	240	0	0	156
year_start	integer	240	0	0	28
year_finish	integer	240	0	0	29
decade	character	240	0	0	4
anti_tax_protests_5000	factor	214	26	0.11	2
neutral_tax	factor	240	0	0	3
green_revenue	factor	240	0	0	3
perc_votes_green	numeric	234	6	0.025	93
after_paris_agree	factor	240	0	0	2
gdp_per_capita_ppp	numeric	240	0	0	234
caretaker_gov	factor	240	0	0	2
percent_change	numeric	93	147	0.61	77
brent_price	numeric	240	0	0	90
gov_debt_gdp	numeric	240	0	0	225
western_eu	factor	240	0	0	2
libdem	numeric	240	0	0	43
share_ff_energy	integer	240	0	0	59
bond_yield	numeric	240	0	0	16

environmental_pressure	factor	240	0	0	2
environmental_disasters	factor	240	0	0	2
subregion_europe	factor	240	0	0	4
Label10	factor	240	0	0	5
Label5	factor	240	0	0	5

Source: own elaboration.

Upon scrutinizing the structure of the data frame, it becomes evident that while the majority of variables exhibit no missing values, the "anti_tax_protests_5000" variable surpasses a 10% missing rate, and the "percent_change" variable exceeds a 60% missing rate. In the former case, the missing instances arise because the data source (Mass Mobilization Protest Data) spans only from 1990 to 2020, resulting in all missing cases occurring for cabinets beyond 2020. Later on, the missing cases were transformed into 0s, with the lack of protests becoming 1s, and the occurrence of protests coded as 2s.

Regarding the "percent_change" variable, the missing values occur when there is no percentage change in the average adjusted tax rate between cabinets, specifically when a cabinet without a carbon tax follows another cabinet without a carbon tax. Five of the six missing cases on the “perc_votes_green” feature are from cabinets in Portugal (1996-2011), while the other is from France in the 1990s.

Table 2 - Measures of central tendency, dispersion, and position.

Variable Name	**Min**	**Max**	**Mean**	**Median**	**SD**	**Skewness**	**Kurtosis**
adjusted_tax_average	0	66.65	4.72	0	11.64	3.43	12.46
bond_yield	0	18	3.93	4	2.94	1.11	2.64
brent_price	26.33	128	71.63	68.90	28.71	0.29	-0.97
gdp_per_capita_ppp	8.77	131.78	33.99	29.96	17.49	2.17	7.98
gov_debt_gdp	4.6	186.8	57.55	51.50	34.47	1.34	2.56
libdem	0.3	0.9	0.77	0.8	0.1	-1.9	4.11

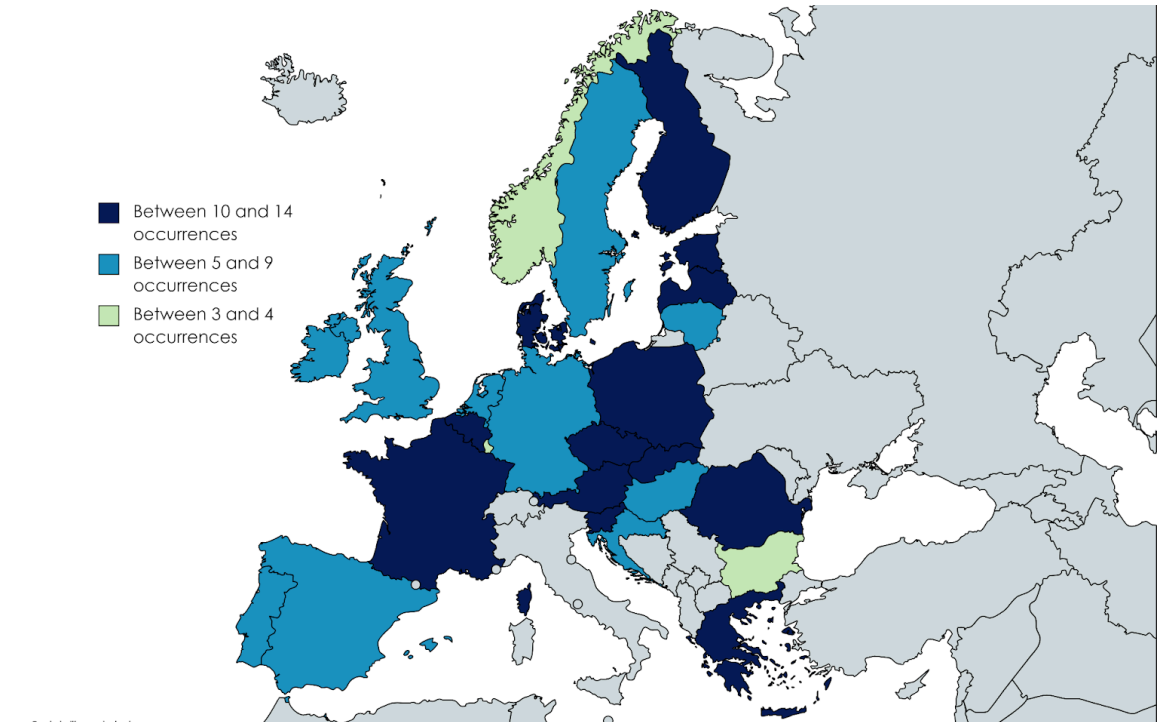
perc_votes_green	0	14.8	3.25	2.07	3.62	0.93	0
percent_change	-100	388.89	19.76	0	65.75	2.67	11.08
share_ff_energy	26	100	76.81	79.50	15.99	-1.05	1.15
weighted_eu	1.53	7	5.70	5.92	1.02	-1.45	2.41
weighted_galtan	0.7	9.2	5.36	5.5	1.63	0.01	-0.32
weighted_leftright	1.68	8.45	5.42	5.42	1.47	-0.14	-0.68

Source: own elaboration.

Table two presents key statistical metrics, encompassing measures of central tendency, dispersion, and position, for the numerical features within the data frame. Examining the "adjusted_tax_average" variable, despite its notable variability (indicated by a standard deviation of 11.64), it is apparent that the 0 tax rate dominates the majority of cases. The relatively low mean and median of the "perc_votes_green" feature underscore the typically modest size of green parties.

The "percent_change" variable exhibits substantial variation (a standard deviation of 65.75), spanning from -100 to 388.89. Notably, the median of 0 underscores the significance of cases where there is no tax. Analyzing the standard deviations of the “ideological cleavages” features, it is evident that "weighted_eu" demonstrates the smallest variation among the three.

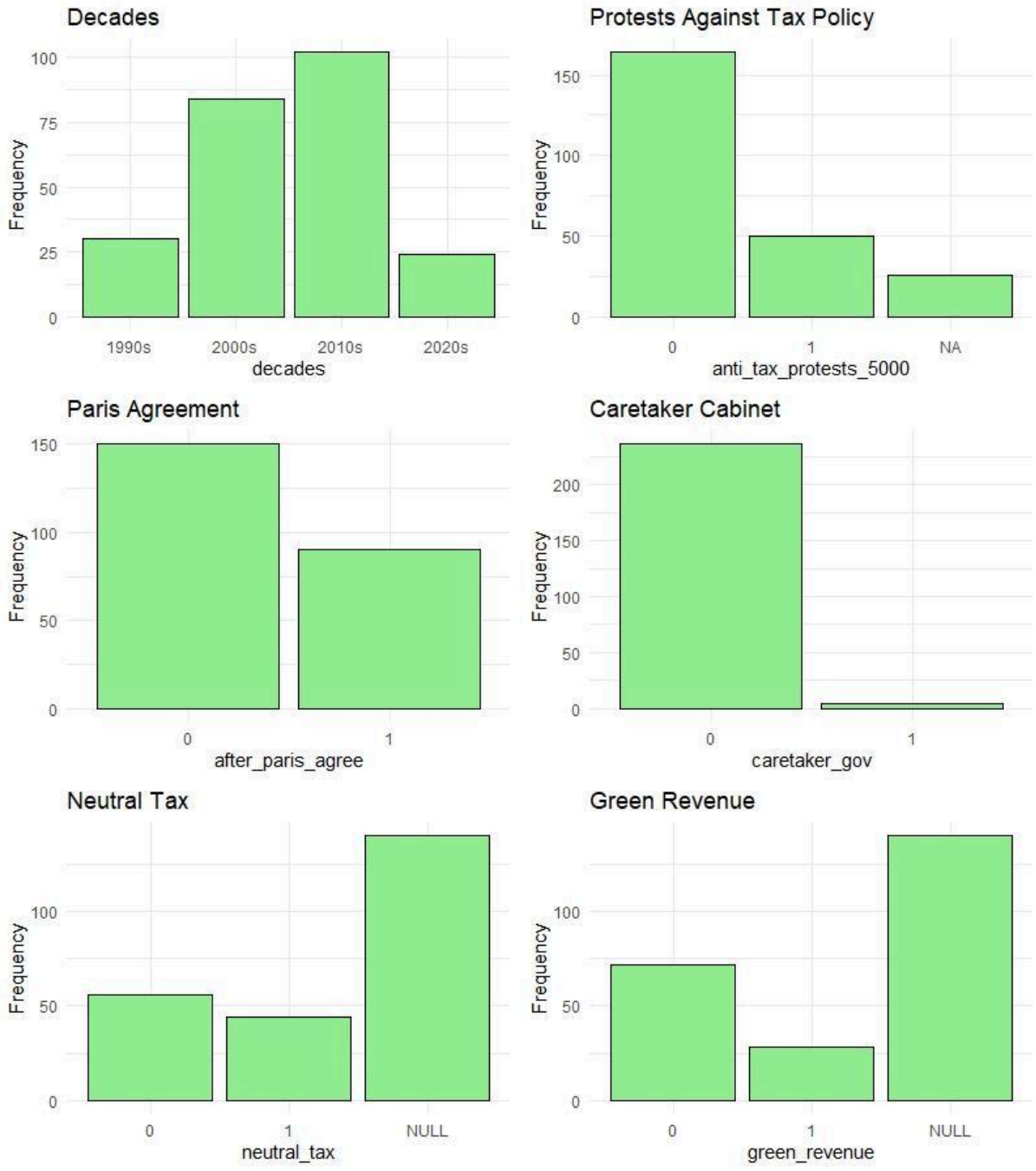
Figure 1 - Number of cabinets by country.



Source: own elaboration.

In Figure one, a map illustrates the distribution of cabinets across countries. Notably, Luxembourg, Norway, and Bulgaria emerge as the least represented nations in the data frame. This discrepancy arises from the fact that Luxembourg and Norway were incorporated into the CHES database only from 2014 onward. Furthermore, these countries predominantly feature cabinets with sustained tenure, completing their full terms. In the case of Bulgaria, certain cabinets had to be excluded due to the inclusion of parties not documented in the CHES database. Since 2002, 24 out of the 26 countries have been part of the CHES database, with the observed variations in the map largely reflecting the overall stability of cabinets within each country.

Figure 2 - Features.



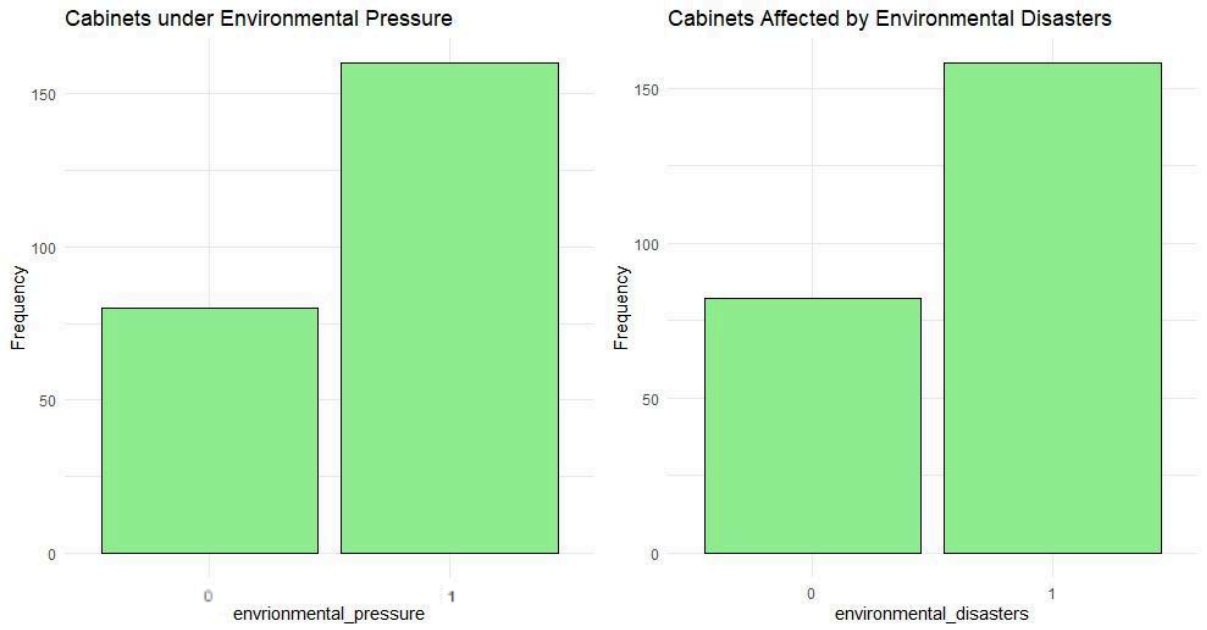
Source: own elaboration.

Figure two presents six of this research's features. In the top-left corner, it is evident that the majority of cabinets in the data frame originate from the 2000s and 2010s, aligning with the research's time frame spanning approximately from 1995 to 2023. Notably, the frequency graph in the top-left corner highlights a substantial incidence of tax policy-related protests, with 50 out of 214 cabinets experiencing anti tax change protests involving at least 5000 people.

Moving to the middle-left corner, a notable observation is that the majority of cabinets predate the 2015 Paris Agreement. In the middle-right corner, the graph indicates that a significant majority of cabinets in the data frame were not caretaker cabinets, affording them the opportunity to propose new policies.

The lower section of Figure two delves into the three primary uses of carbon tax revenues. The "NULL" category in both graphs denotes cabinets without a carbon tax. In the bottom-left corner, the data reveals that adopting revenue-neutral strategies, such as tax reductions or rebates, is a prevalent choice, encompassing nearly half of the cabinets overseeing a revenue-neutral carbon tax. Meanwhile, the bottom-right corner illustrates that around 25% of cabinets allocate revenue to green initiatives. Given the dual possibilities for revenue allocation, some cabinets are represented in both revenue-neutral and green initiative categories. Cabinets directing revenue to the general budget or cases where a political commitment or legal obligation regarding revenue was unverifiable are coded as "0."

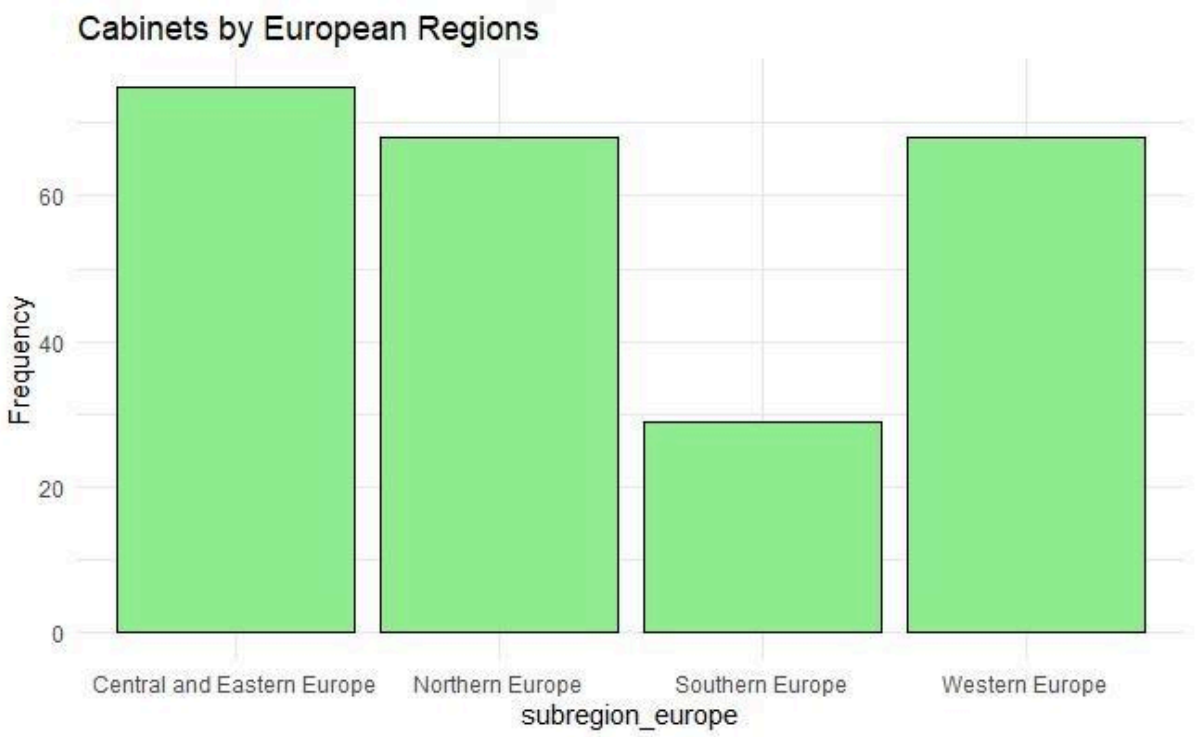
Figure 3 - Environmental features.



Source: own elaboration.

It is interesting to note that both of the environmental features plots present a similar pattern. The majority of cabinets experienced environmental pressure, emanating from international agreed carbon emission reduction targets, and/or environmental disasters during their tenure.

Figure 4 - Cabinets by European regions.

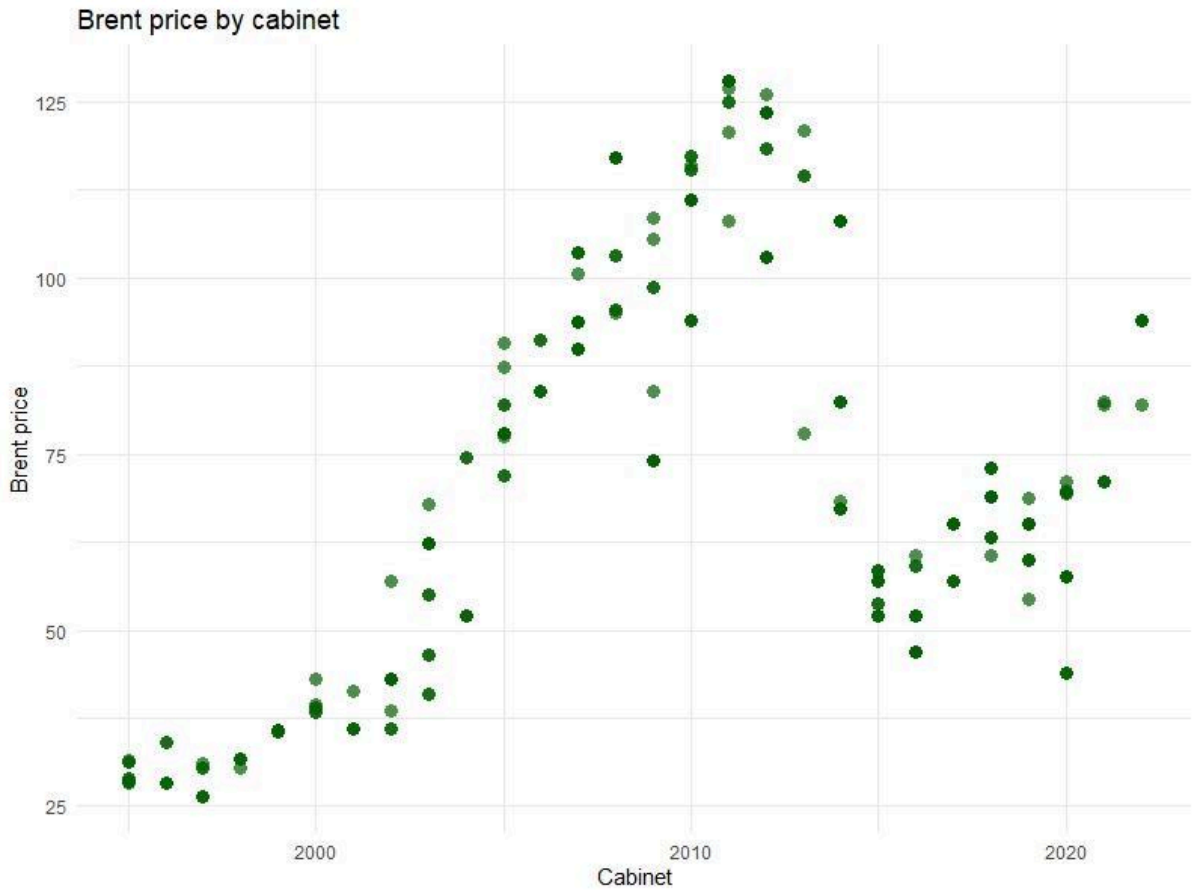


Source: own elaboration.

Examining Figure four, it becomes apparent that most regions are similarly represented, with the exemption of Southern Europe. This is the case, because this region represents only six countries, and three of them (Cyprus, Italy, and Malta) were not included in this research.

.

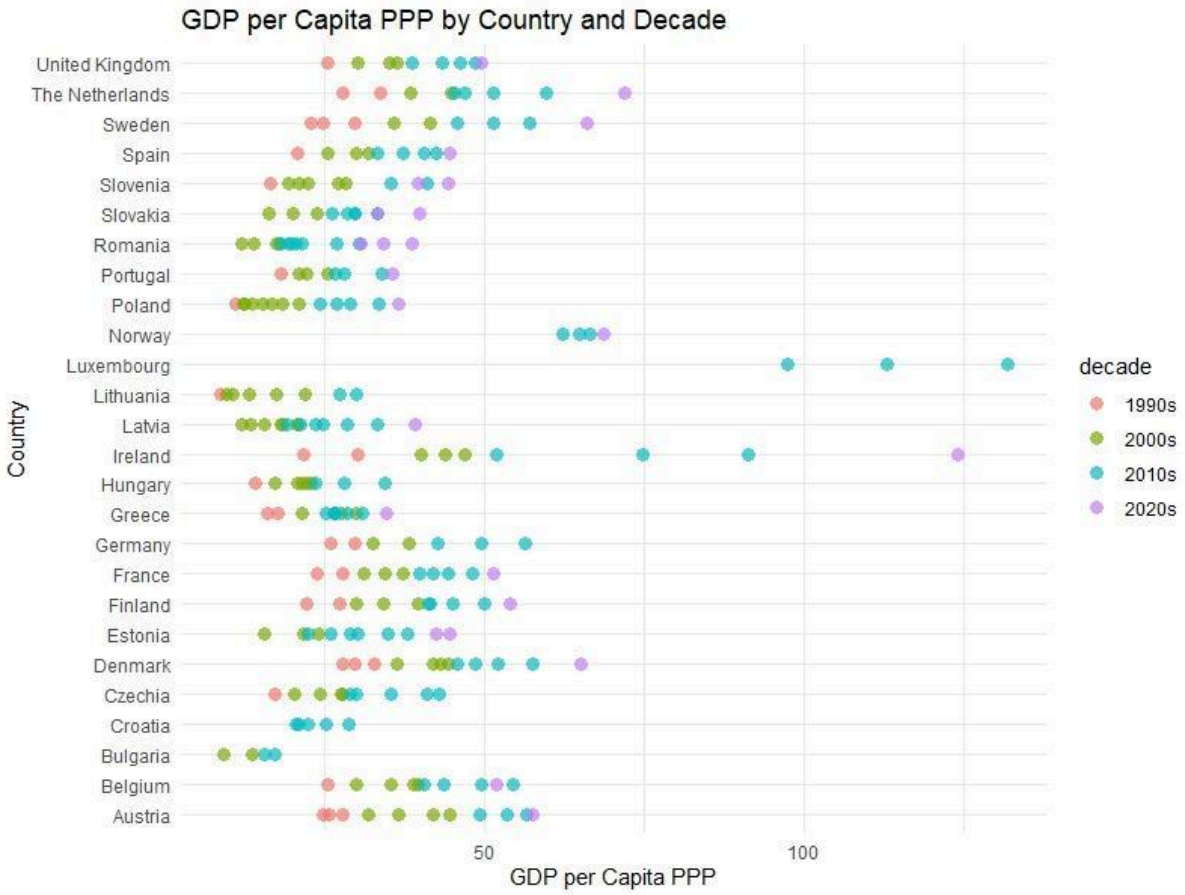
Figure 5 - Brent price.



Source: own elaboration.

In Figure five, the arrangement of cabinets is based on their first year in office for visualization purposes, as the Brent prices represented are the average values for the years the cabinet held power. These prices are adjusted for inflation using 2019 as the base year. Notably, there is a discernible trend of rising oil prices from around 2002 to 2012, followed by a pronounced decline between 2013 and 2015. In the more recent years, there is a notable upswing in Brent prices.

Figure 6 - GDP per capita (PPP).

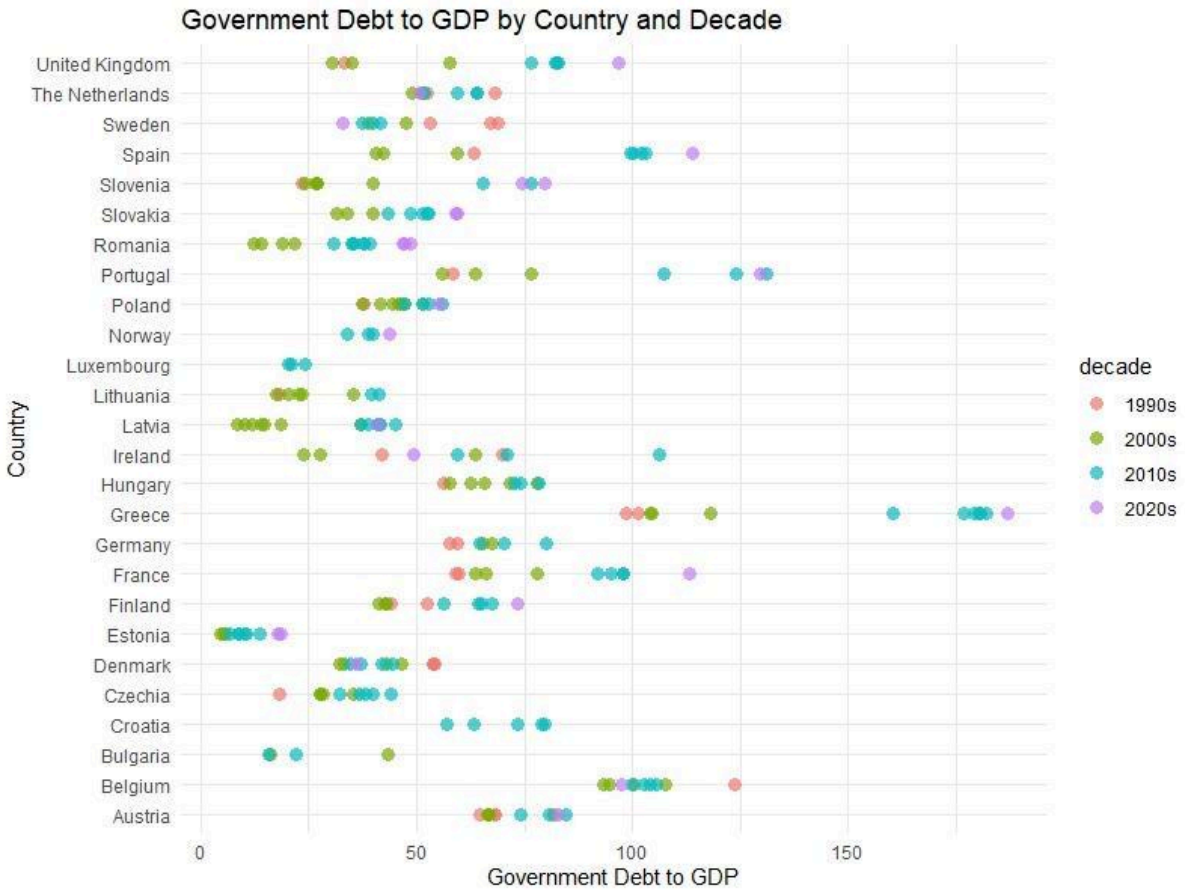


Source: own elaboration.

Observing the plot above, it is evident that almost all cabinets across various countries experienced an increase in their GDP per capita (PPP) over time. Despite this general trend, some exceptions are notable, such as Belgium and Slovenia in the 2020s. Remarkably, Ireland represented the highest GDP per capita (PPP) growth and larger change of all the countries in the research, while Norway had the lowest growth and smaller change.

Notably, there is a substantial variation in this feature among the cabinets in the study. Luxembourg, for instance, had a cabinet overseeing the wealthiest economy in the study, with a per-person GDP exceeding 125 thousand dollars, while Bulgaria's cabinets consistently recorded figures below 25 thousand dollars per person.

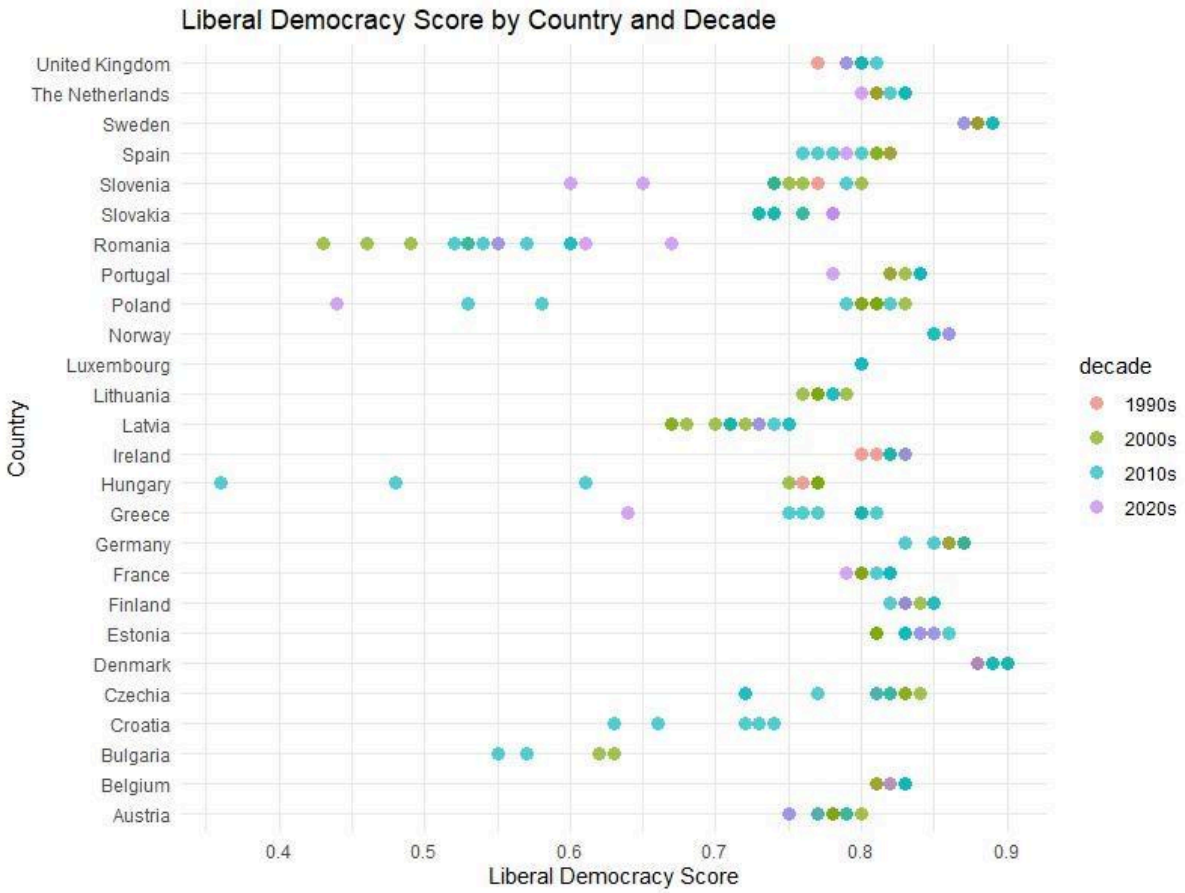
Figure 7 - Government debt to GDP.



Source: own elaboration.

Figure seven demonstrates that the "Government debt to GDP" feature also presents a high variation between the overall cabinets, and between each country's cabinets. Estonia consistently exhibits the lowest levels of government debt to GDP on the lower end of the spectrum, while Greece represents the highest. Cabinets in countries such as Estonia, Norway, and Luxembourg present a low variability when compared with cabinets in countries such as Greece, Portugal, and Spain. It is noteworthy that, despite a general trend of increasing debt levels over time for most cabinets in countries, some exceptions can be pointed out, such as Sweden.

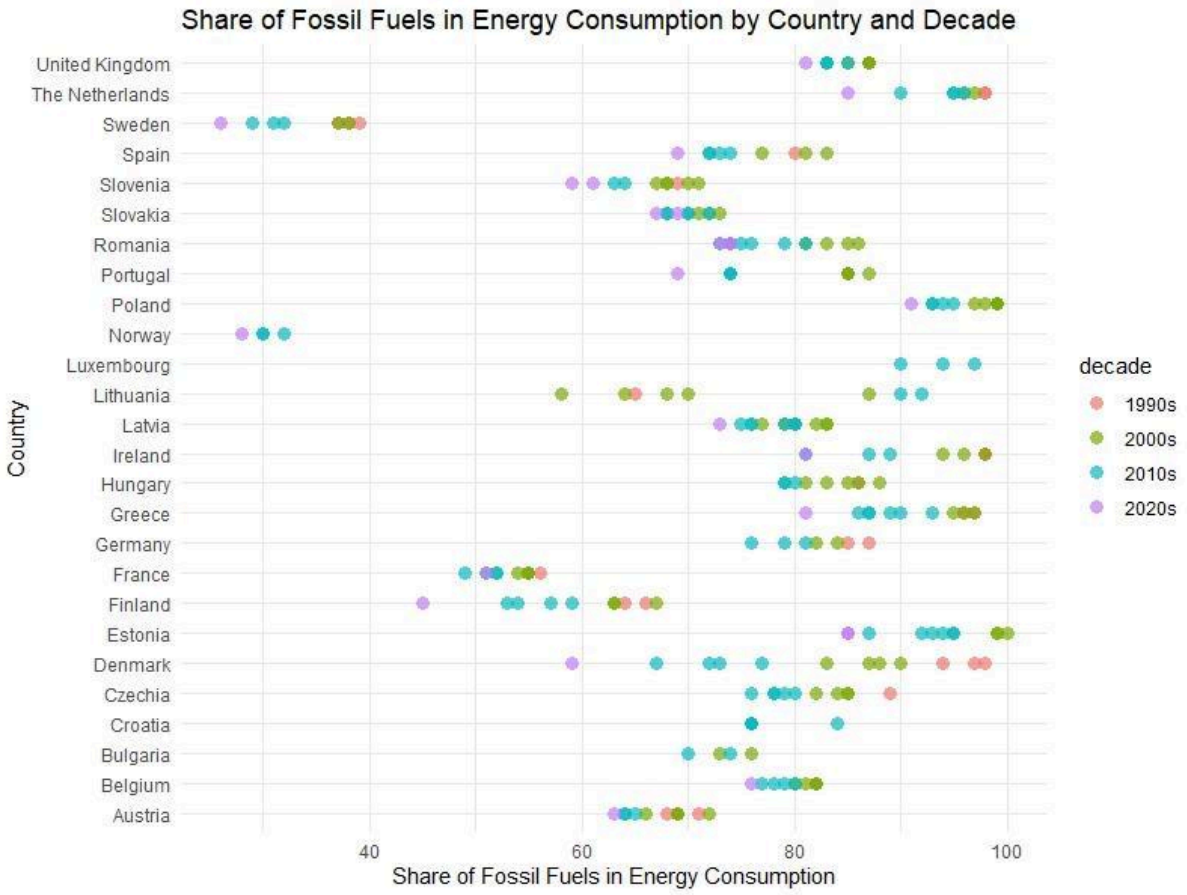
Figure 8 - Liberal democracy score.



Source: own elaboration.

The plot above shows that most cabinets in this research have a high liberal democracy score. However, it also underscores some countries have experienced a significant democratic backsliding in the last decades, with the most outstanding examples being Hungary and Poland. These countries had cabinets that successively deteriorated the democratic institutions. While other countries in this research also had cabinets that presented a lower liberal democracy score, such as France and The Netherlands, than their previous cabinet, the scale of change was considerably smaller. Denmark and Sweden emerge as countries with cabinets attaining the highest scores, while Hungary records the lowest score.

Figure 9 - Share of fossil fuels in energy consumption.



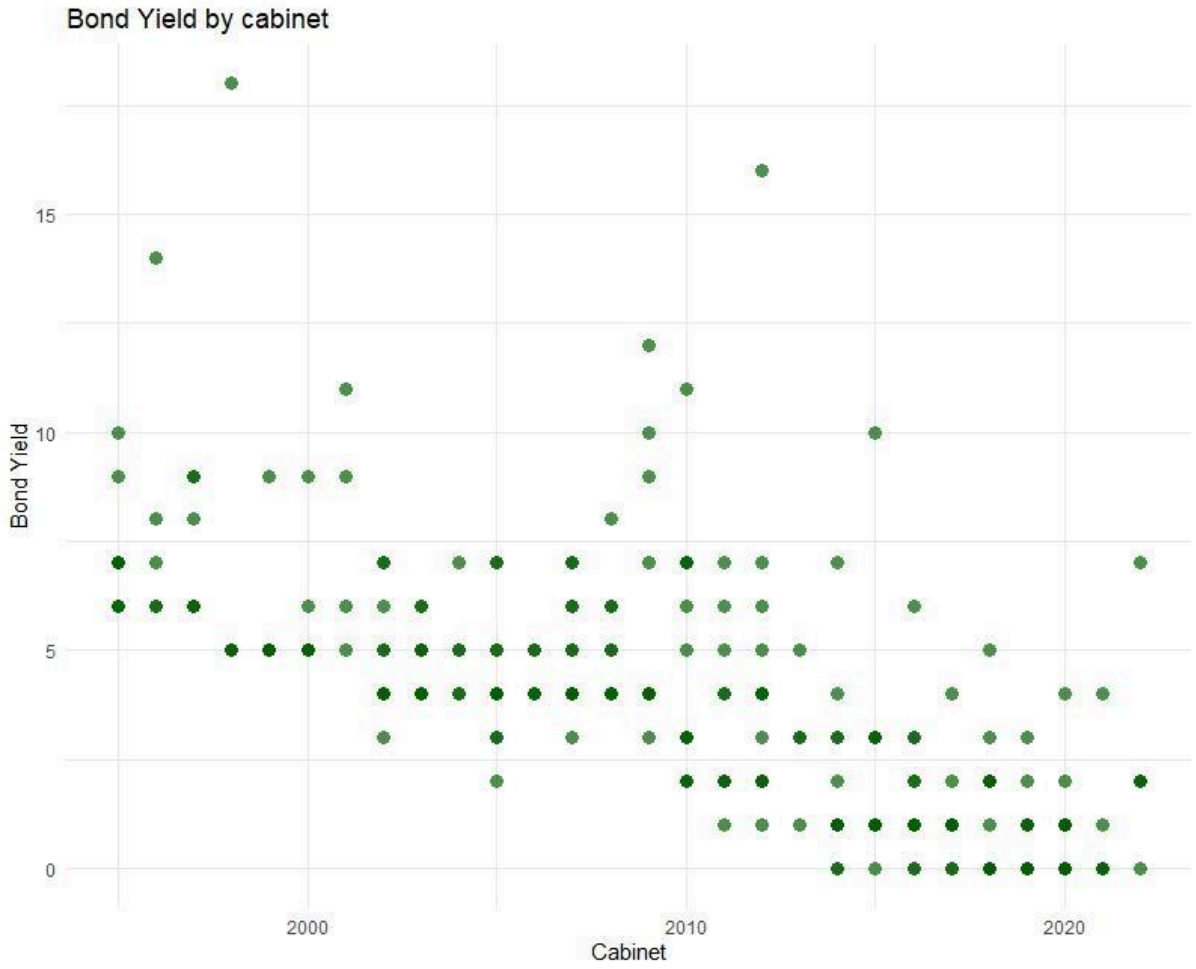
Source: own elaboration.

Figure nine, reflects the efforts of the countries in this research to decarbonize their economies. Almost all cabinets had a lower share of fossil fuels in energy consumption than the previous cabinet in their respective countries. While Sweden and Norway stand out with the lowest shares, other nations like Denmark and Finland achieved substantial reductions. Cabinets in countries which do not have a carbon tax also presided over strong reductions when compared with previous cabinets, examples of this can be seen in Greece and Spain.

Even nations with successive cabinets skeptical of climate change or the human contribution to it, such as Poland and Hungary, have witnessed a decline in the share of fossil fuels in energy consumption. This can be probably explained by their EU membership, which involves being a part of the EU ETS and having renewable energy production and carbon emissions targets. Only Lithuanian cabinets have had an increase in the use of fossil fuels, this can be attributed to the closure of its only nuclear power plant in 2009, which at the time represented about 30% of the country's energy consumption[62].

[62] https://ourworldindata.org/grapher/share-energy-source-sub?country=~LTU

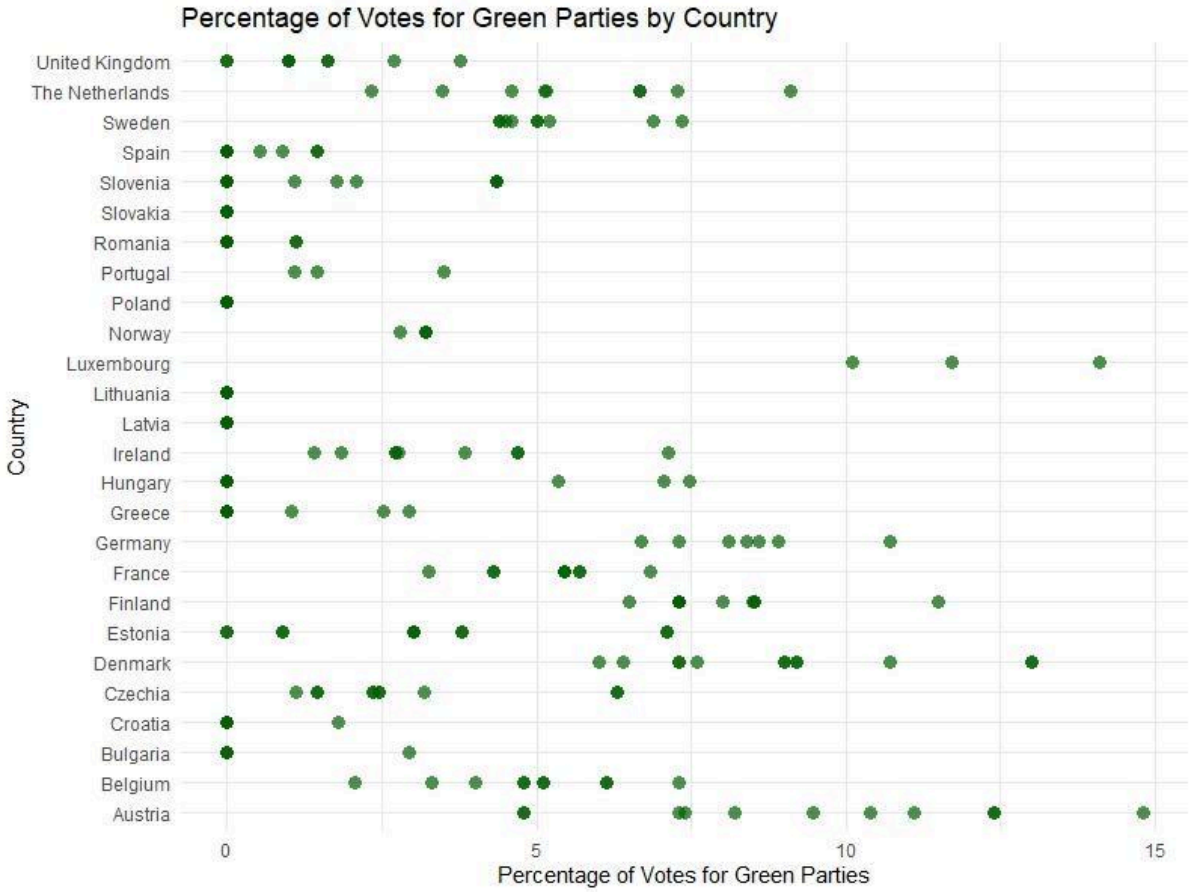
Figure 10 - Bond yield.



Source: own elaboration.

Observing the plot above reveals a prevailing trend of decreasing interest rates over the last decade, with numerous cabinets experiencing rates as low as zero percent. This indicates that even cabinets with high debt levels likely not facing a strong financial pressure. For instance, Greece, by far the most indebted country in this research, which had a cabinet facing a 16 percent average interest rate at the height of the Euro crisis, had its latest cabinet (in the 2020s) working with a 2 percent interest rate.

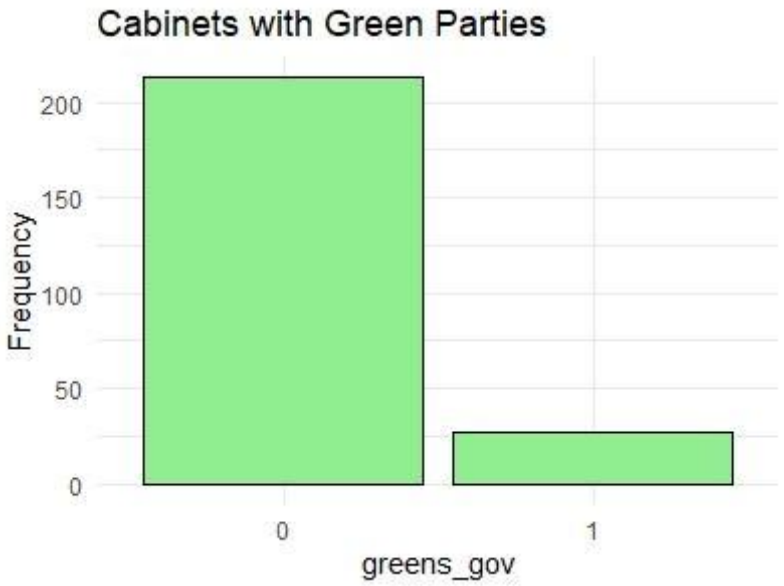
Figure 11 - Green parties election's results.



Source: own elaboration.

Figure eleven illustrates the percentage of votes secured by green parties, categorized by country, in the most recent election for each cabinet. A discernible pattern emerges, revealing a more robust presence of green parties in Western Europe as opposed to Eastern Europe. Notably, some Eastern European nations do not feature a green party at all. Even within the United Kingdom's first-past-the-post voting system, which tends to discourage support for non-mainstream parties, green parties have achieved a higher share of the vote compared to certain Eastern European countries with a plurality-based voting system, as exemplified by Poland.

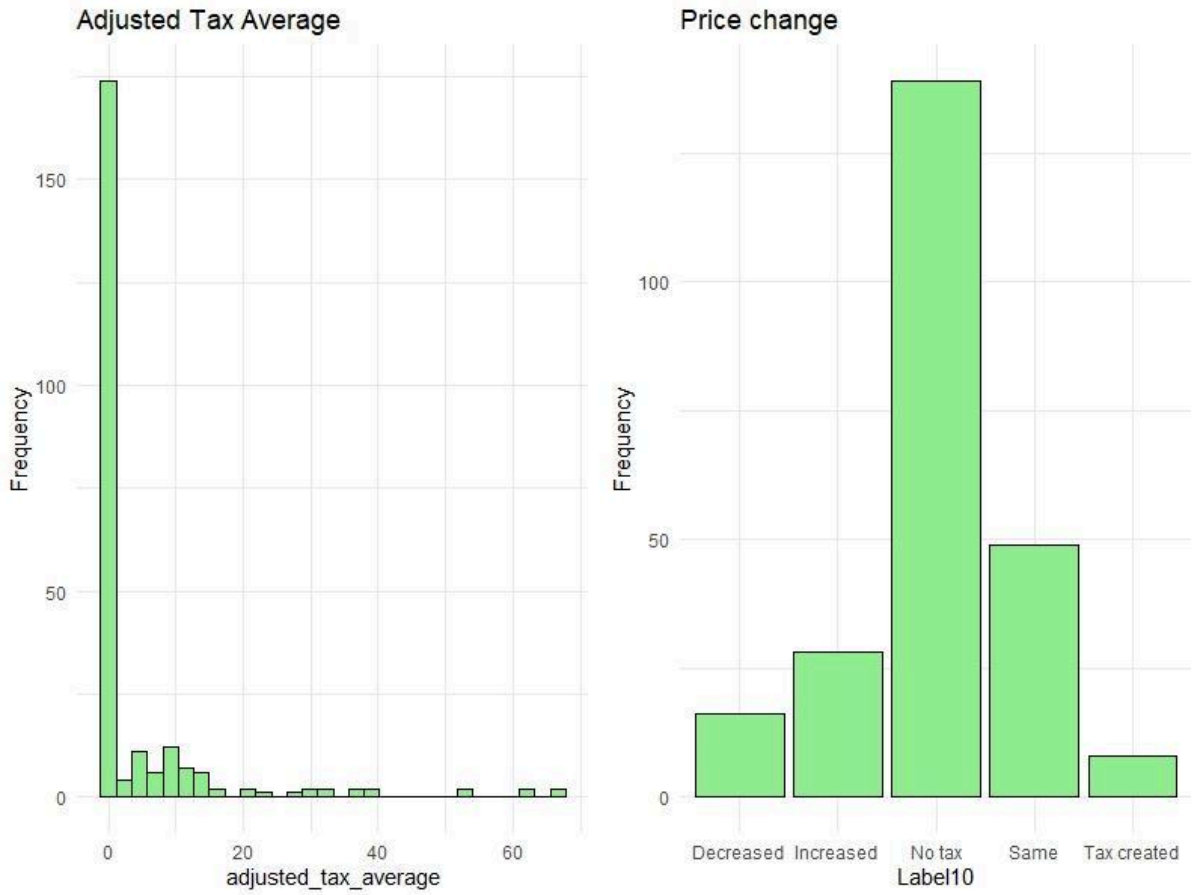
Figure 12 - Number of cabinets with green parties.



Source: own elaboration.

In Figure twelve, it is evident that the presence of green parties in cabinet coalitions remains relatively rare. This reaffirms earlier observations, emphasizing the greater electoral success of green parties in Western European countries. Notably, in the data frame, green parties have yet to participate in the government of any Eastern European country.

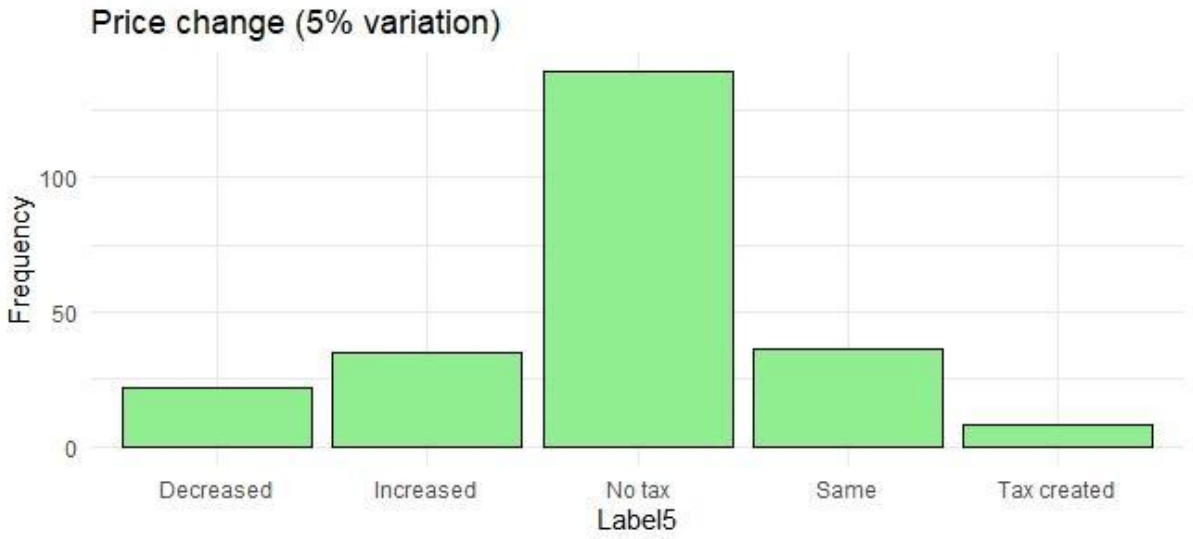
Figure 13 - Tax price and 10% threshold variation.



Source: own elaboration.

In Figure 13, the left side reveals that the Emissions-weighted carbon tax rate across cabinets in the data frame was predominantly zero. When focusing on tax rates exceeding one euro, the majority of cabinets feature rates below 18 euros. On the right side, the depiction of tax rate changes at the 10% variation threshold, categorized into five groups, illustrates that most cabinets did not have a carbon tax. Among those with a carbon tax, the majority maintained a stable rate. Notably, eight cabinets opted to introduce a carbon tax during their tenure.

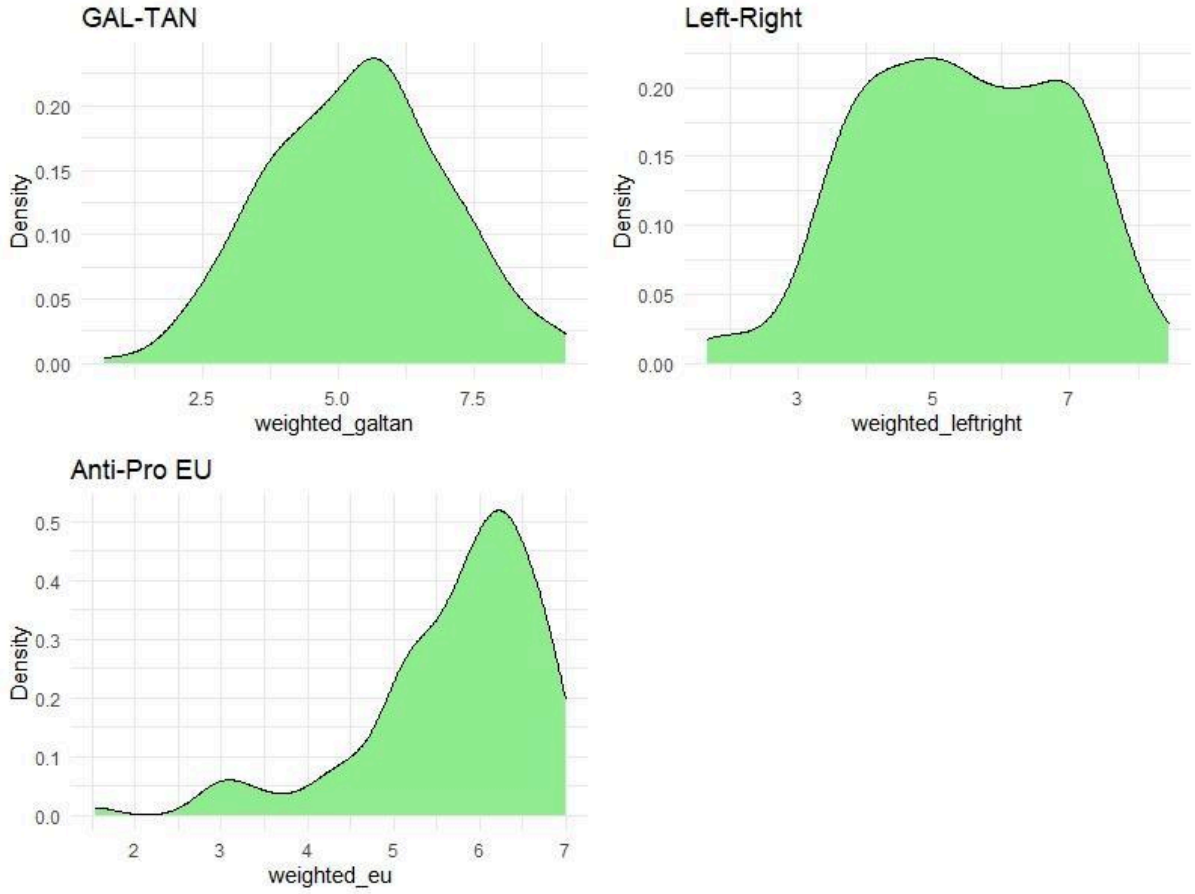
Figure 14 - 5% threshold variation.



Source: own elaboration.

Comparing the plot above with the 10% price variation plot on Figure thirteen, one can discern a reduction in the "Same" category, leading to higher frequencies in both the "Decreased" and "Increased" categories. This suggests that a significant number of variations occur below the 10% threshold.

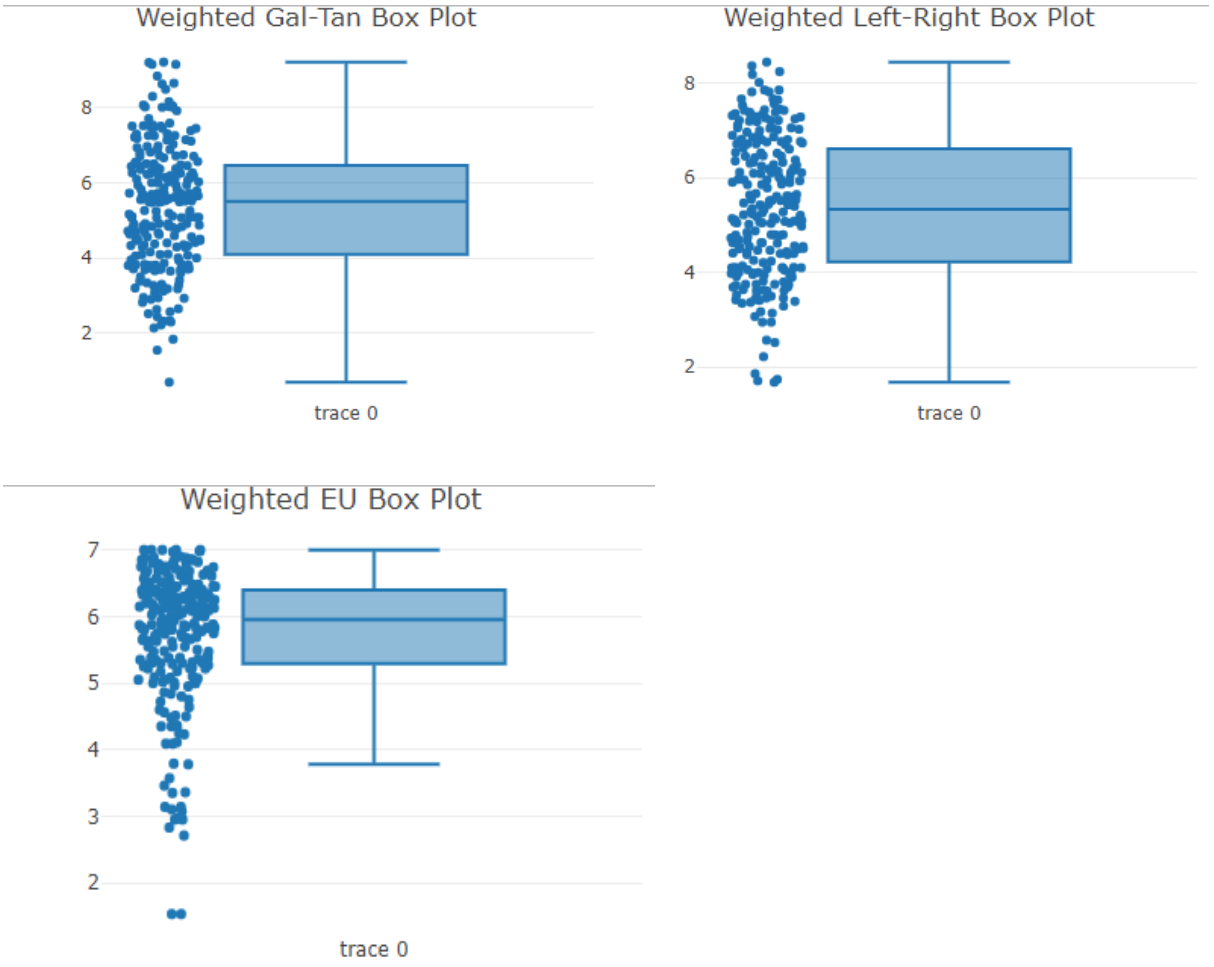
Figure 15 - Ideological features' density plots.



Source: own elaboration.

Figure fifteen provides visual representations of the distributions of data for the ideological features. Notably, the density of the "weighted_galtan" variable is closer to a normal distribution. In contrast, the distributions of "weighted_leftright" and "weighted_eu" lean towards platykurtic and leptokurtic shapes, respectively. Specifically, the distribution of "weighted_eu" reveals a concentration of cases closer to seven than to three and a half, indicating a prevalence of europhile cabinets in the data frame. Additionally, the distribution highlights the presence of outliers in the left tail, contributing to the asymmetry observed in the data.

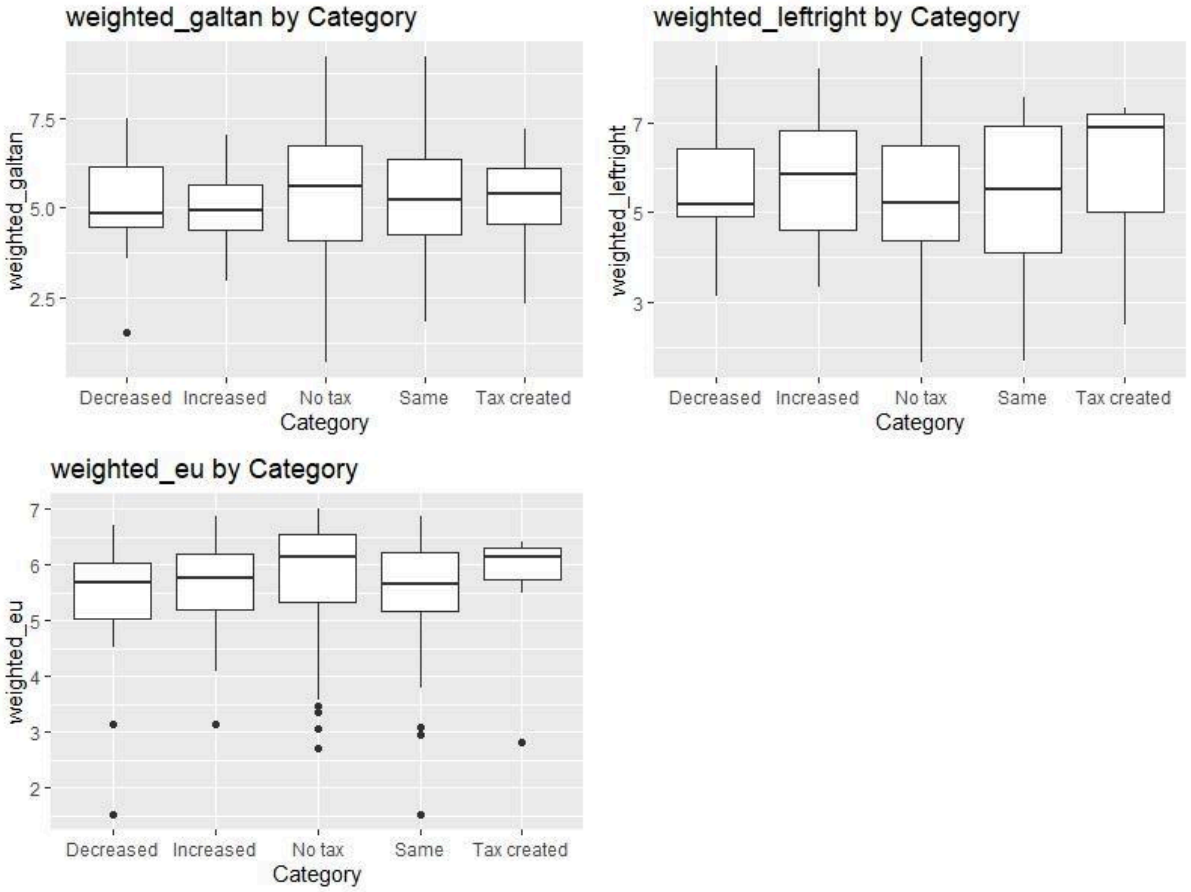
Figure 16 - Ideological features scatter plots with box plots.



Source: own elaboration.

In Figure sixteen, both scatter and box plots visualize the ideological features, reiterating the patterns observed in Figure fifteen. It is noteworthy that the presence of potential outliers in the "weighted_eu" variable are even more evident. It becomes apparent that values below four for this variable are likely outliers.

Figure 17 - Box plots of ideological features by category.



Source: own elaboration.

In Figure seventeen, the box plots detailed in Figure sixteen are further elaborated by categorization. The top-left graph draws attention to a potential outlier within the "Decreased" category for the "weighted_galtan" feature. Aligning with earlier observations, several possible outliers are flagged in the weighted_eu feature.