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# Transport Taxes and Decarbonization in Spain: Distributional Impacts and Compensation

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## Abstract

The importance of energy-environmental taxation in the transition to decarbonized economies does not correspond to its actual role due to several constraints on its application. This paper emphasizes one of the main barriers, distribution and equity, and suggests alternatives to mitigate its effects. In particular, it lists a series of fiscal proposals for road transport and aviation, sources of significant emissions, defined and empirically evaluated for the specific case of Spain, with compensatory packages to reduce their regressive nature and thus support their viability in practice.

**Keywords:** energy, environment, distribution, aviation, hydrocarbons

**JEL classification:** H23, H31, I38, Q48; Q58, R48.

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## 1. Introduction

The risks and threats of current environmental problems pose a major challenge to public policies. In the Paris Agreement (UN, 2015), most countries in the world[1] are committed to maintain the increase in average global temperature below 2°C. The European Union (EU) has led international efforts in this area through the enactment of ambitious goals to reduce greenhouse gas (GHG) emissions, prominently among them carbon dioxide ($CO_2$), by 40% in 2030 as compared to 1990 (European Union, 2015)[2]. To achieve this objective, a key policy instrument is the so-called carbon price, particularly through the use of energy-environmental taxation (EET). This approach enjoys widespread support from academia (e.g. Fullerton et al, 2010; Ekins and Speck, 2011; Gago et al, 2014a) as well as from international institutions (e.g. European Commission, 2015, 2017; OECD, 2015, 2018; OTA, 2017; EAERE, 2019; CLC, 2019a, 2019b; IMF 2019), but still is far from a global and meaningful implementation[3].

Perhaps the main reason for failing to meet EET expectations rests in the institutional, competitiveness, and distributional limits conditioning its practical application. Corrective tax policies are complex, require broad consensus, and special attention to the losers (taxpayers, economic sectors, territories) with selective compensatory devices. The management of the preceding issues defines the condition for good applicability, but the distributional argument probably requires most attention and an accurate assessment.

The main negative impact of EET is indeed associated to effects on income distribution. The distributional profile of these taxes mostly depends on the consumption patterns of taxpayers, on the tax design and on the level of development of the territory of application. There is significant variation on the distributional impacts associated to the aforementioned matters[4], but in general energy costs required to cover basic needs represent a larger share of low-income household expenditure and thus acceptance of EET

[1] To date the Paris Agreement has been ratified by 186 countries and the European Union (UN, 2019).
[2] In recent months the European Parliament has advocated a substantial increase in commitments to reduce GHG emissions. For its part, the new European Commission has put the fight against climate change at the centre of its priorities and therefore proposes a 50% reduction in GHG emissions (if possible, 55%) by 2030 compared to 1990 (see von der Leyen, 2019).
[3] There are nowadays 56 carbon pricing schemes in the world (compared to 47 in 2018, 19 in 2010 or to just 7 in 2000), but they just cover 20% of global GHG emissions, and only 5% use a price at a level consistent with achieving the Paris temperature targets (World Bank, 2019a). The price that would be in line with the Paris Agreement ranges between 40 and 80 US$/t$CO_2$ in 2020 and 50-100 US$/t$CO_2$ in 2030 (CPLC, 2017). For its part, the International Monetary Fund (IMF) indicates that increasing carbon price to 75 US$/t$CO_2$ in 2030 would achieve the Paris target if it is implemented globally and combined with investment policies and other measures for non-fossil emissions (IMF, 2019).
[4] Taxes on private vehicles and fuels are generally less regressive than those on energy consumption for heating and on electricity, especially in developing countries (De Mooij et al, 2012). In fact, taxes on motor fuels might have a positive distributional impact in many developing economies (Peters, 2012; Labeaga et al, 2018).

requires special care in calculating and compensating such effects. Compensation is possible[5] (Klenert et al, 2018) and could be designed to maintain the previous distribution of income or even improve it.

These issues are particularly relevant in Spain, a country with low EET in relative terms, and where significant tax changes will be needed over the coming years to facilitate the low-carbon transition. This is the context of the paper, which aims to provide a comprehensive distributional evaluation of several reform proposals of Spanish EET, already presented in Gago et al (2019; 2020). In particular, this piece of research focuses on the transport sector, with the largest share of Spanish GHG emissions in 2018 (27%) and which has increased 2.7% relative to the previous year. More than 92% of these emissions correspond to road transport and thus special attention is placed on the reform of current taxation in this area. Emissions from the aviation sector are comparatively lower (6.4% of total emissions, including international aviation), but they have experienced a strong increase throughout recent years that is likely to continue unless additional measures are taken (Ministry for Ecological Transition, 2019a). This justifies the inclusion and distributional analysis of a hypothetical Spanish tax on airline tickets.

The article is organized in six sections, including this introduction. The second section discusses the importance of the EET in the transition to low-carbon societies and shows the anomalous Spanish situation in this area. The third section considers the potential distributional problems of EET and the alternatives to offset them. The fourth section presents different Spanish EET in the transport sector and evaluates them in terms of revenue, emissions and income distribution to ultimately consider different compensatory alternatives. The final section concludes and highlights relevant policy implications.

## 2. Energy-environmental taxes and low-carbon transition

### *2.1. Foundations and international context*

Although there are several regulatory approaches to address environmental problems (see Labandeira et al, 2007), a number of advantages make taxes a particularly suitable instrument. From a static point of

[5] Compensation could be applied in various ways. A straightforward approach could employ vouchers or checks for the poorest households without affecting the price incentives to consume less energy. Other alternatives could be linked to personal income taxation, for example by acting on income exemptions or incorporating a specific deduction conditioned by income and of a reimbursable nature. In general, the literature shows that the groups with the lowest income will benefit most from lump-sum transfers, so that a more progressive but less efficient situation would be achieved by reducing overall disposable income. If, on the other hand, the additional revenue is used to reduce social security contributions, the overall household disposable income would increase but would affect negatively (in relative terms) low-income groups.

view, they act as a price for polluting and allow for internalizing environmental damages while minimizing the total costs of achieving environmental objectives (see Fullerton, 2001; Stavins, 2003). From a dynamic perspective, taxes provide continuous incentives to reduce pollution by encouraging agents to invest in cleaner technologies and production processes that allow them to reduce pollution levels and, thus, pay less taxes in the future (see Requate, 2005).

Environmental taxes are particularly important in the energy sector, where public intervention is essential in correcting environmental externalities. Many of the current environmental problems relate either directly or indirectly to the extraction, production, transport and/or consumption of energy products (see Gago et al, 2014b; Ecofys, 2014; Rabl and Spadaro, 2016; van Essen et al, 2019). In the case of climate change, the activities of the energy sector are the main source of GHG emissions: 79% of total emissions in the EU (77% in the case of Spain) in 2017 (Eurostat, 2019b). However, energy taxes are usually below the desired level from an environmental point of view and have shown no significant improvement in recent years[6] (OECD, 2019b). Their profile has traditionally been associated with revenue raising because energy products generally have low price elasticities and therefore can provide sizeable and stable public receipts when taxed (see Labandeira et al, 2017). In 2017 energy-related taxes (mainly on motor fuels) represented 4.7% of EU tax revenue and 1.8% of its GDP[7] (European Commission, 2019a).

However, some countries have introduced environmental factors into the structure of conventional energy taxes to increase their capacity to influence environmentally harmful behaviour, thereby giving rise to the so-called EET. Others have also used these levies as part of broader tax reform packages, the so-called Green Tax Reforms (GTR), characterized by the implementation of these taxes in a revenue-neutral context and the simultaneous reduction of other distortionary levies (see Gago and Labandeira, 1999; Gago et al, 2016; Gago et al, 2019)[8]. The first GTR, mostly in Scandinavia during the early 1990s, employed strong environmental taxes and used their revenues to reduce personal income taxes. By the beginning of the 21st century a second generation of GTR, led by Germany and the UK, raised conventional energy taxes and devoted their revenues to reduce social security contributions. Over recent years, some countries have implemented a third generation of GTR that promotes a more flexible and

[6] In any case, in recent years effective carbon tax rates have increased substantially on road transport and some countries have extended these taxes to emissions from other sectors (OECD, 2019b).
[7] In other developed countries such as Australia, the United States and Japan, the share of these taxes reached 6.4%, 2.6% and 4.5% of total tax revenues and 1.8%, 0.7% and 1.4% of GDP in 2016, respectively, while in China energy taxes accounted for 3.6% of tax revenues and 0.7% of GDP in 2015 (OECD, 2019a). Within EET, carbon tax revenues are showing a remarkable increase: 25% in the latest reported year and are expected to follow this path in the future (World Bank, 2019a).
[8] The theoretical foundations for the introduction of GTR are found in the so-called "double dividend" (environmental and fiscal) theory of environmental taxes (Goulder, 1995).

heterogeneous use of revenues in response to the disturbances brought about by the great recession and to the needs of low-carbon transition (see Gago et al, 2016). Indeed, this paper pays special attention to the use of tax receipts from EET to improve their distributional profile[9].

### *2.2. The Spanish tax anomaly*

Although EET are likely to become central instruments for strategies in the transition towards decarbonized economies and have already played important roles in many advanced countries, Spain has been reluctant to use them based on their alleged negative effects on competitiveness and economic growth (Labandeira et al, 2009). Although empirical evidence for Spain shows that EET could actually generate significant tax revenues with reduced macroeconomic effects and moderate distributional impacts (see Gago et al, 2014a, 2019), so far they have had scarce relevance within the Spanish tax system. Given the lack of interest from the central government, Spanish regions introduced several EET whose environmental and economic assessments have been, overall, negative (see Gago and Labandeira, 2014; Gago et al, 2014b; CERSTE, 2014; OECD, 2015, Montes, 2019). This is mainly explained by the fact that regional EET has usually responded to revenue-raising reasons of revenue rather than to environmental objectives (with inadequate definitions of tax bases and rates).

This explains the limited relevance of Spanish EET, in terms of total public revenues or GDP, when compared to other EU countries[10]. The share of taxes in final prices of most energy products, both for residential and industrial use, is also below the average of the EU countries of the OECD (IEA, 2019). It is therefore no surprise that several international bodies (IEA, 2015; OECD, 2015, 2018; European Commission 2017; IMF 2018), as well as expert committees set up by the Spanish government itself (CERSTE, 2014; CERMFA, 2017; CERSFL, 2017; CETE, 2018) have strongly insisted on a substantial increase in these taxes given the needs of Spanish public finances and the growing environmental concerns.

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[9] For example, the Swiss $CO_2$ tax provides about two-thirds of its revenue to households and companies (FOEN, 2019); France allocates most of its carbon tax revenues to tax credits for competitiveness and employment (Government of France, 2017), also providing support to low-income households affected by higher energy prices (World Bank, 2019a); while the carbon price introduced by Australia in 2012 (and abolished in 2014) earmarked part of its revenue to increasing household benefits and supporting employment in the most affected industries (Australian Government, 2011). In the case of Canada, in 2018 the federal government introduced a carbon tax framework that granted individual provinces and territories flexibility in designing their own policy and revenue use (Government of Canada, 2016), which in several cases have allocated part or all of the revenue to compensating households (World Bank, 2019a).

[10] In 2017 EET represented 4.5% of Spanish tax revenues and 1.5% of its GDP, compared to 4.7% and 1.8%, respectively, on average in the EU (European Commission, 2019a) and well below the shares in major European countries (Germany, France, Italy and the United Kingdom).

### 3. Energy taxation, distributional impacts and compensation

As aforementioned, EET may be associated to negative impacts on the distribution of household income[11]. Energy costs, and thus tax burdens, generally represent a higher proportion of expenditure in low-income households, which tend to consume more energy-intensive products to cover their basic needs given their limited possibilities to substitute them (Wang, 2016). In addition, financial restrictions preclude these households from acquiring more energy-efficient durable goods and thus from reducing energy consumption (Zachmann et al, 2019). Also, the regressive impact of EET is greater (especially for young people) if household wealth is taken into account because it is usually more concentrated than income across population groups (Teixidó and Verde, 2017). In any case, other factors unrelated to the level of household income also influence the distributional impact of EET, e.g. area of residence, type of housing, size of household or availability of public transport alternatives. In general, EET mostly impact households in sparsely populated areas requiring extensive travel, in areas with no public transport infrastructure, or when a very carbon-intensive electricity mix coexists with inefficient housing (Carl and Fedor, 2016).

The distributional impact of EET also depends on the energy product considered. Transport taxes are generally less regressive than those levied on electricity or heating fuels because households in lower income deciles are less likely to own a car and therefore spend a lower share of their income on motor fuels (Ekins and Speck, 2011; De Mooij et al, 2012; Flues and Thomas, 2015). In fact, as indicated before, in certain cases the impact of EET levied on transport might even be progressive (Rausch et al, 2010; Sterner, 2012; Renner et al, 2018, Labeaga et al, 2018). However, transport taxes may cause spatial inequalities because rural households generally spend a higher share of their income on fuel to commute longer distances in areas with limited means of public transport (Titheridge et al, 2014). On the other hand, taxes on air transport are thought to generate a progressive impact because high-income households make a greater use of air travel (Zachmann et al, 2019), even though making low-cost airline tickets more expensive may change the sign of their distributional profile (Falk and Hagsten, 2019). The country's level of development is another important factor in determining distributional effects: EET are more likely to be progressive in developing countries because poor households tend to spend a smaller proportion of their income on polluting goods (Heine and Black, 2019). In the case of rich countries, on the contrary, sizeable and increasing income distribution inequality may exacerbate the negative distributional profile of EET (Andersson, 2019).

[11] This article focuses on the short/medium-run impacts, although it is also important to account for the distributional effects on future generations (see Svenningsen and Thorsen, 2020).

It was already noted that the large public revenues associated to EET may be used with several purposes. Actually, the distributional effects of energy-environmental taxation will critically depend on how the generated revenue is employed, making the recycling of revenue an essential element of any tax reform proposal (Pomerleau and Asen, 2019). As indicated in section 2.1, the first GTR targeted revenue neutrality by reducing other distortionary taxes and thus prioritized the reduction of economic inefficiencies over distributional matters (De Bruin et al, 2019). In this case, the final outcome will depend on the tax targeted for reduction: with progressive personal income taxation, the tax shift will tend to hurt low-income households. Conversely, a reduction in VAT (which tends to be regressive, as low-income consumers tend to spend a larger proportion of their income) could offset negative distributional impacts (World Bank, 2019b)[12]. On the other hand, the impact would be regressive when the revenue is used to reduce corporate taxation because it will mainly benefit the wealthiest households (Pomerleau and Assen, 2019).

The main way to address the distributional problems associated with EET is through direct transfers, either universal or targeting less affluent households[13]. The empirical evidence suggests that only a small part of the revenue would be required to compensate the adverse distributional effects through targeted transfers (see Vivid Economics, 2012; Morris and Mathur, 2014; Dinan, 2015; Berry, 2018). Besides, these policies tend to be popular (Carattini et al, 2018) and their administrative costs are relatively low because they are generally done in cash or easily incorporated into existing systems[14] (World Bank, 2019b).

Alternatively, generalized (lump-sum) transfers could be used when EET have no remarkable impact on poor households or when the determination of affected households is not straightforward. These transfers may seem counter-intuitive from a distributional perspective as they would also compensate rich households, but they might be progressive because the compensation, although equal in absolute terms, would generally be larger in relative income terms for poorer households. Moreover, transfers received by poor households are likely to be larger than the increase in expenditures resulting from the tax because poor households consume less energy, in absolute terms, than do rich households (Carattini et al, 2018).

[12] However, reducing the price of energy products through VAT may negatively affect incentives for energy saving and conservation (Zachmann, 2019).
[13] In both cases, transfers can be calculated by using an equivalence scale or directly per capita.
[14] Such transfers can be difficult to design effectively without creating perverse incentives. On the one hand, many households may be largely affected because of their spatial location and not their income status; on the other hand, if only households below an income threshold receive the transfer, those close to the threshold could have an incentive to (inefficiently) reduce their income to be eligible. Yet, if the system becomes too complex to avoid such perverse incentives, poorer households may be less able to participate (Zachmann et al, 2019).

Another argument in favor of this type of transfers is political stability as, once established, they are difficult to suppress given their benefits across the electoral spectrum (Carl and Fedor, 2016; Schultz and Halstead, 2018; Marten and van Dender, 2019)[15].

Tax revenues may also be used to finance programs that subsidize energy efficiency improvements and help households reduce energy use and costs (CPLC, 2016). However, these subsidies are generally regressive because only affluent households have the capital to invest in new assets associated to low carbon emissions[16]. Indeed, subsidies for energy-efficient investments in the building sector are likely to benefit high-income households that own homes and have the means to retrofit them (Zachmann, 2019). Subsidies for clean vehicles benefit households that can afford a vehicle, and they also incentivize the purchase and use of private vehicles through fleet expansion (illustrated for Norway by Holtsmark and Skonhoft, 2014). To avoid these negative efficiency and equity effects, it could be appropriate to restrict subsidies to low-income households and, in the case of vehicles, to link them to the withdrawal of a dirtier automobile[17].

Recent protests in France against the price implications of carbon taxes on motor fuels, or in Chile and Ecuador over increases in transport costs, have probably uncovered serious problems of social inequality that go beyond the distributional impacts of EET. In fact, over the past few decades income and wealth inequalities have increased in most countries, reflecting the shrinking capacity of governments to address inequality (Alvaredo et al, 2018). In addition, the literature shows that inequality and the regressive impact of EET are strongly correlated (Andersson, 2019). Therefore, a comprehensive tax reform, in which new or higher EET are part of broader redistributive tax schemes, is likely to be necessary so that stronger signals that are compatible with the transition to low-carbon economies are feasible. Note that this approach would be much more than a mere distributional compensation of EET distributional impacts through the use of their tax revenues, which in several countries have not been able to prevent social unrest or opposition to higher EET.

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[15] Yet the amount of transfers could be reduced over time to encourage households to adapt to a low-carbon context, avoiding endless compensations of higher energy costs (which would also counteract the corrective policy).

[16] An additional problem is the existence of free-riders, i.e. subsidies going to households that would have already adopted energy efficiency measures because of the tax. In this case the subsidy would end up being a mere cash transfer, rather than an incentive to additional emission reductions (Marron and Morris, 2016).

[17] Subsidies can also be devoted to promoting low-carbon options, such as public transport or retrofitting of public housing, which are more widely used by poor households (Carattini et al, 2018; Zachmann et al, 2019). Another compensatory alternative would be to return EET receipts through (generalized or restricted to some social groups) reductions in electricity prices or fuel taxes. This approach would provide compensations but would also eliminate the corrective pricing signal, the main objective of the policy (Carl and Fedor, 2016). Tax revenues could also be used to help workers, by improving their skills to the needs of a low-carbon economy, in certain industries or regions significantly affected by the energy transition (CLCP, 2016; IMF, 2019).

Finally, it is important to underscore two issues that are crucial to the proper functioning of distributional compensations. First of all, their salience, i.e. their capacity to be perceived by the agents and thus to increase their effectiveness and viability. Changes in energy taxes are generally accompanied by large media coverage, which makes them very prominent (see Davis and Kilian, 2011; Li et al, 2014). Hence, the mechanism used to offset their distributional impacts must be also salient[18], also requiring a good communication strategy to explain the distributional impacts and offsets to consumers. Moreover, trust in the government and its ability to manage tax revenues in a transparent, fair and effective manner are crucial to the acceptability of tax-based environmental policies (Hammar and Jagers, 2006; Klenert et al, 2018, Criqui et al, 2019). Indeed, the introduction of EET is more difficult when trust in government is low, limiting options for the use of revenues and reducing space for tax reform (Marten and van Dender, 2019).

## 4. Correcting the Spanish anomaly in transport taxation: distributional implications

As discussed in the introduction, this paper intends to contribute in two areas. Firstly, it points out priority actions to correct the Spanish anomaly in the use of EET. This is why the proposed taxes focus on transport as this sector was the largest contributor to Spanish GHG emissions in 2019, and thus intense actions are to be expected if the country intends to comply with decarbonization objectives. Moreover, tax rates on transport in Spain are well below EU average levels, particularly of those in major European countries and there is a clear need to tackle the tax gaps of aviation. A second objective of this paper is to provide detailed information on the distributional impacts of the proposed tax changes and to point out possible compensation mechanisms. In particular, three alternatives are considered: (i) an increase in taxes on motor fuels to reverse the increase of transport GHG emissions during 2018; (iii) a more substantial tax increase on motor fuels to bring them up to the levels of the major European economies; and (iii) the introduction of an aviation tax.

### *4.1. Increased taxation on diesel and petrol*

As indicated, fuel taxes in Spain are well below the EU average. A major tax reform in this area seems advisable given the traditional imbalances in Spanish public budgets and the significant externalities, not

[18] Compensatory transfers can be very salient if they are paid directly to households and at regular intervals (Klenert et al, 2018; Schultz and Halstead, 2018).

only environmental, associated with road transport (see Maibach et al, 2008; van Essen et al, 2011, 2019; Korzhenevych et al, 2014). The paper thus considers two alternatives for increasing motor fuel taxation[19]. Bearing in mind that emissions from the road transport sector increased by 2.6% in 2018 (Ministry for Ecological Transition, 2019a), the first simulation contemplates a tax increase to equalize Spanish petrol and diesel excise taxes[20] and raise them (particularly diesel) until emissions fall by 2.6% (see Table 1). Given the relatively low level of Spanish taxation on motor fuels, a second simulation considers the increase in tax rates to reach the average level of petrol taxation (equalized to diesel) in the four major European countries (Germany, France, Italy and the United Kingdom).

**Table 1. Tax rates considered in the simulations (euros)**

| | Excise tax 2018 | **Simulation 1** | | **Simulation 2** | |
|---|---|---|---|---|---|
| | | Excise tax | Variation (%) | Excise tax | Variation (%) |
| **Gasoline 95** | 0.461 | 0.509 | 10.4 | 0.680 | 47.4 |
| **Diesel** | 0.367 | 0.509 | 38.7 | 0.680 | 85.2 |

Source: IEA (2019) and own calculations

### *4.2. Aviation tax*

Air transport has been experiencing strong and sustained growth in the last decades (ICAO, 2019b), which is expected to double in the next 15-20 years (see Airbus, 2018; IATA, 2018). Given the significant externalities associated with air transport (see van Essen et al, 2019), the environmental costs of aviation will soar throughout the coming years if no action is taken and the sector might become a serious obstacle for the objectives of the Paris agreement (Erbach, 2018). Nowadays the price of airline tickets contemplates none of these externalities, except partly $CO_2$ as the sector is now partially covered by the European Emission Trading Scheme (EU ETS)[21] and by the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)[22] from 2021. In addition, air transport enjoys a singular tax regime characterized by generous exemptions from fuel excises and VAT (except for domestic flights).

[19] The proposal of the IMF (2019) mentioned in the introduction (75 euro/t$CO_2$) would fall somewhere between the two.
[20] Despite the fact that diesel vehicles have higher levels of emissions per liter of both GHGs and local pollutants, the tax rate on diesel fuel is well below the one on petrol in most EU countries and particularly in Spain.
[21] $CO_2$ emissions from aviation were included in the third phase of the EU ETS (2012-2020). However, its application to flights departing from or arriving at an airport outside the European Economic Area, which account for 75% of emissions (Adolf and Röhrig, 2016), was suspended after intense international pressures and the intention to develop a comparable global mechanism within UN framework (Erbach, 2018).
[22] Developed by the International Civil Aviation Organization (ICAO) of the UN, CORSIA is a market mechanism that uses carbon permits to offset emissions that cannot be reduced through the use of technological and operational improvements and sustainable fuels so that the aviation sector does not increase its carbon emissions after 2020 (see ICAO, 2019a).

In this worrying context, it seems necessary to introduce a Spanish aviation tax similar to that of other countries (see Government of the Netherlands, 2019) to moderate demand growth and restrain associated externalities, while equating tax treatments across transport modes[23]. Given the legal and operational complications of introducing fuel taxes or VAT (many bilateral agreements would have to be renegotiated), the most viable alternative would be to levy a tax on air tickets to moderate demand. In order to avoid discretionary tax rates, the paper first considers a tax on $CO_2$ emissions at a rate of 50 euro/t (Simulation 3). However, given the emission by airplanes of other pollutants that considerably increase their climate change impacts[24], the paper also evaluates the extension of the tax to $CO_2$-equivalent emissions (Simulation 4).

Regarding tax design, as approximately 10% of aircraft emissions are produced during airport activity, take-off and landing (LTO cycle) (IPCC, 2006), the proposed levy would consist of two parts: a fixed amount per flight, corresponding to emissions during the LTO cycle, and a variable amount depending on the distance that would cover emissions during the cruise. Table 2 shows the tax rates used in the preceding simulations.

**Table 2. Simulated aviation tax rates**

| | Type of flight | LTO (euro) | Cruise (eurocent/km) |
|---|---|---|---|
| **Simulation 3** | Domestic | 0.645 | 0.482 |
| | International | 0.817 | 0.442 |
| **Simulation 4** | Domestic | 1.193 | 0.892 |
| | International | 1.511 | 0.817 |

Source: Own elaboration

### *4.3. Compensatory packages*

The paper considers different compensatory packages to correct the potentially negative distributional impacts of the preceding tax changes: (i) a lump-sum per capita transfer of the tax revenues from households brought about by the reform[25] (Package A), and (ii) lump-sum transfers that are limited to

[23] The proposed aviation tax could complement the EU ETS because the cancellation mechanism allows for additional national initiatives without affecting the environmental integrity of the market (European Council, 2017). Moreover, neither the EU ETS nor CORSIA cover non-$CO_2$ emissions, which justifies the use of supplementary instruments (Larsson et al, 2019). Finally, in contrast to CORSIA, the tax and market combination would lead to direct emission reductions in the aviation sector instead of relying on carbon credits from occasionally questionable projects.

[24] The impacts may increase up to 40%, without including aviation-induced clouds that may lead up to a doubling of impacts (Lee et al, 2009; Azar and Johansson, 2012).

[25] It could be assumed that tax revenues from other sectors are used for compensatory measures in those sectors.

households in the five lowest income deciles so that their pre-reform situation is maintained in average (Package B). In the case of aviation, as the reform increases the income of all households through a reduction of their expenditure (see Section 5.2.3), the paper contemplates transferring the tax revenue to households in the first five deciles to prevent the tax from driving them out of this transport alternative. Finally, the paper considers (iii) a combined compensation for the additional tax burden and poverty reduction (Package C). In this case, the paper analyzes a 10% reduction of the Spanish poverty rate[26] through lump-sum transfers to households below the poverty line (Foster et al, 1984), considering the poverty line at 60% of median equivalent income (Heindl, 2015)[27].

## 5. Empirical assessment

### *5.1. Data and methodology*

Data on 2018 total consumption of fuels for road transport[28] were obtained from CORES (2019), with the distribution of (non-agricultural) diesel consumption among sectors based on information from Ministry for Ecological Transition (2019b). Data on prices and taxes levied on these products were provided by IEA (2019) and used to compute the pre-reform tax revenues derived from the excise tax on hydrocarbons and VAT. The short-run impacts of tax changes on fuel consumption were calculated using the price elasticities of petrol (-0.253) and diesel (-0.201) obtained for Spain by Labandeira et al (2016) in a meta-analysis of the literature. Post-reform tax receipts were computed with the new fuel consumption, prices and taxes by using the emission factors provided by Ministry for Ecological Transition (2019c) to transform the energy consumed into $CO_2$ emissions.

In the case of aviation, the paper employs the number of air passengers departing from Spain in 2018, distinguishing between domestic and international flights (Eurostat, 2019a). Likewise, the Resident Tourism Survey (INE, 2019b) provides the part of these trips corresponding to households along with the average price of domestic and international tickets. Using the price elasticities of domestic (-1.4) and international (-0.93) flights, calculated respectively by Sainz-González et al (2011) and IATA (2008), it is

[26] This objective was selected because it can be achieved by using part of EET receipts in most cases (not with the aviation tax), even though it would be possible to consider further reductions in the poverty rate.
[27] Although other alternatives can be used, the paper opts for these definitions to keep the exercise simple and comparable to other studies.
[28] Consumption in the Canary Islands, Ceuta and Melilla is not considered in the analysis, as the harmonized excise tax is not levied in these territories.

possible to obtain the short-term demand impact of the aviation tax (following European Commission, 2019b, a 0.552 correction on elasticity is applied on non-residential travel). Based on information from Ministry for Ecological Transition (2019d) and Eurostat (2019a), distinguishing between domestic/international flights and the LTO/cruise cycle, average emissions per passenger are obtained so that the effects of tax changes on demand can be calculated. The aviation tax rate in euro/passenger is then divided by the average distance of domestic and international flights, with data from Ministry of Transportation (2019), to obtain the tax rate for the cruise phase in euro/km.

To analyze the distributional effects of the tax changes, all simulations use 2018 microdata from the Spanish household budget survey (INE, 2019a), the most recent at the moment of writing. There are observations for 21,395 households, a representative sample of the Spanish population[29], and total household expenditure is considered a proxy variable for income[30]. To calculate the distributional (income) impact of the different tax proposals, the paper considers the new final prices and consumption (with the use of the corresponding elasticities), which is then related to total household expenditure. The raising factor to population is subsequently used to calculate the average impact on income deciles. The standard measure of the index developed by Reynolds and Smolensky (1977) is also employed as an indicator of the distributional impact of the reform.

Finally, the paper analyzes the relationship between the share of tax payments on the equivalent income of the household ($me^h$) and the equivalent income ($Ye^h$) by estimating a linear relationship [Equation (1)]. A positive (negative) coefficient of this expression indicates that the tax payment share over income increases (decreases) with equivalent income, and thus the tax burden is distributed progressively (regressively)[31].

$$me^h = a + bYe^h \qquad (1)$$

[29] The INE provides information on the grossing-up factor for each household in the sample, which allows for an easy computation of population results.
[30] As usual in household surveys, there are measurement errors in both income and total expenditure that are usually larger for the former. In addition, total expenditure is generally a better approximation to permanent household income.
[31] Obviously, it is necessary to contemplate not only the sign but also at the significance of the coefficient of the regression to characterize each tax reform. Reforms could actually have different distributional profiles in different deciles of equivalent income, and thus the exercise also includes the adjustment of an equation with the square of equivalent income. Since the derivative of this new expression contains income, a different coefficient whose value depends on the equivalent income can be calculated for each household (see Table A3 in the Appendix).

### *5.2. Results*

*5.2.1. Tax equalization of diesel and gasoline to reverse the increase of transport emissions*

This reform (Simulation 1) would lead to increases of, respectively, 0.048 and 0.142 euro per liter in the excise taxes levied on petrol and diesel, with reductions of 1.1% and 2.9% in petrol and diesel consumption so that the 2018 increase in GHG emissions from transport is reversed. These tax increases would generate an additional annual revenue of 4,239 million euro (Table 3), with significant distributional impacts: the new taxes would lead to a percentage reduction of household income that grows (decreases) with the level of equivalent income[32] in lower (higher) deciles (see Table A1 in the Appendix). The Reynolds-Smolensky index is negative (-0.0001), indicating that the reform is indeed regressive. In addition, the estimation of Equation (1) provides a decreasing relationship, which points to regressivity for both the initial tax burden on gasoline and diesel, the final tax burden and the additional tax burden resulting from the reform (see Table A2 in the Appendix) [33].

**Table 3. Simulation 1. Impact on consumption, emissions and tax revenues**

| Fuel | Change in final price (%) | Change in consumption (%) | Change in $CO_2$ emissions (%) | Additional tax revenue (M euro) | | |
|---|---|---|---|---|---|---|
| | | | | Excise tax hydrocarbons | VAT | Total |
| **Gasoline 95** | 4.50 | -1.14 | 1.14 | 249.30 | 43.81 | 293.11 |
| **Non-commercial diesel** | 14.28 | -2.87 | -2.87 | 2,254.08 | 406.46 | 2,660.53 |
| **Commercial diesel** | 14.28 | -2.87 | -2.87 | 1,285.07 | - | 1,285.07 |
| **Total** | - | -2.57 | -2.60 | 2,525.84 | 450.26 | 4,238.72 |

Source: Own elaboration

In short, this reform would have a regressive impact on households, although the significant increase in tax revenues could be used, totally or partially, to mitigate this effect. Tables 4, A1 and A3 summarize the alternatives considered for this purpose. Package A would involve a transfer of 67.2 euro per person, at a total cost of 2,953.6 million euro. This package would have a very progressive impact, increasing the average income of all the deciles of equivalent income except the ones corresponding to the richest households, with a decreasing increase with the level of equivalent income. Likewise, the Reynolds-

[32] Household equivalent income accounts for household size, corrected for economies of scale through the OECD scale: 1+0.7*(Number of members≥age14-1)+0.5*(Number of members<age14).

[33] When estimating Equation (1) including income squared, the results also show regressivity across the whole distribution (see Table A3 in the Appendix).

Smolensky index would become positive and the estimation of Equation (1) shows progressivity of both the additional tax burden (including transfers) and the final tax burden net of transfers. Hence, the considered tax reform with Package A would not only be progressive but would also lead to a progressive tax. In terms of income deciles, with this compensatory package both the reform and the tax would be progressive for all but the richest income deciles (Table A3 in the Appendix).

With Package B, each household with an equivalent income below 14,053 euro should receive 47 euro, at a total cost of 407.7 million euro (roughly 9.6% of the additional tax revenue). The distributional effects of the reform would be positive, on average, in the two deciles with the lowest equivalent income and negative in the remaining ones, with an increasingly negative impact up to the sixth decile. Moreover, the Reynolds-Smolensky index becomes positive, as confirmed by the adjustment of a growing relationship between equivalent income and net tax payments over equivalent income in Equation (1), which indicates that this compensatory alternative also makes the tax reform progressive.

Finally, Package C only provides compensations to households below the poverty line to reduce the pre-reform poverty rate of 16.5% (2018 data) to 14.9%. To this end, the scheme would require lump-sum transfers of 603 euro to each household at a total cost of 1,768.1 million euro (41.7% of the tax receipts). In terms of deciles of equivalent income, Package C only impacts the two lower deciles, which experience a significant increase. As a result, the Reynolds-Smolensky index is positive, and the tax once again becomes progressive.

**Table 4. Simulation 1 and compensatory packages**

| Package | Targeted households | Transfer | Cost (M €) | Reynolds-Smolensky Index | $\frac{dme^h}{dYe^h} = b$ | |
|---|---|---|---|---|---|---|
| | | | | | Final net tax payments | Net tax reform payments |
| A | All | 67.20 €/person | 2,953.6 | 0.0015 | 0.110** | 0.780*** |
| B | Deciles 1-5 | 46.76 €/household | 407.7 | 0.0005 | -0.553*** | 0.117*** |
| C | Below the poverty line | 603.43 €/household | 1,768.1 | 0.0033 | 1.260*** | 1.930*** |

Note: ***, ** indicate significance at 1% and 5% respectively. The estimated amounts are multiplied by one million.
Source: Own elaboration

*5.2.2. Tax convergence of fuel taxation to the levels of major European countries*

This reform is more ambitious than the one previously considered, representing respectively an increase of 0.219 and 0.313 euro/liter in the petrol and diesel excise taxes (see Table 5). As a result, the reduction in fuel consumption and emissions would be greater than in Simulation 1 (5.2% for petrol and 6.3% for diesel) and the additional tax revenue would almost double with respect to the pre-reform situation, reaching 9,628.8 million euro. The distributional effects of this reform would be similar to those of the preceding simulation (see Table A1 in the Appendix), with an increasing (decreasing) percentage income reduction in the poorest (richest) deciles. In addition, the Reynolds-Smolensky index would have a negative sign (-0.0003), indicating its regressivity, while the estimation of (1) shows that both the final tax burden and the additional tax burden from the reform are regressive (Table A2 in the Appendix) for any income level (Table A3 in the Appendix).

**Table 5. Simulation 2. Impact on consumption, emissions and tax revenues**

| Fuel | Change in final price (%) | Change in consumption (%) | Change in $CO_2$ emissions (%) | Additional tax revenue (M euro) | | |
|---|---|---|---|---|---|---|
| | | | | Excise tax hydrocarbons | VAT | Total |
| **Gasoline 95** | 20.53 | -5.20 | -5.20 | 1,085.68 | 188.98 | 1,274.67 |
| **Non-commercial diesel** | 31.46 | -6.32 | -6.32 | 4,775.84 | 855.51 | 5,631.35 |
| **Commercial diesel** | 31.46 | -6.32 | -6.32 | 2,722.75 | - | 2,722.75 |
| **Total** | - | -6.12 | -6.15 | 8,584.28 | 1,044.49 | 9,628.76 |

Source: Own elaboration

Although Simulation 2 shows large distributional impacts, it also generates sizeable tax revenues that could offset them. Tables 6, A1 and A3 present the results of the different compensatory packages. In this sense, the impact of the considered packages is similar to that of the previous simulation, although it is generally of larger magnitude: A and C are the most progressive packages because they allow both the net additional tax burden and the final net tax payments of the reform to be progressive. With Package A, the use of a larger transfer resulting from higher tax revenue makes it possible to offset the larger distributional impacts: the income increase after compensation is larger for the first eight income deciles than it was in Simulation 1. Package B now requires larger transfers representing a higher (but still small) percentage of the tax revenue, with larger distributional impacts. The Reynolds-Smolensky index of the tax reform with the A or B Packages is positive and higher than in Simulation 1; so higher tax rates and the use of tax revenues to compensate for distributional impacts allow for a significant increase of progressivity. Finally, transfers in Package C represent a smaller percentage of the tax revenue, thereby allowing for more ambitious poverty reduction targets. In this case, the increase in income in the first two deciles is smaller than that of Simulation 1 and so the Reynolds-Smolensky index is slightly lower.

**Table 6. Simulation 2 and compensatory packages**

| Package | Targeted households | Transfer | Cost (M €) | Reynolds-Smolensky Index | $\frac{dme^h}{dYe^h} = b$ | |
|---|---|---|---|---|---|---|
| | | | | | Final net tax payments | Net tax reform payments |
| A | All | 157.11 €/person | 6,906.0 | 0.0034 | 1.140*** | 1.810*** |
| B | Deciles 1-5 | 118.82 €/household | 1,035.9 | 0.0013 | -0.361*** | 0.309*** |
| C | Below the poverty line | 606,74 €/household | 1,769.5 | 0.0032 | 1.090*** | 1.760*** |

Note: *** indicates significance at 1%. The estimated amounts are multiplied by one million.
Source: Own elaboration

*5.2.3. Aviation tax*

As indicated in Section 4.2, the paper first considers a tax rate of 50 euro/t$CO_2$ levied on national and international flights departing from Spain. As shown by Table 7, this reform involves an average tax of respectively 2.94 and 9.06 euro per passenger on domestic and international flights and brings about respectively a 7% and a 3.8% reduction in the demand for domestic and international flights. Simulation 3 shows that this tax change would lead to less $CO_2$ emissions from aviation (4.2%) and generating almost 900 million euro in tax revenues.

**Table 7. Simulation 3. Effects on $CO_2$ emissions and tax revenues**

| Consumer | Flight | Price change (%) | Demand change (%) | $CO_2$ emissions (%) | Additional tax revenue (M Euro) | | |
|---|---|---|---|---|---|---|---|
| | | | | | Aviation tax | VAT | Total |
| Residential | Domestic | 5.38 | -7.54 | -7.54 | 89.34 | -4.59 | 84.75 |
| | International | 7.17 | -6.69 | -6.69 | 199.86 | - | 199.86 |
| Non-residential | Domestic | 5.38 | -4.57 | -4.57 | 19.70 | 0.22 | 19.91 |
| | International | 7.17 | -2.73 | -2.73 | 587.18 | - | 587.18 |
| **Total** | | - | -4.77 | -4.18 | 896.08 | -4.37 | 891.70 |

Source: Own elaboration

Table A1 in the Appendix shows the distribution impact of the aviation tax, considerably below the preceding simulations due to the lower significance of air travel expenses in household budgets (0.44% on average). In addition, the reduction in the demand for airline tickets as a result of the tax leads to lower spending and so to income increases, particularly for the richest households (who devote a larger share of their income in this transport mode). In this sense, the Reynolds-Smolensky index is zero and the estimation of Equation (1) shows an increasing relationship between the level of equivalent income and the share of tax payments over total equivalent income, indicating that the reform is slightly progressive (see Table A2 in the Appendix) except for the richest households (see Table A3 in the Appendix). However, low-income households may be forced to stop using air travel due to tax-related increases in ticket prices[34], thus justifying the introduction of compensatory packages. Tables 8, A1 and A3 show that in all cases the compensatory packages make it possible to increase the progressiveness of the reform, with a positive Reynolds-Smolensky index and an increasing relationship between income and the net tax payments of transfers.

As before, Package A simulates the full return of tax revenues from households by means of a lump-sum per capita transfer of 6.5 euro per person, at a total cost of 284.6 million euro. This compensatory package leads to a very progressive reform; it increases the average income in all the deciles by a percentage that decreases with the level of household equivalent income. In Package B eligible households receive a transfer of 32.7 euro, at a total cost of 284.6 million euro. This package also makes the reform very progressive, increasing the income level of the first five deciles in a percentage that decreases with household income level. Finally, the lack of tax revenues does not allow to fulfill the objective of Package C: a full allocation of tax revenues to this end could provide 304.3 euro to each household in poverty, being only able to reduce the poverty rate by 3.3% (to 15.98%). The first two deciles experience a significant increase in average income, as in previous simulations, turning this package into the most progressive of all.

**Table 8. Simulation 3 and compensatory packages**

| Package | Targeted households | Transfer | Cost (M €) | Reynolds-Smolensky Index | $\frac{dme^h}{dYe^h} = b$ Final net tax payments |
|---|---|---|---|---|---|
| A | All | 6.47 €/person | 284.61 | 0.0001 | 0.094*** |
| B | Deciles 1-5 | 32.65 €/household | 284.61 | 0.0004 | 0.177*** |
| C | Below the poverty line | 304.33 €/household | 891.7 | 0.0017 | 1.040*** |

Note: *** indicates significance at 1%. The estimated amounts are multiplied by one million.
Source: Own elaboration

Finally, Simulation 4 considers the extension of the aviation tax to all GHG emissions caused by flights departing Spain, with a tax rate of 50 euro/t$CO_2$-equivalent that leads to an average tax per passenger of respectively 5.43 and 16.76 euro for domestic and international flights. As a result, the reduction in demand (13% and 7% respectively on domestic and international flights) and in $CO_2$ emissions (7.7%) is higher than in Simulation 3 and so is the revenue generated, which exceeds 1,500 million euro (Table 9).

[34] The effects on the extensive margin are not explicitly considered in this paper due to the lack of participation elasticities for Spain.

**Table 9. Simulation 4. Effects on $CO_2$ emissions and tax revenues**

| Consumer | Flight | Price change (%) | Consumption change (%) | $CO_2$ emissions (%) | Additional tax revenue (M euro) | | |
|---|---|---|---|---|---|---|---|
| | | | | | Aviation tax | VAT | Total |
| Residential | Domestic | 9.96 | -13.94 | -13.94 | 153.83 | -9.64 | 144.19 |
| | International | 13.26 | -12.38 | -12.38 | 347.20 | - | 347.20 |
| Non residential | Domestic | 9.96 | -8.45 | -8.45 | 34.95 | 0.26 | 35.21 |
| | International | 13.26 | -5.06 | -5.06 | 1,060.34 | - | 1,060.34 |
| **Total** | | - | -8.82 | -7.73 | 1,596.32 | -9.39 | 1,586.94 |

Source: Own elaboration

The distributional impacts of Simulation 4 are similar to those of the previous simulation, albeit greater, with the income of all households increasing by a percentage that generally grows with the level of income (see Table A1 in the Appendix). The Reynolds-Smolensky index is also zero in this case, with an increasing relationship between income and the share of tax payments on household income that shows the progressivity of this reform (Table A2 in the Appendix) in all but the richest households (Table A3 in the Appendix).

Tables 10, A1 and A3 summarize the results of the compensatory packages associated to the wider aviation tax. Since larger tax revenues are available, transfers to households will be higher than those of the previous simulation and so will the increase in targeted households by each package. Likewise, the Reynolds-Smolensky index is positive in all cases with an increasing relationship between the level of income and net of compensations tax payments, which indicates the progressiveness of the reform with the proposed packages. Again, Package C does not have enough funds to reduce poverty by 10%, although it gets closer: reducing it by 8.7% and leaving the poverty rate at 15.09%.

**Table 10. Simulation 4 and compensation packages**

| Package | Targeted households | Transfer | Cost (M €) | Reynolds-Smolensky Index | $\frac{dme^h}{dYe^h} = b$ |
|---|---|---|---|---|---|
| | | | | | Final net tax payment |
| A | All | 11.18 €/person | 491.39 | 0.0002 | 0.158*** |
| B | Deciles 1-5 | 56.36 €/household | 491.39 | 0.0007 | 0.301*** |
| C | Below the poverty line | 541.31 €/household | 1,586.9 | 0.0030 | 1.850*** |

Note: *** indicates significance at 1%. The estimated values are multiplied by one million.
Source: Own elaboration

## 6. Conclusions

EET are crucial instruments to achieve the transition to decarbonized economies given the advantages they present in terms of environmental effectiveness, economic efficiency and revenue-raising capacity. However, despite broad academic and institutional support, their potential is clearly underutilized due to issues that hinder their social acceptance: competitiveness and, particularly, equity. Therefore, it seems evident that the viability of EET largely rests on a proper evaluation and compensation of their negative distributional impacts. This is clearly the case of Spain, whose traditional lack of interest in these instruments has caused a sizeable gap in their application (at least when compared to other European countries) and might demand remarkable changes years so that the ambitious external and internal climate objectives can be attained.

The paper has paid special attention to the distributional problems associated with EET, mainly derived from its larger impact on low-income households with limited substitution possibilities and who tend to consume relatively more energy-intensive products to cover their basic needs. In addition, other factors that may be unrelated to income, such as the area of residence, type of housing, household size, the degree of development of the country, or the energy product under consideration, also influence the distributional impact of EET. At any rate, the sizeable tax revenues obtained by these instruments could be partially or totally earmarked to distributional compensations to improve the social acceptability of tax reforms. Compensatory alternatives could take the form, among others, of direct transfers to all or to just a group of affected households (e.g. depending on their income level or other characteristics), subsidies for energy efficiency improvements, or reductions in other taxes. In addition, a GTR could form part of a comprehensive approach to tackle the existing and growing inequality problems, well beyond a mere mitigation of the distributional impacts of EET.

The article formulated and empirically analyzed several proposals for a short-term reform of EET in Spain. The proposals were limited to the area of transport, the largest contributor to current Spanish GHG emissions and a source of other important externalities. The first two simulations focused on the tax proposals for road transport, showing that the increase in fuel prices could have significant environmental and revenue effects and a regressive profile. In any case, different compensatory packages could reverse those effects and make the reforms progressive, especially if the revenue is allocated to poverty reduction or transferred through per capita compensations. The other two simulations analyzed the introduction of a tax on aviation, whose GHG emissions have been evolving alarmingly and thus demand prompt regulatory action. In this case, a tax on air tickets seeking to moderate demand would lead to lower emissions and would generate significant tax revenues. Despite its lower distributional impact, even tending towards progressiveness, the paper suggested several compensations that could mitigate the potential problems of the aviation tax due to the likely exclusion of poor households from air travelling.

In sum, the paper suggested that the much-needed increase in Spanish EET to meet climate change mitigation objectives could be socially viable if tax receipts were allocated, partially or totally, to compensatory measures that cancel out, or at least considerably reduce, their negative distributional impacts. Such compensatory mechanisms could also promote the introduction of tax changes in a gradual but salient manner. In this regard, an initially reduced level of EET could be chosen (Simulations 1 and 3), with a subsequent automatic increase of tax rates to deliver the remarkable changes needed for low-carbon transitions (Simulations 2 and 4).

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# APPENDIX

**Table A1. Impact by deciles of household equivalent income (%)**

| Simulation | Compensatory Package | Decile | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 1 | No | -0.262 | -0.297 | -0.305 | -0.277 | -0.318 | -0.315 | -0.316 | -0.317 | -0.303 | -0.237 |
| | A | **1.487** | **0.743** | **0.536** | **0.435** | **0.301** | **0.226** | **0.151** | **0.082** | **0.022** | **-0.020** |
| | B | **0.184** | **0.008** | **-0.039** | **-0.039** | **-0.104** | -0.315 | -0.316 | -0.317 | -0.303 | -0.237 |
| | C | **5.489** | **2.596** | -0.305 | -0.277 | -0.318 | -0.315 | -0.316 | -0.317 | -0.303 | -0.237 |
| 2 | No | -0.653 | -0.750 | -0.784 | -0.718 | -0.803 | -0.804 | -0.811 | -0.796 | -0.767 | -0.613 |
| | A | **3.436** | **1.682** | **1.182** | **0.945** | **0.644** | **0.461** | **0.281** | **0.139** | **-0.009** | **-0.105** |
| | B | **0.480** | **0.028** | **-0.109** | **-0.114** | **-0.258** | -0.804 | -0.811 | -0.796 | -0.767 | -0.613 |
| | C | **5.130** | **2.108** | -0.784 | -0.718 | -0.803 | -0.804 | -0.811 | -0.796 | -0.767 | -0.613 |
| 3 | No | 0.001 | 0.002 | 0.002 | 0.002 | 0.002 | 0.004 | 0.003 | 0.004 | 0.004 | 0.004 |
| | A | **0.169** | **0.102** | **0.083** | **0.070** | **0.062** | **0.056** | **0.048** | **0.043** | **0.035** | **0.025** |
| | B | **0.312** | **0.215** | **0.187** | **0.168** | **0.152** | 0.004 | 0.003 | 0.004 | 0.004 | 0.004 |
| | C | **2.901** | **1.462** | 0.002 | 0.002 | 0.002 | 0.004 | 0.003 | 0.004 | 0.004 | 0.004 |
| 4 | No | 0.004 | 0.004 | 0.004 | 0.005 | 0.006 | 0.009 | 0.007 | 0.010 | 0.010 | 0.010 |
| | A | **0.295** | **0.178** | **0.144** | **0.123** | **0.108** | **0.099** | **0.085** | **0.077** | **0.064** | **0.046** |
| | B | **0.541** | **0.373** | **0.324** | **0.291** | **0.264** | 0.009 | 0.007 | 0.010 | 0.010 | 0.010 |
| | C | **5.162** | **2.604** | 0.004 | 0.005 | 0.006 | 0.009 | 0.007 | 0.010 | 0.010 | 0.010 |

Note: In bold, deciles with variation resulting from compensatory packages.
Source: Own elaboration

**Table A2. Estimated linear relationship ($\frac{dme^h}{dYe^h} = b$) between income share of tax payments and income**

| | Initial tax payments | Final tax payments | Tax payments of the reform |
|---|---|---|---|
| **Simulation 1** | -0.670*** | -0.797*** | -0.127*** |
| **Simulation 2** | | -0.980*** | -0.310*** |
| **Simulation 3** | - | 0.007*** | 0.007*** |
| **Simulation 4** | - | 0.007*** | 0.007*** |

Notes: *** indicates significance at 1%. The estimated values are multiplied by one million
Source: Own elaboration

**Table A3. Estimated quadratic relationship between the income share of tax payments and income**

| | | $me^h = a + bYe^h + c(Ye^h)^2$ | | Households with a progressive tax | |
|---|---|---|---|---|---|
| | | ***b*** | ***c*** | Equivalent income (€) | Deciles |
| **Fuel taxes** | Initial TP | -0.720*** | -0.947 | >380147 | None |
| **Simulation 1** | Final TP | -0.867*** | 1.340 | >323507 | None |
| | Reform TP | -0.147 | 0.395 | >186075 | None |
| **Simulation 1 + Package A** | Final TP | 1.14*** | -19.6*** | <29082 | 1-9 |
| | Reform TP | 1.86*** | -20.5*** | <45366 | 1-9 |
| **Simulation 1 + Package B** | Final TP | -0.307*** | -4.66** | - | None |
| | Reform TP | 0.413*** | -5.61*** | <36809 | 1-9 |
| **Simulation 1 + Package C** | Final TP | 4.55*** | -62.4*** | <36458 | 1-9 |
| | Reform TP | 5.27*** | -63.3*** | <41627 | 1-9 |
| **Simulation 2** | Final TP | -1.07*** | 1.66 | >322289 | None |
| | Reform TP | -0.348*** | 0.713 | >244039 | None |
| **Simulation 2 + Package A** | Final TP | 3.63*** | -47.3*** | <38372 | 1-9 |
| | Reform TP | 4.35*** | -48.2*** | <45124 | 1-9 |
| **Simulation 2 + Package B** | Final TP | 0.355** | -13.6*** | <13051 | 1-4 |
| | Reform TP | 1.08*** | -14.5*** | <37241 | 1-9 |
| **Simulation 2 + Package C** | Final TP | 4.37*** | -62.3*** | <35072 | 1-9 |
| | Reform TP | 5.09*** | -63.3*** | <40205 | 1-9 |
| **Simulation 3** | Reform TP | 0.018*** | -0.208*** | <43510 | 1-9 |
| **Simulation 3 + Package A** | Reform TP | 0.212*** | -2.23*** | <47534 | 1-9 |
| **Simulation 3 + Package B** | Reform TP | 0.409*** | -4.4*** | <46477 | 1-9 |
| **Simulation 3 + Package C** | Reform TP | 2.75*** | -32.4*** | <42438 | 1-9 |
| **Simulation 4** | Reform TP | 0.018*** | -0.205*** | <43171 | 1-9 |
| **Simulation 4 + Package A** | Reform TP | 0.352*** | -3.69*** | <47696 | 1-9 |
| **Simulation 4 + Package B** | Reform TP | 0.693*** | -7.44*** | <46572 | 1-9 |
| **Simulation 4 + Package C** | Reform TP | 4.87*** | -57.4*** | <42422 | 1-9 |

Notes: ***, ** indicate significance at 1%, 5%, respectively. The estimated values of *b* are multiplied by one million and the estimated values of *c* are multiplied by one billion. TP: tax payments.
Source: Own elaboration