Programa de Doctorado en

Economía y Gestión empresarial

# "ESSAYS ON THE ECONOMETRIC ANALYSIS OF THE USE OF TRANSPORT AND OF THE PUBLIC POLICIES FOR ITS SUSTAINABILITY"

# "ENSAYOS SOBRE EL ANÁLISIS ECONOMÉTRICO DEL USO DEL TRANSPORTE Y DE LAS POLÍTICAS PÚBLICAS PARA SU SOSTENIBILIDAD"

Tesis Doctoral presentada por

JENIFFER NATHALY RUBIO ABRIL

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## RESUMEN

La reducción de la contaminación del sector transporte es fundamental para la transición energética y lograr los objetivos de la agenda 2030. En esta tesis doctoral, a través de tres ensayos, nos hemos centrado en investigar las medidas de política pública que promueven el uso de Transporte Público como alternativa ambiental al automóvil privado y aquellas que promueven la sustitución de vehículos de combustión por vehículos limpios (híbridos y eléctricos).

Específicamente, los dos primeros ensayos evalúan el impacto de la política de subsidios a la tarifa de transporte público a los jóvenes y a las personas mayores sobre el bienestar de los hogares beneficiarios (equidad). En cuanto al segundo ensayo, también se ocupa del análisis del impacto de los subsidios del transpote público urbano en la eficiencia económica. Ambos ensayos se centran en analizar el caso de la región de Madrid. Se utilizaron las técnicas econométricas de Diferencias en Diferencias y de Regresión en Discontinuidad respectivamente. El tercer ensayo se centra en identificar las características socioeconómicas y demográficas que influyen en la compra de vehículos limpios (híbridos y eléctricos) mediante la técnica econométrica de regresión logística para toda España. Los ensayos utilizaron datos de la Encuesta de Presupuestos Familiares del Instituto Nacional de Estadística.

Los tres trabajos han llegado a interesantes resultados: las políticas de subsidio analizadas logran los objetivos de equidad económica ya que benefician a los grupos más pobres de la sociedad. No obstante, los mayores beneficiarios de estas políticas son los hogares con niveles de renta media-alta (subsidios para jóvenes) o niveles de renta alta (subsidios para personas mayores), lo que sugiere la necesidad de incluir criterios de renta para esas políticas de subsidio. En relación a la eficiencia económica de los subsidios al transporte público urbano, los resultados muestran que aun cuando los subsidios son muy generosos, como es el caso de los subsidios para mayores de 65 años, si los beneficiarios están ocupados, y por lo tanto tienen que trasladarse por razones laborales, el aumento del precio relativo de los combustibles, derivado de la medida de política analizada, no es suficiente para incentivar la sustitución del uso del vehículo privado por el transporte público. En cuanto a la penetración de vehículos limpios en el mercado, los resultados muestran que existen barreras económicas a su penetración en el mercado que están relacionadas con el nivel de renta de los compradores potenciales y otras variables estrechamente ligadas al nivel de renta. Sin embargo, también existen características socioeconómicas que son ventajosas para el crecimiento del sector de vehículos limpios, como la edad y el género de los compradores potenciales. Las políticas públicas dirigidas a promover la compra de vehículos limpios deben considerar el primer aspecto y, por lo tanto, las ayudas económicas otorgadas para comprar un automóvil limpio deben estar vinculadas al nivel de rentas del beneficiario. Estos son temas de gran interés académico y social que contribuyen al análisis económico del uso del transporte y diseño de las políticas públicas que fomentan su sostenibilidad social y ambiental.

## ABSTRACT

The reduction of pollution in the transport sector is essential for the energy transition and achieving the objectives of the 2030 agenda. In this doctoral thesis, through three essays, we focus on investigating public policy measures that promote the use of Public Transport as an environmental alternative to the private car and those that promote the substitution of combustion vehicles for clean vehicles (hybrid and electric).

Specifically, the first two essays evaluate the impact of the subsidies on public transport price for young people and the elderly on beneficiary household well-being (equity). As for the second essay, it also deals with the analysis of the impact of urban public transport subsidies on economic efficiency. Both essays focus on analyzing the case of the Madrid region. The econometric techniques Differences in Differences and Regression in Discontinuity were used, respectively. The third essay focuses on identifying the socioeconomic and demographic characteristics that influence the purchase of clean vehicles (hybrid and electric) using the logistic regression econometric technique for all of Spain. The three essays have used data from the Household Budget Survey of the Spanish National Institute of Statistics.

In our studies we have reached interesting results: the subsidy policies analyzed achieve the objectives of economic equity since they benefit the poorest groups in society. However, the greatest beneficiaries of these policies are households with high-middle income levels (subsidies for young people) or high-income levels (subsidies for the elderly), which suggests the need to include income criteria for such subsidy policies. In relation to the economic efficiency of urban public transport subsidies, the results show that even when the subsidies are very generous, as is the case of subsidies for people over 65 years of age, if the beneficiaries are employed, and therefore have commuting for work reasons, the increase in the relative price of fuels, derived from the analyzed policy measure, is not enough to encourage the substitution of private vehicle use by public transport. Regarding the penetration of clean vehicles in the market, the results show that there are economic barriers to their penetration in the market that are related to the income level of potential buyers and other variables closely linked to income level. However, there are also socio-economic characteristics that are advantageous for the growth of the clean vehicle sector, such as the age and gender of potential buyers. Public policies aimed at promoting the purchase of clean vehicles must consider the first aspect and, therefore, the economic aid granted to buy a clean car must be linked to the income level of the beneficiary. These are topics of great academic and social interest that contribute to the economic analysis of the use of transportation and the design of public policies that promote its social and environmental sustainability.

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# I. INTRODUCTION

Transport is a strategic sector for the global development of an economy, as it allows the mobility of both people and goods. Moreover, it is also fundamental for the development of the productive chains. Notwithstanding, it is one of the most polluting sectors both globally and locally. It should be noted that, according to data from the World Bank [1], CO2 emissions from transport represent around 27% of the total Greenhouse Gases (GHG thereafter) emissions in the European Union, in addition, one of the great challenges in large cities is to improve the quality of the local air. In fact, despite the institutional efforts to achieve a better environmental performance of transport, this has been the only sector that has not been able to invert the curve of global polluting emissions. On the other hand, in cities, transport, along with heating, continues to be the main cause of bad air quality. So, the transport sector plays a fundamental role in the energy transition strategy that several countries have adopted. The point is that the poor environmental behavior of transport poses a threat to the achievement of the objectives proposed in the energy transition strategies that seek more environmentally sustainable societies. Given this context, it is necessary to deepen into the research on the behavior of transport users and on the public policies implemented for improving the sector's sustainability. Therefore, at a scientific level, economists, as well as other scientists, must provide results that can be used later for a better design of public policies aiming to improve the economic, social, and environmental sustainability of transport. The energy transition of the whole economy will be difficult to achieve if the transport sector does not change its trend on local and global pollution. This PhD dissertation represents a contribution, through the three essays proposed to this field of research.

Specifically, in this PhD dissertation we focus on investigating about two of the public policy measures that have been among the most applied to achieve a more sustainable behavior of the transport sector:

1- Those that at the urban level try to promote the use of Public Transport (PT thereafter) as an environmental alternative to private cars. These measures are focused on the reduction of local air pollution in cities, but also contribute to the fight against global pollution and climate change.
2- Those that try to promote the substitution of combustion vehicles for clean vehicles (hybrid and electric), these measures are focused on the fight against global pollution and climate change, that is, on energy transition.

Regarding the first measure, the use of public transport is the ideal alternative to achieve more sustainable cities. The challenge for many cities is to convert PT into the main mobility option. Using collective transport, in many cases powered by electricity, as is the case of the metro, or by clean engines (many urban buses use already clean fuels), is a good strategy to reduce the emission

[1] https://datos.bancomundial.org/indicator/EN.CO2.TRAN.ZS

of gases (such as NOx) and pollutant particles, that are the main cause of local air pollution. In addition, less use of private vehicles, that are still powered by combustion engines, in densely populated areas, such as cities, would also have a positive impact on reducing global pollution. In this context, many cities in the world allocate a large part of their financial resources to provide subsidies that encourage the use of PT, that is encourage the substitution of private vehicles for PT.

When implementing public policies of PT subsidization, municipal governments all over the world usually take it for granted that these policies meet the criteria of economic efficiency (they correct the negative externalities that urban traffic generates on the environment and other factors) and equity (they favor social inclusion). Nevertheless, given the high level of public spending allocated for this purpose, it is necessary to ask whether what municipal governments give for granted is true or not. To ask this question, it is important that scientific research evaluates, first whether urban PT subsidies benefit more the most vulnerable social groups, complying thus with a criterion of equity, and second, whether they have reached economic efficiency, that is, they have prompted a substitution of the use of private vehicles for PT.

In relation to the issue of equity, traditionally, urban PT subsidies have been designed considering eligibility factors such as age (for example, subsidies for young people and elderly) and excluding other criteria, such as the income level of the beneficiaries. Therefore, such polices may have not had the distributive effects that could be expected on equity grounds. Thus, the equity of urban PT subsidies is analyzed in the first two essays presented in this PhD dissertation. As for the second essay, it also deals with the analysis of the impact of urban PT subsidies on economic efficiency. Both essays focus on analyzing the case of the Madrid region, the third largest urban area in the European Union, with a highly developed PT network, and an ambitious subsidization policy, especially for the young and the elderly.

Regarding the second measure, for reaching the decarbonization of the transport sector, it is essential to substitute traditional vehicles powered by fossil fuels with electric or hybrid vehicles. These types of vehicles generate much less (GHG) emissions than traditional cars, avoid noise pollution and generate savings in fuel and maintenance (they do not need oil changes, filters, lubricants etc.) The purchase of these cars has tax benefits (VAT reductions), and other incentives, like parking advantages or preferential roads. Unfortunately, despite all these stimuli, the commercialization of clean vehicles (both hybrid and electric) has not yet achieved the expected success: drivers are reluctant to replace their traditional car with a clean one. This situation, given the importance of the transport sector in GHG emissions, is an obstacle to achieving the objectives of the 2030 Agenda linked to climate change. It is necessary, therefore, to investigate which variables influence the penetration of clean vehicles in the market and how. Or in other words, it is important to analyze how the characteristics of the social group treated by the measure, in this case the entire society, can positively or negatively influence the policy proposed. And this is so because, the energy transition must lead to a generalized decarbonization of the economy, but it must be done in such a way that its costs are affordable and do not fall disproportionately on the

treated population. As argued in the European Green Deal, the energy transition must be fair and inclusive to be successful. It must put people first, and pay attention to the regions, industries and workers that will face the greatest challenges (European Commission 2019). The characteristics of the potential vehicle buyers can make it difficult to choose less polluting vehicles. Although the focus has been placed on the first direction of the relationship (how decarbonization can negatively affect the consumers), the other direction of the relationship, that is, how the characteristics of car drivers influence the decision to use clean or conventional cars, has not received a comparable level of attention in the literature. This PhD thesis intends precisely to cover this gap in knowledge, which is highly relevant for public policy decision-making, by analyzing this relationship and, more specifically, the effect of the characteristics of car users on the choice of clean vehicles. The results could help to design or propose more effective public policies than the current ones. The third essay of this PhD dissertation, focused on analyzing the case of Spain, where sales of clean vehicles are far below what is expected, based on the objectives that should be reached by 2030, represents a contribution within this field.

Therefore, this PhD dissertation analyzes, through three essays, issues that within the scientific literature focused on the economic analysis of the use of transport and public policies that promote a more sustainable use of it, are of great relevance. In addition, the cases analyzed are, due to their characteristics, excellent laboratories for applying this research.

Specifically, the first essay, which as we have said before, focuses on the case of the Madrid region that has been a world reference in terms of the development of an integrated PT system, and whose flagship product is the travel-pass, which is a highly subsidized transport ticket that allows users to travel unlimitedly and switch between PT means within its validity date and geographical range. There are three types of travel-passes with different prices depending on the age of the user: normal pass (for people between 26 and 64 years of age), young pass (for younger of 26) and elderly (for people over 65). Concretely, this essay analyzes the distributive impact on households grouped by income quintiles, of the reduction of the public price of the travel-pass for young people that came into force in December 2015. This policy established a monthly flat rate of 20 euros regardless of the distance traveled and the number of trips made. Previously, the rate was increasing depending on the distance travelled. The new measure meant a price reduction of up to 79% in the most distant peripheral areas from the city of Madrid. To quantitatively measure the impact of the public policy measure described above, the quasi-experimental impact evaluation econometric technique called Differences in Differences (Diff-Diff) has been used. This technique allows measuring the effect that the implementation of a policy measure has on the social group that benefits from it with respect to a control group, that is a group composed by non-beneficiaries. In our specific case, the variation in spending on PT of households with young members has been evaluated before and after the application of the measure. Data from the Spanish Households Budget Survey (HBS thereafter) for 2014 and 2016 were used. The treated group (households affected by the measure) was composed by households that spend a minimum of 20 euros per month on travel-pass and have least one member beneficiary. The control group (those not affected by the measure) was composed by households that spend a minimum of 20 euros per month on travel-pass and don't have beneficiary members. This work was published in 2019 in the international journal

"*Transport Policy"* ranked in the first quartile (Q1) of the Journal citation Reports in the section Economics.

The second essay, also applied to the case of the Madrid region, analyzes too PT subsidies. In this case, subsides for the other group considered vulnerable, that is the elderly (people over 65 years of age). PT subsidy policies in countless cities have traditionally focused on this social group as they are considered the most vulnerable in society. However, today, the economic vulnerability of the elderly may be questionable due to their current income levels, and the wealth, and assets that some among them manage to accumulate over the years (own home, cars, etc.). For example, the level of average retirement pensions in many countries is already above average wages. These facts could cast doubt on whether the criterion for subsidizing vulnerable retirees, should only be guided a criterion of age. On the other hand, from the point of view of economic efficiency and the correction of negative externalities of transport on the environment, the high subsidies to PT for this social group - who in developed countries have a growing demographic importance- also seek to encourage them substitute the use of cars with the use of PT.

What is concretely evaluated in the second essay are first, the distributive and, second the efficiency impact of PT subsidies on the group of people over 65 years of age, who is the most subsidized social group in the Madrid region. In the period analyzed the price of the travel-pass was a monthly flat rate of 12 euros, for all areas of the region, while for the rest of population the rates can exceed 100 euros. The dependent variables selected in the analysis are, on the one hand, the expenditure on travel-pass and, on the other the expenditure on automotive fuel by households in the Region. The analysis has been carried out with the quasi-experimental impact evaluation econometric technique called regression discontinuity (RD), since there is a clear rule for assigning the benefit (eligibility cut-off point or threshold) which is age. The data used came from the Spanish HBS for the period 2015-2019. Two quantitative exercises have been carried out in the work. In the first quantitative exercise, in order to find out the effects of the subsidy on household public transport spending, the control group (those not affected by the measure) has been selected as households that spend on PT and whose main breadwinner has an age ranged between 60 and 64 and is retired or not employed, while the treatment group (households affected by the measure) are households that spend on PT and whose main breadwinner is between 65 and 69 and retired. The estimates have been repeated for the same control and treatment groups for the case in which the main breadwinner is employed, that is, he works. In addition, as a second quantitative exercise to evaluate the behavior of the same households in their spending on automotive fuel, the control group (those not affected by the measure) has been selected as households that spend on automotive fuel and whose main breadwinner has a age range between 60 and 64 years and is not employed, while the treatment group (households affected by the measure) are households that spend on automotive fuel and whose main breadwinner is between 65 and 69 years old and is not employed. The estimates have been repeated for the same control and treatment groups for the case in which the main breadwinner is employed, that is, is working. To find out the distributional implications of this impact at the expenditure level, we repeated the estimates of the RD regressions by income quartiles to test the differences by income groups. The article has been

published online since July 2022 in the international journal *Research in Transportation Economics*, indexed in the second quartile (Q2) of the Journal Citations Report index, in the section Economics.

The third essay focuses on analyzing the situation of the clean vehicle market (electric and hybrid) in Spain. The country has implemented various ambitious policies to replace combustion vehicles with clean ones, such as subsidies, tax incentives, mandatory environmental labels (providing benefits such as preferential roads, free parking, access to downtown areas), monetary aid for the replacement of old vehicles, among others. Despite this, its effect has been limited. Spain is still one of the countries with the lowest penetration of clean vehicles in the market. Clean cars barely represent 2.7% of the total number of vehicles, a situation far from the objective set for 2030 that 16% of the fleet must be composed by clean vehicles (Ministerio para la Transición Energética y el Reto demográfico, 2020). The objectives of the 2030 Agenda for sustainable development depend to a large extent on the transport sector being able to decarbonize, so it is crucial to increase the market penetration of clean vehicles. As this market is new, there is much room for improvement and action, but for this, the advantages and disadvantages that arise at the socioeconomic level for the penetration of this type of vehicle in the market must be well known and identified. Thus, the third essay focuses on determining the socioeconomic and demographic characteristics of Spanish households that, despite the existing supply barriers -high relative price, low autonomy, and scarcity of recharging points- have already acquired a clean vehicle (hybrid or electric). The data for the analysis came from the Spanish HBS for the period 2016 to 2019. The econometric model applied to the analysis is a logistic regression since there is an analysis variable with two alternatives (household spending in electricity for vehicles or in fuel for vehicles). The results obtained can help to a better knowledge of clean car potential buyers, this can help to a more realistic and performant design of policies aiming to the decarbonization of the sector. This third essay has been been published in Papeles de Trabajo del Instituto de Estudios Fiscales in December 2022, and was submitted for evaluation in the international journal "*Transport Policy".*

The PhD dissertation is structured as follows: in the following section is presented the first essay that analyzes the impact of the PT fare subsidy policy on young people in terms of equity, the section 3 presents the second essay that addresses and evaluates the effectiveness of the PT price subsidy policy for elderly to meet equity and efficiency criteria, the section 4 is related to the third essay where the socioeconomic and demographic characteristics of clean cars buyers are determined. The work is closed with a last section of general conclusions.

## II. SUBSIDISATION OF PUBLIC TRANSPORT FARES FOR THE YOUNG: AN IMPACT EVALUATION ANALYSIS FOR THE MADRID METROPOLITAN AREA

**Abstract.**

This paper analyses the distributive and individual welfare implications on households of an urban demand transport policy with a high subsidisation of Public Transport (PT) fares for young users. This measure came into force in October 2015 in the Madrid Metropolitan Area. The fares of the travel-pass for young users were reduced by 56.8% on average, reaching up to 79.8% in the more distant peripheral areas. Moreover, the age of the beneficiaries was enlarged from 23 to 26 years old, for these few new beneficiaries the price was on average be reduced by 72.8%. Using data from the Spanish Households Budget Survey (HBS) for 2014 and 2016, we use impact evaluation techniques to measure the distributive effect of this transport policy. Results show first that households of medium and high-medium income levels are the main beneficiaries of this measure, which has increased their individual welfare because their PT expenditure has decreased by 42% and 49% respectively. Second, PT has become more accessible to the poorest households. Finally, there is no effect on the richest households and on the low-medium income level ones.

**Key Words:** Transport policy, Impact Evaluation, Fare Transport Subsidies, Distributive effects, Households.

**JEL Code:** C21, H20, R21, R28, R48

## 2.2.Introduction

Subsidising Public Transport (PT) fares is a widespread policy all over the world. The purpose of this policy is to encourage the use of PT instead of the private car, as well as to make PT accessible to all citizens regardless of their income level. Therefore, these measures are justified for reasons of economic efficiency and social equity. The common perception among policy makers is that PT subsidies on prices have always had progressive distribution effects (Bueno Cadena et al., 2016). However, the academic literature is not conclusive about the positive results in terms of equity of applying this type of measure (see for example, Serébrisky, 2009; and Gómez Lobo, 2009).

Typically, subsidies on PT prices positively discriminate certain social groups, such as young people or the elderly. This discrimination based on age is founded on policy makers' generalised idea that young people and the elderly are more vulnerable and sensitive to PT prices than the rest of the population. Therefore, this policy is basically guided by issues of equity (Cascajo et al., 2017). However, the equity effects of such a policy could be a priori questioned because it is applied to general categories (age limit criterion), that are not directly associated with the economic

situation of the beneficiaries. Thus, subsidies may be used by people who are not necessarily vulnerable to the price of PT. Academic work on the subject is needed to shed light on this issue.

An additional argument to subsidise PT fares for the young is based on the idea that they have more mobility needs than other groups (Nuworsoo et al., 2009; Bueno Cadena et al., 2016). In this sense, such a policy is searching the consumer loyalty of this group to PT. This argument is then linked to efficiency issues. As Serebrisky et al. (2009) and Bureau and Glachant (2011) pointed out, there is extensive literature in the transport field justifying PT demand subsidies on economic efficiency arguments (internalisation of private transport externalities), but welfare and distributional issues of these policies have drawn significantly less attention in the literature than efficiency ones. This work seeks to address this gap in the literature, analysing the distributive and the individual welfare impacts on households of a new PT demand policy, which highly subsidises PT fares for the young under 26 in the Madrid Metropolitan Area.

This region is one of the largest metropolitan regions in Europe. It has an integrated PT system like those of other big metropolitan areas in the world such as London, Paris, Rio de Janeiro or New York (Burguillo et al., 2017b). In fact, the number of trips in PT in Madrid Region has grown from 951 million in 1986 (year of the implementation of the integrated system) to 1.385,7 billion in 2015, this means an increase by 45.7% (CTRM, 2016). At the same time, the total populations increased from 4.879 to 6.495 millions of persons, so by 33.1%. On the supply side, the Madrid transport policy has consisted in a strong public investment aimed at expanding PT infrastructures, especially the underground network. In 1995, Madrid underground had 120 km of tracks and 164 stations. In 2009, 287 km of tracks and 291 stations were reached, which is the current network size. During these 14 years, the underground network grew 139%. The Madrid underground system is now the second largest in Europe following the London Underground.

On the demand side, the flagship product of this integrated PT system is a travel-pass, a highly subsidised transport title that allows users to travel unlimitedly and switch between PT means within his date and geographical range of validity. Vassallo et al. (2009) found that the normal travel-pass price covered only 37% of the operational costs. The travel-pass subsidy has been traditionally higher for the young; Bueno Cadena et al. (2016) calculated that young people paid, on average, a price of 0.33 Euros per trip with the travel-pass whereas normal users paid 0.47 Euros per trip.

Moreover, the travel-pass has had a high level of acceptance: according to the Regional Transport Consortium of Madrid (CRTM, 2016), 45% of the population between 4 and 85 years has a travel-pass and 72.2% of PT trips are made with a transport ticket. Muñoz-Miguel et al. (2014, p.114) showed that Madrid had in 2010 the highest PT usage ratio compared to 21 other European cities, and the degree of satisfaction found among PT users reached 78%. In this context of highly-subsidised travel-pass rates and great acceptance by users, the government of the region decided to go a step further and in October 2015 implemented a very aggressive policy of subsidies for the young. The new travel-pass for the young extended the beneficiaries' age from 23 to 26. In fact, defining the young group under 23 was not in line with international standards, where it is mainly defined until 26[2]. The new policy tried to update this. Moreover, it modified the tariff scheme previously differentiated by distance (zones) to one of a flat rate of 20 Euros per month for all areas; in that sense, this vulnerable group[3] received in this new policy program the same treatment than the elderly, which traditionally had benefit of a flat rate per month in all areas. Other urban areas in Europe, like Paris, provided also a flat rate for young. The fares of the travel-pass for usual young users (under 23) were reduced by 56.8% on average, reaching almost 80% in the more distant peripheral areas. Moreover, a small group of citizens, those between 23 and 26 have benefit on average of a reduction by 72.8% in the price of travel- pass.

The objective of this paper is to analyse the distributive impacts of the abovementioned measure on Madrid households travel-pass demand and its implications on individual welfare. To the best of our knowledge, this is the first study tackling the analysis of such a measure. The magnitude of the measure and the fact that the subsidisation increases with distance - with this variable positively related to the possibility of having more economic difficulties to access to PT and of being more sensitive to its price (Li et al., 2015) - makes this case an optimal one to analyse PT demand subsidies from an equity point of view. Moreover, the Madrid Metropolitan area by itself is a relevant region to analyse and improve knowledge on PT issues since for decades Madrid Region

[2] The European youth association defines a young until 26, and other transport policy programs as the one of Paris, Milan or Rome define also a young until 26.

[3] Most young are students or non-employed, in fact in Spain the rate of youth unemployment (15-24 years old) is one of the highest in the developed world (53.2% in 2014 and 44.4% in 2016, see OECD dataset). Moreover, the other vulnerable group, the elderly, have an average annual revenue (the medium retirement pension) higher than the Spanish medium-wage, and benefit of flat transport fare of 12 Euros per month in Madrid Region. Then this new demand PT policy came to decrease the differences of treatment among these two vulnerable groups. It seems that the differences existing before the reform of the young prices scheme between young and elderly were to big considering the socioeconomic characteristics of young and elderly.

public authorities have considered the PT policy a main budget priority in both the demand and supply sides (Burguillo et al., 2017b).

This paper uses data from the Households Budget Survey (HBS) for 2014 and 2016. It defines two groups of households: households affected by the measure (treatment group) and those not affected by it (control group). We use data before (2014) and after (2016) the change in prices of the young travel-pass. The control group includes households that spend a minimum of 240 Euros per year on the travel-pass (20 Euros per month) and without members beneficiaries from the young travel-pass. The treatment group includes households that spend a minimum of 20 Euros per month on the travel-pass and with at least one-member beneficiary from the young travel-pass.

An econometric model is estimated using Impact Evaluation (IE) techniques as Differences in Differences or Double Differences (DID) to evaluate the impact of the change in the young travel-pass fare on the household's expenditure on travel-pass (dependent variable); this impact has implications on individual welfare. In order to know the distributional implications of this impact we repeat the DID estimations by quintiles to test it by social income groups[4]. DID techniques apply to transport are not scarce in the literature and the applications are very diverse. For example, Mohammad et al. (2017) analysed, using DID, the impact of the newly operated Dubai Metro on the sale transaction value of dwellings and commercial properties. Olarte (2013) used DID to test the causality of the transport system in the evolution, in different periods, of crime rates in Bogota. Hoelz et al. (2003) examined the impact of an extension of the Bay Area Rapid Transit System (BART) on hiring practices of firms in the San Francisco Bay Area using DID[5]. However, we have not found any studies using DID to analyse equity impacts of PT demand subsidies. In this sense, this paper introduces this technique to an issue that by itself is scarce and important in the transport policy debate.

The paper proceeds as follows. Section 2 presents a review of the literature on PT demand subsidisation distributional issues. Section 3 provides an overview of the urban transport features in the Madrid Region and its new pricing policy. The econometric model and the impact evaluation

[4] As works based on expenditure surveys usually do, total expenditure is considered a proxy of income.

[5] These papers are a few examples of impact evaluations in urban transport. See Boarnet (2007) for a further review of papers evaluating the impact of transport on economic opportunities, labour market, on land prices and on access to and use of services.

technique (double differences) is presented in section 4. Section 5 presents the data and descriptive analysis. Section 6 discusses the estimation results, and Section 7 concludes.

### 2.3.Related Literature

The literature that analyses the relevance of applying subsidies to PT demand is mainly based on two questions. On the one hand, there are works that address the issue of PT demand subsidisation as a pricing policy that helps to internalise the external effects of the transport sector, basically those related to local and global air pollution, and congestion of cities and roads. On the other hand, it addresses the issue of PT demand subsidies based on equity criteria, referring then to the distribution of its impacts among members of the society and whether this distribution is considered appropriate (Bueno Cadena et al., 2016).

Our work is part of the second type of studies, and as we said in the introduction, the literature on this subject is quite scarce. A consequence of this scarcity of works is that almost every paper uses its own methodology; generally, these are well developed in the welfare economics and income distribution literature, but frequently introduced for the first time to transportation research by each study (Burguillo et al., 2017b). As previously mentioned, this paper introduces the DID techniques to such an issue. Moreover, PT policy is implemented through different types of subsidies: subsidies on operational costs (fares or quality of service), on infrastructures, on different social groups, for different transport modes etc. Each work is focused on one type of subsidy depending on the case analysed. In fact, these subsidies can subsidize the demand or the supply of PT. On the one hand, quality of services and infrastructure subsidies are connected to the supply. These supply subsidies can affect different social groups and different transport modes. On the other, fares subsidies have to do with the demand, and can be applied to different social groups or different transport modes. In this context, PT equity research has been tackled in the literature from a supply perspective, like the work of Del Bosca and Currie (2011) that used Lorenz Curves to measure equity in transit supply in Melbourne or the work of Sanchez (2008) that analyses the problem of equity and quality of service (supply, frequency, etc.) in the United States (where the poorer still living in areas with poor transportation supply services). Our work, analyses distributional implications of transport demand subsidies, and therefore we will review mainly similar works. In fact, studies like ours relying on consumer expenditure surveys, are only able to consider the

effects of fare changes (Bureau and Glachant, 2011). This is what we do in this work, like Asensio et al. (2003), Bueno-Cadena et al. (2016) and Burguillo et al. (2017b). To the best of our knowledge, these are the only studies analysing distributional impacts of fare transport subsidies for the case of some Spanish cities.

Asensio et al. (2003) analysed the redistributive effects generated by the subsidies to PT services in several Spanish cities, including Madrid. They found that these subsidies were progressive; the groups with the lowest income benefitted the most from these policies. Bueno-Cadena et al. (2016) evaluated the equity impact of travel-pass subsidies in all neighbourhoods of Madrid city in 2004. These authors found that subsidising travel-pass fares in Madrid City was a progressive policy because the travel-pass was more intensively used in the poorer neighbourhoods. Burguillo et al. (2017b) found that the impact on welfare of Madrid region households generated by the increase in PT prices in the period 2008-2012 was similar for low and middle-income households, and therefore, this policy did harm the middle classes (not the poorest). From this work, it is inferred that PT subsidies are good measures in terms of equity.

Other works carried out for other countries also find that transport subsidies are positive from the point of view of equity and distribution. This is what Bureau and Glachant (2011) found for the case of Paris (France), Bandegani and Akbarzadeh (2016) for the case of Isfahan (Iran) and Guzmán and Bocarejo (2017) for the case of Bogotá (Colombia).

However, there are studies, also based on consumer expenditure surveys, which found just the opposite: PT subsidies are not good measures in terms of equity. Among them we highlight the following:

- The work of Frankena (1973) for the case of different Canadian cities in the 60s and early 70s, found that the PT subsidies were in general regressive, although it depended on the type of neighbourhood and the group to which it was addressed. This author did not find a clear effect in the case of PT subsidies to students.
- The work of Flynn (2007) for the case of Mexico City found that transportation subsidies were not effective in directing benefits to the poor.
- The work of Serebrisky et al. (2009), for the case of several developed and developing countries, found that subsidy policies for urban PT do not benefit the poorest.

- The work of Gomez Lobo (2009) for the case of Santiago de Chile found that from an equity point of view lump sum transfers were a better policy than subsidies to fares. This work also examined PT subsidies for students (considered a vulnerable group) and found that clearly this policy benefited the households with the highest income levels.

In sum, the academic literature focusing on the distributive impacts of PT subsidies on fares is controversial. Even if the works analysing PT subsidies on prices in the case of Madrid City or Region have obtained positive results, it is interesting to go further by studying the impacts of the new price policy for the young travel-pass. On the one hand, to the best of our knowledge, the specific PT policy for the young has not been analysed neither for the case of Spain nor for the case of Madrid and is scarce in the literature; Frankena (1973) and Gómez Lobo (2009) are some exceptions. On the other hand, assuming that all young people are vulnerable to PT prices seems to be a very strong hypothesis. In fact, the two studies tackling with this issue as mentioned above found that subsidising young people is not a progressive policy. Therefore, this paper could be of great interest in the debate on PT policies.

## 2.4.Features of the Madrid Region PT system, policies and mobility trends

### 2.4.1. The Madrid Region PT system

The Madrid Region has significantly improved its infrastructure and PT services to position itself as a successful case in terms of quality, price and degree of integration[6]. This integrated PT system is based on three pillars: administrative, fare and modal (Vassallo et al., 2009).

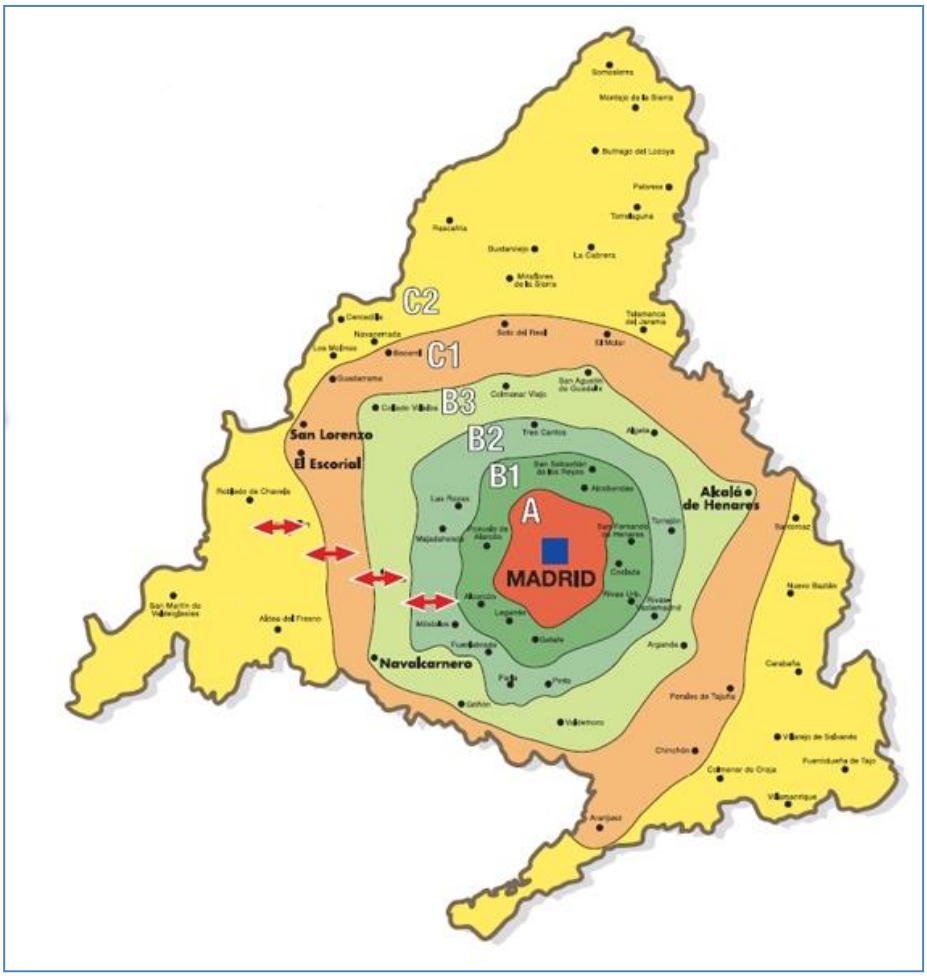
The administrative pillar is supported by the CTRM created in 1985. This department plans, manages and coordinates PT issues for all the region's municipalities. The fare pillar consists of an integrated fare system for the whole PT network in the form of a travel-pass (there is a normal travel-pass and specific ones for the population under 26 and over 65). The third level is the physical integration of transport modes. Large infrastructure investments have been carried out to improve the physical connection between modes and extend the bus, underground and rail

[6] In fact, the quality of service is very high, with the whole region well connected by PT (i.e. the underground is the second largest in Europe after the one of London, which however is a more populated urban area), the prices are highly subsidized, and infrastructures of underground, buses and trains supply are high and well interconnected.

networks. In this respect, during the years prior to the economic crisis the improvement of the underground infrastructure was remarkable.

The fares scheme is designed according to the distance travelled (zoning) and the frequency of use. On the one hand, the CTRM has divided the region into zones[7] and has assigned them a fare. There are eight zones (Graphic 1): a central area (A) which is Madrid city, three metropolitan areas (B1, B2 and B3), and two zones that complete the administrative limit of the Community (C1 and C2). The fares are positively related to the distance.

**Figure 1**. Transport area in Madrid region.




[7] These zones were designed in function of the distance to Madrid City (ring A) and did not correspond with any administrative unit (province, region, etc.) or with rural or urban areas.

Source: Regional Consortium of transportation of Madrid

On the other hand, the fares are based on the frequency of use. There are three types of fares (CTRM, 2016): 1) A single ticket for occasional users (it represents around 9% of demand) who pay the highest price per trip; 2) a multi-ride ticket of ten trips for frequent users generally travelling only within Madrid city (representing about 18% of the demand); 3) a travel-pass for very frequent users, with a monthly or annual fee. This is the cheapest and most widely used ticket (it represents about 70% of the demand) because PT users can make unlimited trips within the fare area, (the supply is perfectly elastic). It constitutes an important implicit subsidy for very frequent users (Vassallo et al., 2009; Bueno Cadena et al., 2016). In fact, the more the users travel, the smaller the average price they pay per trip. In other words, the more they travel the bigger the subsidy they receive. Moreover, the travel-pass is the only transport ticket with special prices for the young and elderly.

### 2.4.2. Trends of passenger mobility in the Madrid Region

The Madrid Region is made up of 179 municipalities located in an area of 8,021 km2, with a population of 6,466,996 inhabitants. This region is the most populated in Spain and the third largest in Europe (Méndez Gutiérrez del Valle, 2012). In 2015, the population under 26 was 1,768,880 people representing about 27% of the total population.

The Madrid Region is a sprawling metropolitan area following a radio-centric scheme, then from a central point other area form rings around it. So, three areas can be distinguished:

- The Central ring – Madrid City (zone A) with a population of 3,165,541 people representing 48.9% of the total regional population.
- The metropolitan ring (Zones B: B1, B2 and B3), composed mainly by medium-sized cities, with more than 2 million inhabitants that represent 45% of the total regional population.
- The peri-urban ring (Zone C: C1 and C2) with a total population of 374,660 people representing 5.7% of the total regional population. This area is composed by 129

municipalities, of which 127 have less than 10,000 inhabitants (so for their size these municipalities are considered rural areas in Spain). However, the 2 municipalities with more than 10,000 inhabitants, represent 48.34% of the total population of the area, in that sense this ring is peri-urban and not rural.

From an economic point of view, the Madrid Region is the richest in Spain with a GDP per capita of 32,723 Euros in 2016 (INE, 2017). Following Burguillo et al. (2017b) we can assert that households with the highest income levels are concentrated in Madrid city and in a few medium-size cities located within 40 kilometres to the North and to the West of Madrid (in ring B). In 2011, the average income per capita in Madrid city was approximately 37,500 Euros, reaching 45,700 Euros in seven small and medium towns located North of Madrid city. These seven towns have an aggregated population of 325,484 and represent 5% of the entire population of Madrid[8]. There are also 11 cities to the West of Madrid representing 7.3% of the entire population with an income per capita close to 30,000 Euros[9]. In the rest of the region, the income per capita is around 20,000 Euros on average, which is lower than the Spanish income per capita, around 22,000 Euros (Madrid Statistics Institute, 2013).

In 2014 passenger mobility in the region was distributed as follows: 41% of trips were made by car, 27.8% by PT, 29.9% by foot and 1.3% by others (i.e. taxi, bicycle, car-pooling, etc.) (Wang and Monzon, 2016). Thus, there is a prevalence of the car as mean of transport. Moreover, as in other metropolitan areas of Spain and in the world (Burguillo et al., 2017a), the use of the car is positively related to the distance to ring A. For example, 68% of the total trips in the peri-urban ring (Zone C) were made by car in 2014. In addition, households with lower average incomes, who tend to live in the more peripheral areas due to the price of housing, are the ones that need to move the most, since work, study and leisure places are usually at a great distance from their homes. For example, in this region approximately 63% of jobs are in Madrid City (Méndez Gutiérrez del Valle, 2012).

[8] Those towns are Alcobendas, Algete, Cobeña, Colmenar Viejo, Tres Cantos, San Agustín de Guadalix and San Sebastián de los Reyes referred to as the Metropolitan North Statistical Area by the Madrid Regional Government.

[9] Those cities are Boadilla del Monte, Brunete, Collado-Villalba, Galapagar, Hoyo de Manzanares, Las Rozas, Mahadahonda, Pozuelo de Alarcón, Torrelodones, Villanueva de la Cañada and Villaviciosa de Odón referred to as the Metropolitan West Statistical Area by the Madrid Regional Government.

Given this context, the new design of the young travel-pass prices, in which distance is not a variable related to fares, seems on the one hand to be motivated by obvious reasons of equity. In this sense, Cascajo et al. (2017) indicate that sustainability-oriented transport policies that promote PT and reduction of automobile dependence can help to limit the budget for family transportation. On the other hand, this design also searches to achieve economic efficiency. It is true that as we move away from the central ring, in Madrid and other metropolitan areas around the world, the supply of PT and therefore its accessibility decreases providing an explanation for greater use of the car by the inhabitants of those areas. But the price also matters. Li et al. (2015), for example, demonstrate for the case of Brisbane in Australia, that if the price of PT is relatively high in the areas farthest from the city, people use the car instead of PT even if it is accessible. The data on the travel-pass sales by areas that we saw in the previous section showed that the more peripheral the zone is, the greater the impact on the demand of the new price policy. In this sense, this policy is helping the price to not be an obstacle to using PT in peripheral areas by young people.

### 2.4.3. The new price policy for the young

In October 2015, a new fare scheme for the young travel-pass came into force: the age limit criterion increased from 23 to 26 years and new fares were reduced and not positively related with distance[10]. The new monthly fare is 20 Euros for all the zones. This entails an important increase on this type of ticket subsidisation.

The table 1a shows the prices by transport zones (A, B1, B2, B3, C1, C2) of the "traditional" young travel-pass (under 23) before and after the implementation of the new policy program. It shows also the size of the reduction in this price as consequence of the measured implemented. As it can be shown, before October 2015 the prices vary, from 35€ in zone A to 61.8€ in zone C2, and after they were 20€ for all zones. Then, on average, the travel-pass for these "traditional young" has been reduced by 56.8%, being this reduction upward by zones from 42.8% in zone A to 67.6% in zone C2.

[10] Unfortunately, we cannot evaluate the impact of the subsidy scheme by zones because the Transport Zones designed by the CTRM in Madrid Region did not correspond to any administrative unit, or specifically to rural or urban municipalities. In that sense, there is not an official survey -and the HBS is not an exception- collecting socioeconomic information of households located in these Madrid Transport Zones.

The table 1.b shows the prices for the "new" young (23-26) of the travel-pass, before and after the implementation of the new transport policy as well as the size of the reduction in this price by transport zones (A, B1, B2, B3, C1, C2). As it can be shown, in all the zones, before the implementation of the measure these individuals payed the price of the normal travel-pass: from 54.6€ in zone A to 99.3€ in zone C2. And after, they had to pay the price of 20€ stablished for the young travel-pass in all the transport zones. Therefore, for this group of population the price of the travel-pass has decreased by 72.8% on average; being this reduction upward by zones from 63.3% in zone A to 79.8% in zone C2.

**Table 1a.** Prices of the travel-pass for the "traditional young" (people under 23) before and after the implementation of the policy measure, and size of the reduction in the price as consequence of this new policy.

| | **Zones** | | | | | |
|---|---|---|---|---|---|---|
| | **A** | **B1** | **B2** | **B3** | **C1** | **C2** |
| ***Before October 2015*** | | | | | | |
| *Travel-pass price* | 35€ | 39.6€ | 45€ | 51.6€ | 56.2€ | 61.8€ |
| **After October 2015** | | | | | | |
| *Travel-pass price* | 20€ | | | | | |
| *Price reduction* | 42.8% | 49.4% | 55.5% | 61.2% | 64.4% | 67.6% |

Source: Own elaboration using data from RCTM (2016).

**Table 1.b** Prices of the travel-pass for the "new young" (people between 23 and 26) before and after the implementation of the policy measure, and size of the reduction in the price as consequence of this new policy.

| | **A** | **B1** | **B2** | **B3** | **C1** | **C2** |
|---|---|---|---|---|---|---|
| ***Before October 2015*** | | | | | | |
| *Travel-pass price* | 54,6 | 63.7€ | 72€ | 82€ | 89.5€ | 99.3€ |
| **After October 2015** | | | | | | |

| *Travel-pass price* | 20€ | | | | | |
|---|---|---|---|---|---|---|
| *Price reduction* | 63,3% | 68.6% | 72.2% | 75.6% | 77.6% | 79.8% |

The latest demand data provided by the CTRM (2016) (until December 2015) show that this measure has had an immediate effect on the sales of the young travel-pass. Thus, from January to September 2015, the young travel-pass represented a 15.4% of the sales of travel-passes and from October to December, it represented a 30.7 % of total sales (CTRM, 2016). Then, the share of the young travel-pass in total the total sales of this kind of transport ticket has doubled after the new policy implementation. Moreover, the sales of the young travel-pass between 2014 and 2015 have increased by 26.2%. That inter-annual trend is influenced, following the CTRM (2016), by the sharp rise experienced by the sales of the young travel-pass in the first three months of new prices implementation.

We do not have data that are more current yet, as the CTRM has not made them public at the time of writing this work. However, the data for the first three months of implementation of this measure seem to indicate that it has been successful in the aim of encouraging young people's loyalty to PT.

### 2.5. Methodological Approach

In this section[11], we present the empirical model used to estimate the impact of a reduction of the young travel-pass fares over the total expenditure on travel- pass in order to know its distributional and individual welfare implications. For this purpose, we use an IE technique known as DID. The IE techniques seek to answer a specific cause and effect question: What is the impact (or causal effect) of a program (P) on an outcome of interest (Y)? In our case, the question is what is the impact of the reduction in young travel-pass fares (P)[12] over the expenditure on travel-pass (Y) of Madrid households that spend a minimum of 240 euros per year in this service? The answer could be given by the impact evaluation formula:

[11] This section is based on Cerulli (2015) and Khandker et al. (2010).
[12] Implemented in the Madrid Region in October 2015.

$$\Delta = (Y|P = 1) - (Y|P = 0) \qquad (1)$$

Where the causal impact (Δ) of a program (P, travel-pass fare) on an outcome (Y, household expenditure in travel-pass) is the difference between the outcome Y with the program (P=1) and the same outcome (Y) without the program (P=0). This basic IE formula is valid for any unit (household) that is being affected or not by the program. However, we know that the household cannot be observed simultaneously in two different states (with and without the program). We do not have a clone of households. This is the called counterfactual problem in IE. The main challenge across different types of IE is to estimate a good counterfactual: How the outcome (Y) would have been for a program participant –in the absence of the program (P)?

A number of different quantitative and ex post quasi-experiment methods[13] can be used to address the question of the counterfactual (propensity score matching (PSM), instrumental variables (IV), regression in discontinuity (RD) and DID). Methods vary by their underlying assumptions regarding how to resolve selection bias in estimating the program treatment effect and the estimation of the counterfactual. DID is suitable[14] in our evaluation context where observational data for treated and untreated households are available before and after treatment or program intervention and allows unobserved heterogeneity effect.

The DID can be estimated within a regression analysis. In particular, the estimation equation could be specified as follows:

$$Y_i = \beta_0 + \beta_1 D_i + \beta_2 T_i + \beta_3 D_i T_i + \beta_4 X_i + \varepsilon_{ui} \qquad (2)$$

In this specification, $Y_i$ is the variable measuring the outcome of interest (household's travel-pass expenditure) in logarithms for household i. $D_i$ is a dummy variable indicating if the household

[13] We use quasi-experiment method because we do not have a randomized experiment.

[14] In contrast, PSM evaluates the program in one moment of the time while DID technique can be used in repeated cross-sectional data and allows for unobserved heterogeneity that may lead to selection bias. DID also deal with endogenous selection without the need for IV or additional assumptions (Abadie, 2005). Finally, RD is suitable when selection is based on an assignment score and a clear cut-off (for example, 26 years old). However, the exercise focuses only on individuals or units closely situated around the threshold.

benefits or not from the young travel-pass (it takes the value of 1 if it was affected by the young travel-pass -treatment group- and 0 otherwise- control group). $T_i$ is the dummy variable for the policy change adopted in October 2015: it takes the value of 1 for all the households after the change in fares for the young travel-pass took place (year 2016) and 0 before the change (year 2014). $X_i$ represents a vector of exogenous control variables of the households (if the household lives in Madrid City or not, the number of students in the household, the age of the household breadwinner and the nationality of the household breadwinner) and $\boldsymbol{\varepsilon}_i$ is the error term in the model.

In the estimation of the model, $\beta_0$ is the mean outcome effect of the control group on the baseline or before intervention (year 2014). $\beta_0+\beta_1$ is the mean outcome for the treated group on the baseline (year 2014). $\beta_1$ is the single difference between treated and controls groups on the baseline. $\beta_0+\beta_2$ captures the mean outcome effect for the control group in the follow-up or after the intervention (year 2016). $\beta_0+\beta_1+\beta_2+\beta_3$ is the mean outcome effect for the treated group in the follow-up or after the intervention. $\beta_1+\beta_3$ is the single difference between treated and controls groups on the follow-up. Finally, the DID effect, of the change in prices is captured by the parameter $\beta_3$, since $(\beta_1+\beta_3)- \beta_1= \beta_3$. In other words, this latter parameter identifies the causal effect under the "parallel trend" assumption[15], namely that any time-varying unobservable variables have the same effect on treated and non-treated households. The interpretation of this parameter is that it measures the change on travel-pass expenditure of households from the treatment group in relation to the households from the control group after October 2015 and relative to the change on travel-pass expenditure by households from the treatment group in relation to the control group before October 2015.

### 2.6. Data

Data used in this paper come from two waves of the Households Budget Survey (HBS), in 2014 and 2016. HBS is a repeated survey that includes detailed information about 256 expenditure

[15] This means that unobservable characteristics affecting the policy decision do not vary over time with treatment status. In other words, the outcome of the programme would increase or decrease at the same rate in both groups without the intervention. This is when the error term is uncorrelated with other variables in the equation.

groups and socio-economic characteristics of each household. In this paper, we use data for the Madrid Region. The total number of households in the Madrid region are 1,634 and 1,653 households in 2014 and 2016, respectively[16].

As we are interested to evaluate the impact of the change in the young travel-pass fare where the dependent variable is household´s expenditure on travel-pass (in other words, household's consumption on travel-pass), we focus on households spending at least a minimum of 20 Euros per month on the travel-pass. The travel-pass is used by very frequent PT users, and is designed to subsidise this type of traveller; we considered that households spending less than this minimum of 20 Euros per month, which is the new price of the young travel-pass, are not frequent users of PT.

After the sample selection, Table 2 provides summary statistics, for the sample before (2014) and after October 2015 (2016). In this table, we observe 427 households in 2014 (224 treated and 203 not treated) and 445 households in 2016 (249 treated and 196 not treated)[17]. The control group are households whose members could not benefit from the young travel-pass neither in 2014[18] nor in 2016 and spending at least 20 Euros per month in the travel-pass. The treatment group includes households with at least one member beneficiary from the young travel-pass in 2014 and 2016, and spending at least 20 Euros per month on the travel-pass.

The covariates are the number of members in the household, if the household is located in Madrid City[19], the number of students in the household, the age of the household breadwinner, the nationality of the household breadwinner, if the household is located in a rural area and the total expenditure in Euros. As income declared in the household budget surveys is often lower than the actual one, it is typical in the literature, as we do in this paper, to use total household's expenditure as a proxy of income (Burguillo et al., 2017b, among others). An additional advantage of using expenditure is that it is a good proxy for permanent income. Following West and Williams (2004),

[16] They represent using the weighting factor for the HBS 2,515,290 and 2,568,451 households in 2014 and 2016, respectively. These numbers are similar to the official census numbers of habitants for 2014 and 2016 in this region.
[17] The 427 households in 2014 and 445 households in 2016 in the sample represent respectively 636,469 and 673,703 households in weighted terms.
[18] There are 27 households in 2014 with all its "young" members between 23 and 26. This 27 households are included in the control group in 2014. In that year no member of these households could benefit of the young travel-pass.
[19] Unfortunately, we cannot estimate the impact of the subsidy scheme by zones because we do not have information about residence of households in different district of Madrid. In a future research, we will try to get data from the Regional Transport Consortium of Madrid.

among others, total expenditure of households has been adjusted using the OECD scale (2008, 2011)

**Table 2.** Descriptive analysis of some variables. HBS, total and 2014 and 2016 years.

| Variables | Description | 2014 | | 2016 | |
|---|---|---|---|---|---|
| | | Mean | S.E. | Mean | S.E. |
| **Log Y** | Expenditure (in log) in travel pass (euros) | 6.666 | 0.862 | 6.727104 | 0.7834665 |
| **Y** | Expenditure in travel pass (Euros) | 1178.676 | 1272.693 | 1167.229 | 1204.77 |
| **X3** | If the household live in the Capital (1 Yes, 0 No) | 0.684 | 0.466 | 0.656 | 0.476 |
| **X4** | Number of students in the household | 0.375 | 0.709 | 0.396 | 0.708 |
| **X5** | Age of the household breadwinner | 53.145 | 12.752 | 52.962 | 13.156 |
| **X6** | Nationality of the household breadwinner | 0.876 | 0.330 | 0.834 | 0.373 |
| **D** | Dummy variable that takes value 1 for the treatment group- and 0 otherwise, control group | 0.525 | 0.500 | 0.560 | 0.497 |
| **T** | Dummy variable for the policy change adopted in October 2015: it takes the value 1 for all the households in 2016 and 0 otherwise. | 0 | 0 | 1 | 0 |
| **Type of household** | | | | | |
| TIP1 | One person aged over 65 | 0.040 | 0.196 | 0.076 | 0.266 |
| TIP2 | One person aged under 65 | 0.084 | 0.278 | 0.043 | 0.202 |
| TIP3 | Couple without children | 0.159 | 0.366 | 0.182 | 0.386 |
| TIP4 | Couple with a child | 0.187 | 0.391 | 0.187 | 0.390 |
| TIP5 | Couple with two children | 0.211 | 0.408 | 0.231 | 0.422 |
| TIP6 | Couple with 3 children or more | 0.052 | 0.221 | 0.040 | 0.197 |
| TIP7 | One adult with children | 0.126 | 0.333 | 0.128 | 0.335 |
| TIP8 | Other type of households | 0.141 | 0.348 | 0.112 | 0.316 |
| Number of observations | | 427 | | 445 | |

Note: S.E. means standard error.

## 2.7. Results

This section reports the estimate results of the model presented above. All estimations have been carried out using the DID method to evaluate the impact of the young travel-pass fare scheme

implemented in the Madrid Region in October 2015. First, we estimate the DID method to evaluate the policy intervention on young travel-pass fares since 2015, first for the Madrid Region households as a whole and second for households by income quintiles.

Table 3 presents the estimation results using the DID method excluding explanatory variables in panel A, and in panel B including them. Estimations are reported using the bootstrapping standard error. Our main interest focuses on the estimate of the parameter $\beta_3$ from equation (2), that captures the DID effect of the change in prices after October 2015.

**Table 3**. DID estimations results. BHS 2014 and 2016 years.

| | **Panel A** | | **PANEL B** | |
|---|---|---|---|---|
| **Outcome variable** | **Parameter** | **Bootstrap S.E.** | **Parameter** | **Bootstrap S.E.** |
| D | 0.253*** | 0.082 | -0.140 | 0.100 |
| T | 0.135* | 0.074 | 0.173*** | 0.068 |
| DID (D*T) | -0.176** | 0.091 | -0.188** | 0.090 |
| **Type of household** | | | | |
| One person (TIP 1 or TIP2) | | | - | - |
| Couple without children (TIP3) | | | 0.254*** | 0.086 |
| Couple with a child (TIP4) | | | 0.345*** | 0.084 |
| Couple with two children (TIP5) | | | 0.459*** | 0.092 |
| Couple with 3 children or more (TIP6) | | | 0.455*** | 0.158 |
| One adult with children (TIP7) | | | 0.514*** | 0.103 |
| Other type of households (TIP8) | | | 0.456*** | 0.103 |
| **If the household live in the Capital (1 Yes, 0 No) (X3)** | | | 0.064 | 0.061 |
| **Number of students in the household (X4)** | | | 0.154*** | 0.043 |
| **Age of the household breadwinner(X5)** | | | -0.013*** | 0.002 |
| **Nationality of the household breadwinner (X6)** | | | -0.131 | 0.092 |
| **Constant** | 6.550*** | 0.062 | 7.094*** | 0.194 |

Note: Significance levels: * p<0.10, ** p<0.05, *** p<0.01

We find that the impact of the change in prices significantly decreased the expenditure on the travel-pass by 17.6% on average (see Table 3 panel A). A basic assumption in the implementation

of this DID method is that explanatory variables are invariant across years. But if these variables change they must be controlled in the regression to obtain the net impact effect on the travel-pass expenditure. Table 3 panel B includes an extended model incorporating the explanatory variables mentioned above[20]. Results are similar in the two specifications. In the latter estimation, the changes in prices reduced the travel-pass expenditure by 18.8% on average[21].

In addition, we measure the impact of the reduction of the young travel-pass fares over the total expenditure in travel-pass (Y) by total expenditure (income) quintiles. For that purpose, we considered that the quantile difference in difference (QDID) is an optimum approach to estimate the impact of new young travel-pass fares for a given quantile in the distribution of the outcome Y, conditional to observed covariates. Table 4 shows QDID regression income by quintiles (Q)[22]. In this table, Panel A includes estimations without explanatory variables and Panel B with them. In the estimation of these models, the shrinking young travel-pass fares has had a significant effect for the first (Q1), the third (Q3) and the fourth (Q4) quintiles and no effect on the second (Q2) and the fifth (Q5) quintiles. The households with members beneficiaries of the young travel-pass (treatment) that belong to Q1 (poorest income group) have increased on average their travel-pass expenditure by 16% with control variables, after the new travel-pass prices were adopted. This significant impact can be explained because before October 2015 many of these poorest household's young members could not afford to buy the travel-pass. In contrast, the households in Q3 and Q4, households with respectively intermediate and high-intermediate income levels, have reduced on average their travel-pass expenses by 43.1% and 41.4% respectively. This means that as a result of the PT prices shrinking those households have saved money, or in other words have increased their budget constraints. However, we observe that the change in young travel-pass fares has not had any impact on the budget of the households with medium-low income levels (Q2) or the highest income level (Q5). The estimation effects remain similar when we do not include explanatory variables in the estimations, with the only difference that the parameters for Q1 and Q3 are higher.

[20] Total expenditure –proxy of income– and if the household breadwinner lives in a rural area were included as covariates in previous estimations, but their effects were not significant.

[21] In order to know if the estimation results can be affected by family composition, we have reduced the sample to comparable groups of total household's members of two, three or four members. We observe that DID estimation (available upon request) is not affected by family composition. In particular, we observe that there is only a significance effect in households with a total number of household members equal 2 and no effect in household with three or four.

[22] See Athey and Imbens(2006) and Khandker et al. (2010) for further details about QDID regression.

**Table 4.** QDID estimations results by quintiles. BHS 2014 and 2016 years.

Panel A: Without explanatory variables

| | Q1 | | Q2 | | Q3 | | Q4 | | Q5 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Param.** | **Boot. S.E.** | **Param.** | **Boot .S.E.** | **Param.** | **Boot .S.E.** | **Param.** | **Boot. S.E.** | **Param.** | **Boot. S.E.** |
| *D* | 0.001 | 0.066 | 0.359 | 0.233 | 0.697*** | 0.150 | 0.326*** | 0.105 | 0.003 | 0.037 |
| T | 0.040 | 0.060 | 0.096 | 0.200 | 0.357*** | 0.140 | 0.228* | 0.120 | -0.033 | 0.076 |
| DID(D*T) | 0.319** | 0.133 | -0.153 | 0.257 | -0.701*** | 0.227 | -0.382** | 0.193 | 0.012 | 0.083 |
| Constant | 5.762*** | 0.003 | 6.097*** | 0.195 | 6.507*** | 0.075 | 7.309*** | 0.067 | 5.548*** | 0.032 |

Panel B: With explanatory variables

| | Q1 | | Q2 | | Q3 | | Q4 | | Q5 | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Outcome variable** | **Param.** | **Boot.S.E.** | **Param.** | **Boot. S.E.** | **Param.** | **Boot.S.E.** | **Param.** | **Boot. S.E.** | **Param.** | **Boot. S.E.** |
| *D* | -0.104 | 0.098 | -0.117 | 0.181 | -0.128 | 0.205 | -0.204 | 0.210 | 0.005 | 0.062 |
| T | 0.127*** | 0.048 | 0.129 | 0.092 | 0.230** | 0.097 | 0.304*** | 0.103 | 0.033 | 0.064 |
| DID(D*T) | 0.160* | 0.096 | 0.036 | 0.141 | -0.431** | 0.190 | -0.414** | 0.190 | -0.081 | 0.076 |
| ***Type of household*** | | | | | | | | | | |
| TIP1 or TIP2 | - | - | - | - | - | - | - | - | | |
| TIP3 | 0.166** | 0.070 | 0.433*** | 0.129 | 0.412*** | 0.129 | 0.152 | 0.184 | -0.056 | 0.119 |
| TIP4 | 0.139** | 0.072 | 0.416*** | 0.133 | 0.575*** | 0.177 | 0.535** | 0.253 | -0.069 | 0.122 |
| TIP5 | 0.147** | 0.067 | 0.530*** | 0.174 | 0.671*** | 0.195 | 0.611** | 0.270 | -0.090 | 0.123 |
| TIP6 | 0.203 | 0.211 | 0.726*** | 0.263 | 0.609*** | 0.188 | 0.437 | 0.324 | -0.055 | 0.131 |
| TIP7 | 0.210*** | 0.074 | 0.485*** | 0.145 | 0.811*** | 0.185 | 0.712*** | 0.211 | -0.046 | 0.124 |
| TIP8 | 0.077 | 0.093 | 0.455*** | 0.166 | 0.611*** | 0.202 | 0.555*** | 0.213 | -0.116 | 0.131 |
| **X3** | 0.136*** | 0.050 | 0.259*** | 0.077 | 0.067 | 0.108 | -0.086 | 0.105 | 0.069*** | 0.027 |
| **X4** | 0.120** | 0.052 | 0.078 | 0.071 | 0.252*** | 0.069 | 0.212*** | 0.074 | 0.048 | 0.033 |
| **X5** | -0.004** | 0.002 | -0.010*** | 0.004 | -0.017*** | 0.004 | -0.020*** | 0.004 | -0.003 | 0.002 |
| **X6** | -0.017 | 0.093 | -0.113 | 0.132 | -0.343*** | 0.135 | -0.117 | 0.133 | -0.015 | 0.041 |
| **Constant** | 5.836*** | 0.121 | 6.340*** | 0.329 | 7.449*** | 0.308 | 8.192*** | 0.207 | 5.760*** | 0.166 |

Note: Significance levels: * p<0.10, ** p<0.05, *** p<0.01. Boot. S.E. means bootstrap standard error.

## 2.8.Conclusions

This paper analyses the impact on travel-pass expenditure of Madrid households after regional authorities adopted the new PT price policy for the young in October 2015. This measure has implemented a "flat" PT fare of 20 Euros per month to young under 26 years, allowing them to move through all the areas of the region without extra charges and unlimitedly during its period of validity. We used the double difference technique for the HBS cohorts of 2014 and 2016 to evaluate the impact. To the best of our knowledge, this is the first study tackling this issue.

The results show that for the total sample this measure has reduced the travel-pass expenditure of beneficiary households. When the analysis is carried out by quintiles, the results are different: on the one hand, beneficiary households located in the third and fourth income quintiles have reduced their expenditure on the travel-pass, by a rather high magnitude and was similar for both groups. This means that their budget constraint has increased, and they have more disposable income to buy other goods or to save. Then, it can be asserted that this policy has significantly increased the individual welfare of medium and high-medium income households using the travel-pass in Madrid, which are then the main beneficiaries of the measure analysed. Those results are in accordance with other results in the literature: Burguillo et al. (2017b) also found, using expenditure data, that Q3 and Q4 households in the Madrid Region are the most affected in welfare terms by PT price policies. On the other hand, the results show that the measure has not increased the budgetary restriction of the poorest households (first quintile) but has encouraged them to spend more on the travel-pass; therefore, this measure has made PT more affordable to the poorest. In any case, the magnitude of the impact is much lower than the one for Q3 and Q4. Moreover, the measure has not had significant effects for the households in the second and the last quintile, or the medium-low income level and the richest. These results are also in accordance with those in the literature: Burguillo et al. (2017b) found that the richest Madrid households were not affected much by PT price policies and concerning Q2 Burguillo et al. (2017a) found using expenditure data for the case of Spain that households with medium-low income levels are the least responsive to changes in PT prices and have the lowest own price elasticity of car use demand. This could also be the case for low-medium income Madrid households and can explain our results.

In sum, we can conclude that the public policy object of this analysis has been positive from an equity point of view in the sense that first it has complied with the premise of making PT more accessible to the poorest, which should be, following Serebrisky et al. (2009), the main objective of PT price subsidies based on equity. Second, the measure is not significant for the richest households, who are mainly concentrated in zone A, which is the area where the relative price of the young travel travel-pass has decreased the least. However, and this is not positive, it seems that many households having low-medium income levels have not benefitted from this measure. More research is needed to shed light on what could be the reason for this result. A hypothesis is that most of these households are located in peri-urban areas with poor PT services[23].

As a general conclusion, we can state that even if a priori the age could not be a criterion to discriminate public policy beneficiaries on equity grounds, from the example of the Madrid Region PT policy for the young, that can be extended to other urban areas, like Paris or Rome that also apply this kind of policies, we can infer that it could be but with restrictions. First, the design of such a policy is of great importance. In the case analysed, a "flat" fare scheme has been implemented and this generally works as a cross subsidy for the demand, allowing the financing of long distance trips (generally made by people with fewer resources) with short-distance trips (ASPA, 2014). Second, it seems that the equity impact of PT focussing on the young depends also on having a good service supply in peripheral areas where are usually located the cheaper dwellings.

Further research can be developed on estimating the total cost of the policy analyzed, therefore the public financial impact of the strong subsidization of TP prices for young. Moreover, analysing the impacts of TP policy on young from a supply point of view could also be an interesting issue.

[23] Even if the Madrid Region has a very good PT supply there are still many municipalities on ring B and especially ring C without metro or commuter train infrastructure and a low-quality bus service. Burguillo et al. (2017a) explain that in the last twenty years, a sprawling urban model has developed in Spain and many households of low-medium income levels are located in peripheral areas where the real estate is much cheaper. Those households are the most car dependent to go to work.

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## III. ARE PUBLIC TRANSPORT POLICIES INFLUENCING THE TRANSPORT BEHAVIOUR OF OLDER PEOPLE AND ECONOMIC EQUITY? A CASE STUDY OF THE MADRID REGION

*Abstract*

This article assesses the impact of a subsidy for public transport prices in the Madrid Region for the elderly on PT and automotive household expenditures. Data from the Spanish Household Budget Survey and a discontinuity regression model are used to analyse this PT policy from an equity and efficiency point of view. The results show that as a consequence of this public policy, households from quartiles 1 and 2 whose main-breadwinner is elderly and not employed have reduced their expenditure on PT by 83.9% and 65.3% respectively, and households from quartile 1 having an employed and elderly main-breadwinner have reduced it by 106.4%. All these households have been the main beneficiaries of the policy in terms of economic well-being. Therefore, in distributive and equity terms these subsidies benefit the poorest households among those whose main breadwinner is an elderly, and the richest ones. In terms of efficiency, the high increase of the relative price of automotive fuel due to PT subsidization has only had an impact on households in which the main breadwinner is elderly and not employed, concretely those households from quartiles 1, 2, and 3 have reduced their expenditure on automotive fuel by 38.8%, 30.3% and 51.9%, respectively.

Keywords: Transport policy, impact evaluation, fare transport subsidies, elderly.

JEL code: C21, H20, R21, R28, R48

### 3.1.Introduction

Subsidies for public transport (PT) fares are a general policy in most countries. The justification of these subsidies is to achieve greater economic efficiency and greater social equity in the use of transportation. In relation to achieving greater economic efficiency, the objective is encouraging through lower PT relative prices, an increase of PT use and a decrease of private car use, considering the former as a cleaner means of transport than the latter. This would internalise the externalities arising from the use of pollutant means of transport and increase in economic efficiency. In relation to the objective of achieving greater social economic equity, the object is to subsidise PT prices in order to favour mobility and access to transport for people considered

economically vulnerable, giving them the possibility of not sacrificing their need for transportation for other goods, or other goods for transportation. In this sense, young people and those over 65 are generally the groups considered economically vulnerable and, therefore, for these groups the subsidies for PT are higher than for the rest of the population. This kind of policy is applied in many cities around the world and specifically in the Madrid Region (MR), where this work is focused.

In fact, this work analyses the effects of PT subsidies for people over 65, who are, generally, the social group most subsidised in the cities applying subsidies to PT prices. This is also the case in the Madrid Region, where the price of the PT travel-pass for the elderly is 87% lower than the price (also subsidised) for the population between 26 and 64; and 52.5% lower than the travel-pass for those under 26. These high subsidies are usually justified by arguing that, generally, those over 65 are economically vulnerable. The argument is that these individuals live on retirement pensions that are on average lower than average wages. This argument has been historically true until recently. However, the current situation is not exactly like that, neither in Spain nor in many other countries; in fact, it is expected that by 2030, worldwide, those over 60 will be the social group with the highest purchasing power (Guillén, 2020).

Regarding the economic situation of the population over 65 in Spain and the Madrid Region, the average salaries have historically been approximately double the average retirement pension. However, the differences have been narrowing over time. According to data from the Spanish Ministry of Inclusion, Social Security and Migration in Spain, the average salaries represented 2.18 times the average retirement pension in 2006 and 1.74 times in 201824. These numbers are similar in the Madrid Region25 where the average salaries represented 2 times the average

24 In Spain the average retirement pension was 1,090 euros per month in 2018, which represented an increase of 51% compared to 2006 when it was 722 euros per month. The average salary was 1,944 euros per month in 2018, which represented an increase of 24% compared to 2006 when it reached 1,573 euros per month. It is expected that in Spain in 2050, persons over 65 will be 40% of the total population. See data from the Spanish Ministry of Inclusion, Social Security and Migration (Ministerio de Inclusión, Seguridad Social y Migración, 2021a).

25 Specifically, the average pension was 876 euros per month in 2006, while it was 1,333 euros per month in 2018, which represented an increase of 47% compared to 2006. The average salary in the MR in 2006 reached 1,730 euros per month and 2,265 euros per month in 2018, with an increase of 31%. This shows

retirement pension in 2006 and 1.6 times in 2018. Moreover, households with an elderly main breadwinner (MBW) have continuously improved their economic situation in terms of income and wealth, which is not the case for younger groups. According to the Survey of Living Conditions (ECV) of the National Institute of Statistics of Spain (INE), the average income per person aged 65 and over in 2018 was 16,339 euros, while the average income per person with an age between 18 at 64 was 13,689 euros. Therefore, persons over 65 had an average income 14% higher than the population of legal working age in 2018. Additionally, the elderly have levels of net wealth higher than the population in other age groups; they have more accumulated assets such as their own home (Pérez et al., 2020). All these data put into question whether elderly people as a whole, by the mere fact of having reached the legal retirement age should, without further criteria, be considered economically vulnerable compared to other age groups26. In this regard, it may be questionable that for reasons of equity the whole population over 65 should receive high subsidies for PT. Therefore, it is interesting to analyse which income groups among those over 65 benefit the most from these subsidies.

The population over 65 represents an increasing percentage of the total population in Spain. Following the statistics of the INE, the population over 65 was 1.1 million in 2018 while it was 772,000 in 2000. Therefore, the population over 65 years of age increased by 49% in the last 20 years. This group represented 14% of the total population in the Madrid Region in 2000, and 18% in 2018. This growing trend is expected to accelerate in the coming years due to the aging of the population. The consumption patterns of people over 65 will thus have an increasingly important impact on the environment. In this demographic context, it would be interesting to evaluate the impacts of PT subsidies to the elderly from an efficiency point of view, which is not the criterion that has traditionally guided transport policy to positively affect this population group. The group of elderly, by itself, represents an interesting group to analyse how agents respond to incentives to use a clean means of transport compared to dirty ones. This is so for two reasons: (i) the high level

that the average pensions between 2006 and 2018 grew by 16 percentage points more than the average wages. See data from the Spanish Ministry of Inclusion, Social Security and Migration (Ministerio de Inclusión, Seguridad Social y Migración, 2021b).

26 As retirement is not compulsory, there are people over the legal retirement age who are still working, and also people under 65 who are already retired; moreover, this legal retirement age has been corrected upwards: in 2021 the retirement age in Spain is 66 years.

of PT subsidies makes the relative price of the PT compared to the price of using a car very low for this social group and (ii) this is a group that generally has fewer restrictions than other groups of the population to choose one means of transport or another. Most of them are not conditioned by work or study obligations, which could limit their schedule and the means of transport that they use depending on where they reside.

In this context, the contribution of this paper to the literature is twofold. First, it assesses to what extent the high subsidies for PT for those over 65 really meet the objective of equity, increasing the disposable income of households who are truly economically vulnerable compared to the rest of the population and making PT accessible for them without the necessity of sacrificing other goods. To the best of our knowledge, the literature on policies for PT subsidies has not evaluated the impact on the economic well-being of households (that is, on the material living conditions which determines people's consumption possibilities and their command over resources) when these subsidies are allocated to the elderly. In fact, it has generally been taken for granted that this policy was equitable, since it has been considered that all those over 65 are economically vulnerable. However, as we have previously commented, this idea, which has perhaps been valid historically, is currently questionable since not all people over 65 are economically vulnerable. In this regard, this work fills that gap in the literature.

Second, given the demographic importance of the elderly, it is interesting to evaluate whether these subsidies promote a more sustainable use of transport in this population group prompting a reduction in the use of cars and thus achieving a greater economic efficiency through this policy. As far as we know, the efficiency of PT subsidies for the elderly has not yet been tackled. Notwithstanding, it is interesting to focus the analysis of transportation efficiency on the elderly due to their characteristics for urban mobility, which can help to a better understanding of the impacts that come from a price transport policy that promotes the use of a clean means of transport. The results will therefore provide new input for discussing transport policies aiming at economic efficiency through the promotion of a more sustainable urban transport, which continues to be an issue to be solved in most of the world's major cities.

The study is focused on the Madrid Region, which is an excellent laboratory to perform this analysis, given (i) the high proportion of people over 65 out of the total regional population, (ii) its excellent supply of PT and (iii) the high subsidies to PT prices for the elderly. Estimates are based on data from the Spanish Household Budget Survey (HBS, *Encuesta de Presupuestos Familiares*) from the INE for the period 2015-2019. We define two groups of households in our analysis: one affected by the PT subsidy (treatment group) and another not affected by it (control group). The control group includes household spending in PT whose MBW is younger than 65, with an age range between 60 and 64. The treatment group includes household spending in PT whose MBW is older than 65, with an age range between 65 and 69 years. Thus, we use such impact evaluation techniques as regression in discontinuity (RD) to evaluate the impact of PT subsidies on the expenditure for travel-passes and on automotive fuel for households whose MBW is elderly. To know the distributional implications at the expenditure level of this impact, we repeat the RD estimations by income quartiles to test differences by income groups. In addition, the exercise will be repeated to evaluate the behaviour of the same households in their expenditure on automotive fuel.

This paper proceeds as follows. The following section presents a description of the PT system and the transport demand policy in the Madrid Region. In Section 3, a review of the existing literature on the efficiency and equity of the application of subsidies to PT prices is presented. Section 4 presents the HBS database and descriptive analysis. The RD impact evaluation technique is explained in Section 5. The empirical results are presented in Section 6 and finally, Section 7 presents the conclusions of the work and its policy implications.

### 3.2.Literature review

The literature related to PT and people over age 65 is focused mainly on analysing questions related to their physical accessibility to PT, see, for example, Marquet and Miralles-Guasch (2015), Mifsud et al. (2017), Aguiar and Macário (2017), and Yang (2018), or on studying the economic, social and demographic factors that influence their use of PT in order to prompt their participation in social activities, see, for example, Wong et al. (2018), Laverty et al. (2018) and Cheung and Tao (2018). However, these issues are outside the scope of our study, which is focused on a novel issue for the analysis of PT policies aimed at older people. In fact, as far as we know, the literature on

PT has not yet analysed the impact that high subsidies for urban PT to elderly users can have, from the point of view of economic equity and economic efficiency. This is what we analyse in this paper. Thus, this work fills an important gap in the literature on PT policies regarding older people, analysing, on the one hand, which income quartiles within the population over 65 benefit the most from these subsidies, and what impact they have on the promotion of less use of a private car. Analysing these questions for this population group is of the greatest interest, (i) given that it has generally been considered that all people over 65 were economically vulnerable (something questionable nowadays, since many households in this group are among the social groups with higher levels of income and wealth) and (ii) because the population over 65 is a group with a growing demographic weight, so its consumption patterns must be taken into account for analysing and designing a PT policy aiming to promote urban transport sustainability. The studies that analyse the effect of subsidies to urban PT from an equity point of view are scarcer than those analysing efficiency issues. Furthermore, their results are controversial and there is no clear conclusion on whether these subsidies benefit the poorest more, as would be the objective of a policy based on equity criteria (Serebrisky et al., 2009). Table 1 presents a selection of these works: some of them found that subsidising PT improves the economic well-being of the most vulnerable people, but others reached opposite results, finding that the most vulnerable are not the greatest beneficiaries of subsidies for PT. In this sense, the literature is controversial and more studies on this issue are necessary. Due the level of PT subsidies to older people, analysing its impact for this social group (which, as far as

we know, has not been done) is quite important to shed light on such an important issue.

**TABLE 1** Works measuring the redistributive effects of public transport subsidies

| Authors | Case study | Period analysed | Sample | Findings. (Do PT subsidies Benefit the poorest?) |
|---|---|---|---|---|
| Pucher (1981) | United States | 1970-1990 | All population | No |
| Guriai, J.C and Gollinz, A.E.A. (1986) | New Zealand | 1986 | All population | Yes |
| Asensio, J. Matas, A. and Raymond, J.L. (2003) | Spain | 1985- 1995 | All population | Yes |
| Serebrisky, T.; Gómez-Lobo, A, Estupiñán, N. and Muñoz-Raskin R. ( 2009) | Various | Various | All population | No |
| Bureau, B. and Glachant, M. (2011) | Paris (France) | 2001-2002 | All population | Yes |
| Tscharaktschiew and Hirte (2012) | Germany | 2010 | All population | Yes |
| Li, T.; Dodson, J. an Sipe, N. (2015) | Brisbane (Australia) | | All population | No |
| Bueno-Cadena, P. C.B.; Vassallo, J.M. ; Herraiz, I. and Loro, M. (2016) | Madrid (Spain) | 2004 | All population | Yes |
| Arranz, J.M.; Burguillo, M. and Rubio J. (2019) | Madrid (Spain) | 2014-2018 | Young | No |

As we said previously, the literature that has focused on the efficiency of subsidies to urban PT is very abundant (although it has not been focused on subsidies to older people). There are papers that have focused on analysing how this pricing policy can reduce the negative externalities of private transportation such as congestion, environmental pollution, accidents, and occupation of infrastructure. However, the results from this literature have not been conclusive. Moreover, reversing the curve of transport pollution in cities and achieving a reduction in the use of private cars is still a pending issue in most large cities in the world. Given the abundance of literature and the scarcity of works that address the subject for those over 65, we will mention only a few works here. Monzón and Guerrero (2004) estimated the social costs of transport-related air pollution in

Madrid. Their research recommends taxing car use or subsidising public transportation on the grounds of economic efficiency. Elgar and Kennedy (2005) conclude that subsidies to urban PT are often justified on the grounds of a second-best pricing policy to reach allocative efficiency when private cars are not priced at their social marginal cost.

There are other works analysing whether the policy of price subsidies can prompt a modal shift. Several studies show that PT subsidies do not meet the efficiency criteria given the low cross-price elasticity of demand of private transport with respect to the price of PT, which reduces the effectiveness of the subsidy as a mechanism for changing the transport modality (see Asensio et al., 2003; Pestana and Prieto, 2008; Burguillo et al., 2017a). Among the works focused on Madrid, Matas (2004) and Jalón et al. (2014) analyse the efficiency of PT demand public policy for the case of Madrid. They show that the promotion of PT is positive from an environmental point of view as PT is more efficient than private vehicles in terms of energy consumption, infrastructure occupation and pollution; however, they remark that Madrid PT policy can be questioned because it imposes a high burden on the budget for the government that could be unmaintainable over time.

### 3.3.Description of the PT system and the transport demand policy in the Madrid Region

The Madrid Region has an integrated PT system. Political decisions on PT in the Madrid Region have been taken by the Madrid Regional Transport Consortium (CRTM) since 1985. These political decisions have been guided by economic efficiency criteria with the aim of encouraging the use of PT and to reduce, as far as possible, the use of private cars for traveling in the urban area. This policy has been relatively successful because the number of trips using PT has grown each year. For example, in 2018, 1,548 million trips were made by PT in the Madrid Region, which represented 41% more trips than in 1990 (PT's infrastructure network was very significantly increased in that period and is one of the best in the world; see *Consorcio Regional de Transportes de Madrid, 2018*). However, this increase in the use of PT has not led to an improvement in economic efficiency since the transport sector continues to be highly polluting. A study shows that transport generates 41% of the total polluting gases produced in Madrid (Siemens, 2017). Of that,

private cars cause 80% of the pollution – that is, 6 metric tons of CO2 equivalent. Of the 23 billion kilometres that the inhabitants of Madrid travel per year, 62% are done by car, so the car continues to be the priority means of transport in the MR. Therefore, it is necessary to improve the design of PT demand policies so as to increase the efficiency of the sector. It is still necessary to encourage the use of alternative means of transport instead of the private vehicle. Recently, the Madrid City Council (2020) carried out an analysis of air quality during the state of alarm due to COVID-19, in which it concluded that there is a clear relationship between road traffic and the levels of pollutants in Madrid. Hence, there is the need to reduce motorised traffic and polluting vehicles to improve air quality and be able to comply with the values set for the different pollutants by European and national legislation, especially for nitrogen dioxide.

The transport demand policy implemented in the Madrid Region, which is the subject of this study, is based on subsidies for PT fares. The travel-pass is the star transport ticket in the PT's public pricing policy. It was created in 1987 and is a personal and non-transferable title, which allows an unlimited number of trips within the scope of its temporal and spatial validity. It is the most used PT ticket (especially by frequent users). For example, in 2018, 78% of trips in PT were made with a travel-pass (*Consorcio Regional de Transportes de Madrid, 2018*). With regard to the temporal scope of a ticket, there are season tickets with monthly and annual fees. Regarding the spatial scope, the PT rates are designed according to the distance from Madrid City, and for this, the CRTM has divided the region into six zones. Zone A corresponds to Madrid City. Zone B is divided into zones B1, B2 and B3 that include a set of small and medium-sized cities surrounding Madrid City. Finally, Zone C is divided into zones C1 and C2 that include several small cities in the most peripheral area of the region.

There are three types of travel-passes with different prices depending on the age of the user: normal pass (between 26 and 64 years old), young pass (age 26 and younger) and elderly (age 65 years and older). In 2018, about 20 million travel-passes were sold for all areas and types of users; 39% of sales were normal travel-passes (it is the one that has been sold the most since its creation), followed by travel-passes for the young population (33%) and lastly, the one for the elderly

population (25%) (*Consorcio Regional de Transportes de Madrid, 2018*). Historically, all travel-passes have had their rate subsidised. According to the latest information available, the average cost per traveller in 2017 was 1.55 euros, of which the average collection per traveller was 0.66 euros and the difference of 0.89 euros represented the average subsidy per traveller – that is, a subsidy of 57% of the average original rate (*Consorcio Regional de Transportes de Madrid, 2017*).

The travel-pass for elderly (over age 65), which is the subject of this work, was created in 1989. The age of 65 has been the official age for retirement in Spain and other neighbouring countries although retirement is not compulsory and there are people that continue working after this legal retirement age. Thus, following the example of other cities, where this group was considered vulnerable for accessing PT, Madrid implemented this PT policy for them. Therefore, the prices for the travel-pass for the elderly were established seeking an equity objective. This ticket has a single 'flat' rate (constant price) to circulate through all areas of the Madrid Region. In 2018, 5 million elderly travel-passes were sold, which is 7 times more sales than in 1990, while the number of older people doubled during the same period (*Consorcio Regional de Transportes de Madrid, 2018*). The monthly price of the elderly travel-pass in 2020 was 9.5 euros, or one-ninth the price of a normal pass (ranging from 54 to 132 euros depending on the area). In other words, older people pay 87% less on average for a travel-pass than users between 26 and 64, regardless of their income levels. Likewise, the price for those under 26 years of age is 20 euros per month for all areas, so the prices for those over 65 is 52.5% lower than the one for the young.

### 3.4.HBS dataset and descriptive statistics

The data used in this research come from the HBS for the period 2015-2019. The HBS is prepared annually and includes detailed information on 256 groups of expenditures and socioeconomic characteristics of each household in the 17 regions of Spain. The spending groups used for our research are available in the survey. Specifically, we used the data about expenditure on transport travel-passes and expenditure on automotive gasoline and diesel, which represents household

spending on automotive fuel. For the analysis, the MBW of the Madrid Region households is considered as the statistical unit of study. The HBS obtains its information through personal interviews with about 24,000 randomly selected households.

As we are interested in evaluating the impact of the price of the elderly travel-pass, where the dependent variable is the household´s expenditure on travel-passes (in other words, the household's consumption of travel-passes), we focus on household spending on travel-passes every year. After the sample selection, Table 2 provides information about the entire sample and for the control group and treatment group. The control group are households with a MBW aged 60-64 years whose members could not benefit from the elderly travel-pass rules. The treatment group includes households with at least one member beneficiary from the elderly travel-pass with a MBW aged 65-69 years. In this table, we observe 722 households: 324 treated and 422 not treated. Of the 722 households, 17% belong to the year 2015, and then the same for 2016, 21% to the year 2017, 22% to the year 2018 and 23% to the year 2019. The average number of members in the household is 2.6-2.7 and 86% of the households with an MBW aged 60-70 years have less than two members and 96% less than 3. By the labour market situation of the MBW, we have 174 households with an MBW not employed in the control group (288 households in the treatment group) and 224 households with an employed MBW in the control group (36 households in the treatment group). Table 2 also contains information of more descriptive statistics.

Table 4 presents the average expenditure (€) on PT, automotive fuel by income quartiles and the average income levels27 of household spending every year of the period analysed for the treatment and control groups. The information distinguishes between the labour market situation of the

27 As income declared in the household budget surveys is often lower than the actual income, it is typical in the literature, as we do in this paper, to use the total household expenditure as a proxy of income (Burguillo et al., 2017b, among others). An additional advantage of using expenditure is that it is a good proxy for permanent income. Following West and Williams (2004), among others, total expenditure of households has been adjusted using the OECD scale (2008, 2011).

MBW, employed or not employed, because we need similar MBW households to evaluate the impact of the policy analysed.

**Table 2. Descriptive statistics for the control group (MBW 60- 64 years) and treatment group (MBW 65-69 years). HBS 2015- 2019. Madrid region.**

**Panel A. Public transport.**

| | All sample | | | MBW not employed | | | MBW employed | | |
|---|---|---|---|---|---|---|---|---|---|
| | **All** | **Control** | **Treatment** | **All** | **Control** | **Treatment** | **All** | **Control** | **Treatment** |
| **Number of members in household** | 2.6 | 2.7 | 2.5 | 2.6 | 2.6 | 2.5 | 2.7 | 2.8 | 2.4 |
| **Live in Madrid Capital (1= Yes)** | 0.514 | 0.538 | 0.485 | 0.487 | 0.506 | 0.476 | 0.562 | 0.563 | 0.556 |
| **Information about MBW** | | | | | | | | | |
| **Gender(1= Male)** | 0.719 | 0.681 | 0.765 | 0.745 | 0.695 | 0.774 | 0.673 | 0.670 | 0.694 |
| **Nationality (1= Español)** | 0.938 | 0.917 | 0.963 | 0.959 | 0.937 | 0.972 | 0.900 | 0.902 | 0.889 |
| **Civil Status (1= Married)** | 0.731 | 0.736 | 0.725 | 0.714 | 0.678 | 0.736 | 0.762 | 0.781 | 0.639 |
| **Level of studies** | | | | | | | | | |
| *Primary* | 0.209 | 0.176 | 0.250 | 0.255 | 0.236 | 0.267 | 0.673 | 0.129 | 0.111 |
| *Secondary* | 0.411 | 0.427 | 0.392 | 0.407 | 0.431 | 0.392 | 0.900 | 0.424 | 0.389 |
| *Higher education(University)* | 0.380 | 0.397 | 0.358 | 0.338 | 0.333 | 0.340 | 0.762 | 0.446 | 0.500 |
| Total sample (households) | **722** | **398** | **324** | **462** | **174** | **288** | **260** | **224** | **36** |

**Panel B. Automotive fuel**

| | All sample | | | MWB not employed | | | MWW employed | | |
|---|---|---|---|---|---|---|---|---|---|
| | **All** | **Control** | **Treatment** | **All** | **Control** | **Treatment** | **All** | **Control** | **Treatment** |
| **Number of members in household** | 2.7 | 2.8 | 2.6 | 2.7 | 2.8 | 2.6 | 2.9 | 2.4 | 2.8 |
| **Live in Madrid Capital (1= Yes)** | 0.485 | 0.501 | 0.465 | 0.459 | 0.471 | 0.452 | 0.525 | 0.563 | 0.530 |
| **Information about MBW** | | | | | | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Gender(1= Male)** | 0.758 | 0.707 | 0.823 | 0.786 | 0.713 | 0.832 | 0.702 | 0.750 | 0.709 |
| **Nationality (1= Español)** | 0.943 | 0.921 | 0.972 | 0.961 | 0.930 | 0.980 | 0.914 | 0.906 | 0.913 |
| **Civil Status (1= Married)** | 0.779 | 0.777 | 0.780 | 0.764 | 0.720 | 0.792 | 0.823 | 0.688 | 0.804 |
| **Level of studies** | | | | | | | | | |
| *Primary* | 0.758 | 0.707 | 0.823 | 0.273 | 0.242 | 0.292 | 0.131 | 0.094 | 0.126 |
| *Secondary* | 0.943 | 0.921 | 0.972 | 0.391 | 0.408 | 0.380 | 0.424 | 0.375 | 0.417 |
| *Higher education(University)* | 0.779 | 0.777 | 0.780 | 0.337 | 0.350 | 0.328 | 0.444 | 0.531 | 0.457 |
| Total sample (households) | **637** | **355** | **282** | **407** | **157** | **250** | **230** | **198** | **32** |

**Table 3** Average expenditure (€) on PT and income (proxy of expenditure) per household. Control (MBW 60-64 years old) and treatment group (MBW 65-69 years old). MBW not employed or employed. HBS 2015-2019 years. Madrid Region.

*Panel A: Public Transport: MBW not employed and employed*

| **MBW NOT EMPLOYED** | | | **Control group(MBW 60- 64 years)** | | **Treatment group (MBW 65-69 years)** | |
|---|---|---|---|---|---|---|
| **Quartile** | **Descripción** | **Range income** | **PT (mean)** | **Income(mean)** | **PT (mean)** | **Income (mean)** |
| Q1 | Low | 8,323 -22,151 € | 496 € | 17,346 € | 278 € | 17,333 € |
| Q2 | Medium-Low | 22,483-32,057 € | 288 € | 27,702 € | 393 € | 27,482 € |
| Q3 | Medium | 32,131-46,050 € | 533 € | 38,307 € | 412 € | 38,523 € |
| Q4 | High | 46,289-211,483 € | 455 € | 66,626 € | 630 € | 69,952 € |
| All | | 8,323 -211,483 € | 455 € | 38,300 € | 434 € | 39,009 € |
| Total sample (households) | | 462 | 174 | | 288 | |
| **MBW EMPLOYED** | | | **Control group(MBW 60- 64 years)** | | **Treatment group (MBW 65-69 years)** | |
| **Quartile** | **Descripción** | **Range income** | **PT (mean)** | **Income(mean)** | **PT (mean)** | **Income(mean)** |
| Q1 | Low | 9,627-22,394 € | 575 € | 17,466 € | 506 € | 17,017 € |
| Q2 | Medium-low | 22,494-31,732 € | 739 € | 27,307 € | 421 € | 26,634 € |
| Q3 | Medium | 32,409-45,985 € | 939 € | 38,562 € | 204 € | 40,140 € |
| Q4 | High | 46,153-147,985 € | 878 € | 68,964 € | 545 € | 73,738 € |

| | | | | | |
|---|---|---|---|---|---|
| All | 9,627-147,985 € | 817 € | 44,595 € | 462 € | 47,575 € |
| Total sample (households) | 260 | 224 | | 36 | |

*Panel B: Automotive fuel: MBW not employed and employed*

| **MBW NOT EMPLOYED** | | | **Control group(MBW 60- 64 years)** | | **Treatment group (MBW 65-69 years)** | |
|---|---|---|---|---|---|---|
| **Quartile** | **Descripción** | **Range income** | **Fuel (mean)** | **Income(mean)** | **Fuel (mean)** | **Income (mean)** |
| Q1 | Low | 8,942-23,406 € | 685 € | 17,413€ | 583 € | 18,272€ |
| Q2 | Medium-Low | 23,444-33,121 € | 1,156 € | 28,666€ | 982 € | 28,412 € |
| Q3 | Medium | 33,263-47,297 € | 2,074 € | 39,679€ | 1,566 € | 40,091€ |
| Q4 | High | 47,650-211,483 € | 2,205 € | 67,710€ | 2,673 € | 72,688€ |
| All | | 8,942-211,483 € | 1,565 € | 39262€ | 1,478 € | 40,592€ |
| Total sample (households) | | 407 | 157 | | 250 | |
| **MBW EMPLOYED** | | | **Control group(MBW 60- 64 years)** | | **Treatment group (MBW 65-69 years)** | |
| **Quartile** | **Descripción** | **Range income** | **Fuel (mean)** | **Income(mean)** | **Fuel (mean)** | **Income(mean)** |
| Q1 | Low | 9,627-23,292€ | 720 € | 18,215€ | 607 € | 17,358€ |
| Q2 | Medium-low | 23,416-33,197€ | 1,522 € | 27,527€ | 1102 € | 26,633€ |
| Q3 | Medium | 33,492-47,553€ | 1,720€ | 39,948€ | 1701.602 | 41,929€ |
| Q4 | High | 47,645-134,171€ | 3,022€ | 69,879€ | 4017.504 | 75,519€ |
| All | | 9,627-134,171€ | 2,038 € | 45,489€ | 2,466 € | 50,011€ |
| Total sample (households) | | 230 | 198 | | 32 | |

There are several aspects that should be highlighted from Table 3. First, households spend a much higher proportion of their income on fuel than on PT. This means that independent of the age of the MBW, his/her labour situation and the income quartile, households in Madrid Region that spend on PT are also using with a certain intensity their private car.

Second, the income level per household is higher when the MBW is employed than when he/she is not employed; however, this difference comes basically from the difference in income in households in the fourth quartile. In the rest of the quartiles, the level of income is quite similar.

Third, when the MBW is not employed, households from the treatment group belonging to quartiles 1 and 2 spend less on PT in comparison with households that do not receive the subsidy, whereas households subsidised and belonging to quartiles 3 and 4 spend more on PT than households that are not subsidised. This means that with PT much cheaper, households with low and low-medium income levels can spend less on PT and more on other goods. Households with a medium-high- and high-income level spend more on PT, which means that they are using PT much more frequently now that the price is much lower. As for the expenditure on automotive fuel, members from quartiles 1, 2 and 3 of subsidised households spend less on automotive fuel than households from the control group. This means that also considering their situation on PT expenditure, they have substituted PT for cars, as the latter is now relatively more expensive.

Finally, subsidised members from quartile 4 spend more on fuel than their peers from the control group, therefore they are using more PT and cars. Thus, as a consequence of the reduction of PT price, households from quartiles 1 and 2 have replaced cars by PT and have more of their budget to spend on other goods; thus, we can infer that the income effect of the price change has been higher than the substitution effect, and in the case of households from quartile 3 the substitution effect has been bigger than the income effect. For all these income social groups, the subsidisation of the price of PT has had a positive consequence on a sustainable modal shift, and for the poorest and low-medium level group it also had a positive consequence on well-being, as they have now more disposable income to buy other goods. For members of quartile 4, the positive consequence has only been on well-being.

Finally, when the MBW is employed, households from the treatment group as a whole spent 56.6% less on PT than households from the control group. The reduction in PT expenditure (now much cheaper) is observed for all quartiles and is remarkable for quartile 3. These households as a whole also increased their expenditures on fuel by 42.6% compared to the households that do not receive the PT subsidy. However, in this case, households from quartiles 2 and 4 of the treatment group expend less on fuel than their peers from the control group. In the case of households having an employed MBW, the PT subsidy has had a positive consequence on modal shift and well-being for members of medium-low and high income groups. In the case of quartiles 1 and 3, the positive

consequence has been on well-being as they now have more disposable income to buy other goods, and among these goods there is also automotive fuel whose consumption has increased.

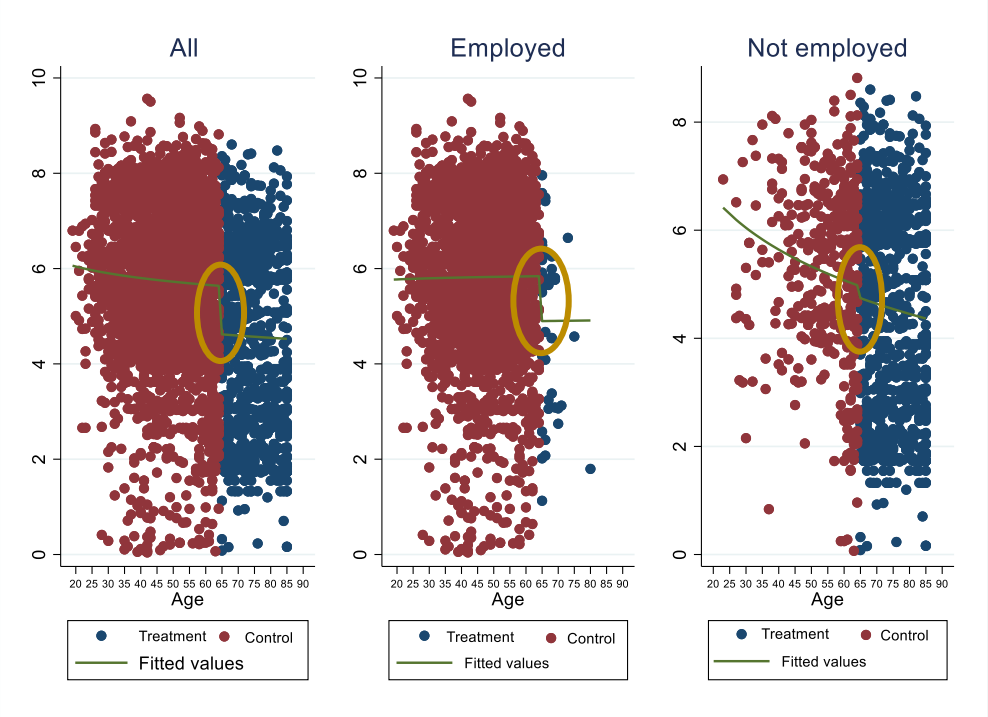
### 3.5.Econometric model: Regression in discontinuity

In order to evaluate the impact of PT subsidies on the expenditure for travel-passes (and on automotive fuel) for households whose MBW is elderly, we use impact evaluation techniques such as regression in discontinuity (RD). Impact Evaluation techniques seek to answer a specific cause and effect question: What is the impact (or causal effect) of a program (P) on an outcome of interest (Y)? In our case, the question is what is the impact of the subsidies on the travel passes (P) for elderly over the PT expenditure (Y)? here, the causal impact of a program (P, travel-pass) on an outcome (Y, household expenditure in travel-pass) is the difference between the outcome Y with the program (P=1) and the same outcome (Y) without the program (P=0). This basic IE formula is valid for any unit (household) that is being affected or not by the program. However, we know that the household cannot be observed simultaneously in two different states (with and without the program), something which is referred to as the counterfactual problem. A number of different quantitative and ex post quasi-experiment methods can be used to address the question of the counterfactual (propensity score matching, instrumental variables, regression in discontinuity (RD) and double differences). Methods vary in their underlying assumptions regarding how to estimate the program treatment effect and the estimation of the counterfactual. RD is suitable in our evaluation context (see Khandker et al., 2009; Gertler, 2011) for our evaluation because there is a clear rule for the assignment of beneficiaries based on a quantitative criterion – a continuous index of eligibility and a cut-off point (above and below) of eligibility – to determine who is eligible and who is not. So, a difference in mean outcomes of treated and control groups restricted to the vicinity of the cut-off point shows the impact of the intervention. The idea is that this rule can simulate a good experiment and thus build a counterfactual. In this case, the programme evaluated in this study complies with the components that characterise RD: it has a score (which in this study is age), deterministic cut-off points or threshold (the age of 65 years) and there is an assignment rule, namely, the treatment, to receive the PT subsidy, is only granted to people aged 65 and over. RD has two versions. When all the units comply with their assignment based on their

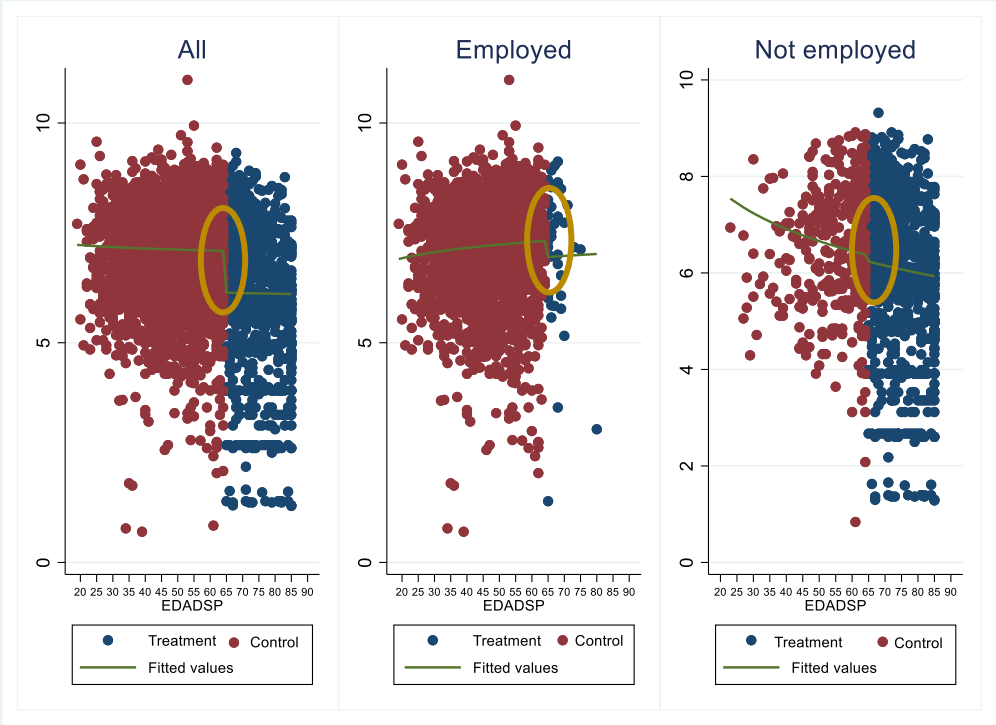
eligibility index, the RD is known as 'sharp/clear', and if there is non-compliance on either side of the cut-off score, the RD is known as 'fuzzy/diffuse'. In the case of this study, a sharp RD is realistic because the assignment to the treatment or comparison group in the policy evaluated is clear (see Figure 1). In this figure, we observe the sharp discontinuity relationship between spending on PT according to the age of the MBW, disaggregating whether the MBW is employed or not. In all of the graphs, a sharp discontinuity relationship is observed because to the left of the borderline value of 65 years we only have values of the control group (and not of the treated group) and to the right only values of the treatment group and none of the control group.

**Figure 1.** Expenditure in PT and fuel (in log) by age of the MBW. All sample, employed and not employed MBW. HBS 2015-2019 years. All ages. Madrid Region.

*Expenditure in PT. All ages*




*Expenditure in fuel. All ages*




This method can be calculated within a regression scheme. In particular, the equation to be estimated is specified as

$$Y_i = \beta_0 + \beta_1 D_i + \delta(S_i) + \varepsilon_i \qquad (2)$$

where

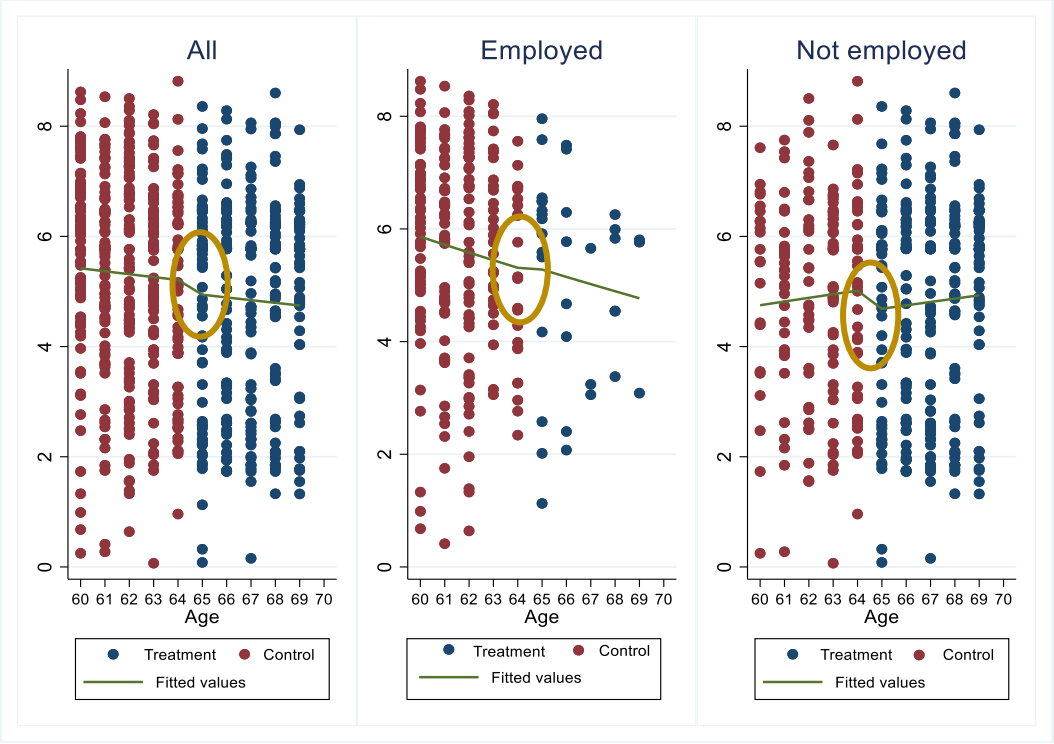
1. *$D_i$ = 1 if household i spends on PT and the MBW>=65 years (treatment group). Receives the PT subsidy.*
2. *$D_i$ = 0 if household i spends on PT and the MBW<65 years (control group). Doesn't receive the PT subsidy.*

3. *$\delta$(score) is a continuous function at the cut-off point, age.*

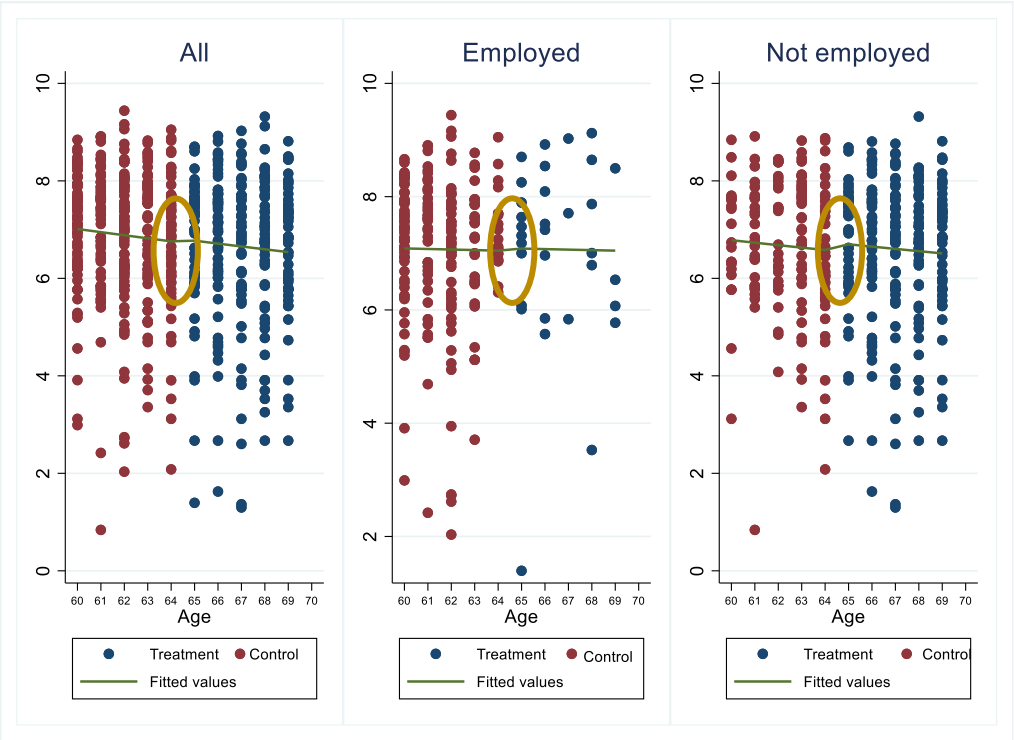
A comparison is made of the average expenditures on PT of households (dependent variable) between the control and treatment groups (variable D). The observations closest to the cut-off point (65 years) are usually more similar to each other because they are close to the threshold, above and below it. For that reason, a bandwidth must be defined to evaluate the impact. In this study the bandwidth is selected for the households that are in a neighbourhood of +/- 5 years of the cut-off point (65 years), establishing the treatment group in those households that spend on PT and whose MBW has an age between 65 and 69, and the control group in those households that spend on PT and whose MBW has an age between 60 and 64. We also see in Figure 2 a sharp discontinuity relationship between spending on PT according to the age of the MBW between 60 and 70 years, disaggregating whether the MW is employed or not.

**Figure 2.** Expenditure in PT and fuel (in log) by age of the MBW. All sample, employed and not employed MBW. HBS 2015-2019 years. Aged 60-70. Madrid Region.

*Expenditure in PT.Aged 60-70*




*Expenditure in fuel.Aged 60-70*




To estimate equation (2) we will use non-parametric RD methods in which no a priori form is established to determine the relationship between the explanatory variables. We will estimate two nonparametric regressions between Y and S using local polynomial regressions, a type of approximation to nonparametric models. A first regression will focus on households with an MBW between 60 and 64 years old and will save the results of the mean of those outcomes within that range. The second regression will be for households with an MBW between 65 and 69 years of age and will keep the mean of the outcome estimates within that range. With the means of outcomes computed, their difference can be taken to get estimated impacts of PT subsidies on PT expenditure in the neighbourhood of the cut-off point.

As non-parametric methods will be used to estimate the regressions, this implies that no assumptions have been made about the implicit distribution of the data, making it impossible to make a statistical inference because this process does not give the standard error. To solve this problem, bootstrap will be used, which will allow us to generate the necessary randomness for the construction of dispersion measures and to know the significance of the impact. For the estimations

of the local polynomial regressions, we specify a kernel weighted local polynomial regression. As different bandwidths can produce different estimations, another estimation will be carried out, expanding the bandwidth considering the households that are in a neighbourhood of +/- 10 years of the cut-off point (65 years). In our estimations we will use a kernel weighted local polynomial regression (see Khandker et al., 2009) using the Stata programme (locpoly). We have specified different degrees for the polynomial in the smoothing and the results do not change much. Nevertheless, we will report estimations with a degree one polynomial, a kernel linear regression. Estimates with different specifications of the polynomials are identical and are available upon request from the authors. By expanding this bandwidth, we will verify whether or not the estimates are sensitive to the bandwidth used.

### 3.6.Estimation results

#### 3.6.1. Analysis of household spending on PT

Table 4 shows the results of our estimation for the whole sample. As can be observed, the results are negative and significant both for the case of households having an employed MBW and those having an MBW who is not employed. Households receiving a subsidy from the former case have reduced their PT expenditure by 91.2%, and households from the latter case have reduced it by 28.7%. Thus, the reduction of the PT price has had a larger impact on households where the MBW is employed. This result is logical as the employed have a bigger need of transportation than the non employed.

**Table 4.** RD estimation results of the impact on PT expenditure for the elderly. Bandwidth +/- 5 years. (60-64 vs 65-69 years). HBS 2015-2019. Madrid Region.

| | **MBW not employed** | **MBW employed** |
|---|---|---|
| **MBW households 60 - 64 vs. 65-69 years** | | |
| Coef. | **-0.287*** | **-0.912*** |
| Bootstrap Standard Errors (S.E.) | (0.130) | (0.320) |

Significance level: *** p<0,01; **p<0,05; *p<0,1.

Table 5 shows the estimation by income quartiles. Results are significant for quartiles 1 and 2 when the MBW is not employed, and also for quartile 4 when the MBW is employed. In the rest of the cases, results are not significant. In fact, households with a non employed MBW receiving the subsidy and belonging to quartile 1 have reduced their expenditure on PT by 83.9% and those from quartile 2 have reduced it by 65.3%. These results show that the subsidy has had a significant impact on the poorest members of society, who now have more disposable income for consuming other goods, having thus a higher level of well-being. We can say that in equity terms, the PT subsidy to the elderly in the MR has reached its objectives: it has had an impact on the low and medium-low income households where the MBW is not employed. In the case of households where the MBW is employed, the results are only significant for members from the quartile 4 – in this case, those households have reduced their expenditure on PT by 106.4% and thus have more disposable income to buy other goods. In terms of well-being, the main beneficiaries of the subsidy have been the richest households, then in parallel to its desirable impacts on equity grounds, the subsidy is also benefiting people who are not vulnerable. In case different bandwidths might produce different estimations, we repeated the estimations, expanding the bandwidth, considering the households that are in a neighbourhood of +/- 10 years of the cut-off point (65 years). As we can see in Table A1-A2 in the Appendix, the results do not change.

**Table 5.** RD estimation results of the impact on PT expenditure for the elderly. Income quartiles . Bandwidth +/- 5 years. (60-65 vs 65-69 years). HBS 2015- 2019. Madrid region.

| | | QUARTILES | | | |
|---|---|---|---|---|---|
| **MBW between 60-- 64 vs. 6-69 years** | | **Q1** | **Q2** | **Q3** | **Q4** |
| **MBW not emplead** | Chef. | **-0.839*** ** | **-0.653*** ** | **-0.235** | **-0.050** |
| | Bootstrap S.E. | (0.221) | (0.194) | (0.262) | (0.295) |
| **MBW employed** | Coef. | **-0.929** | **-0.148** | **-1.602** | **-1.064*** |
| | Bootstrap S.E. | (1.309) | (0.691) | (1.513) | (0.425) |

See legend Table 2.

### 3.6.2. Analysis of household spending on automotive fuel

Table 6 presents the results of our estimation for the whole sample. As can be observed, the results are only significant for those households where the MBW is not employed. This means that those households receiving a PT subsidy have seen an impact on their automotive fuel expenditure that has led to a reduction of it by 33.6%.

**Table 6.** Estimation RD results of expenditure on automotive fuel for the elderly. Bandwidth +/- 5 years. (60-64 vs 65-69 years). HBS 2015- 2019. Madrid region.

| | **MBW not employed** | **MBW employed** |
|---|---|---|
| **Households with MBW 60-64 years vs 65-69 years:** | | |
| Coef. | **-0.336*** ** | **-0.055** |
| Bootstrap Standard Errors | (0.123) | (0.194) |

See legend Table 2.

Table 7 shows the results by income quartiles. As can be observed, the results are significant for those households where the MBW is not employed. In this case, households belonging to quartiles 1, 2 and 3 receiving the PT subsidy have had a positive impact in terms of efficiency, as they have reduced their expenditure on automotive fuel by 38.8%; 30.3% and 51.9%, respectively. The households from the richest quartile and those where the MBW is employed have not seen a significant impact. On sustainability and efficiency grounds, the PT subsidy has not had the desirable effect on society as a whole, as there are still members of society that are not responding to such a big incentive to reduce their use of private cars when the relative price of automotive fuel has substantially increased. As different bandwidths can produce different estimations, we have repeated the estimations expanding the bandwidth considering the households that are in a neighbourhood of +/- 10 years of the cut-off point (65 years). As we can see in the table A3-A4 in the appendix, the results do not change.

**Table 7.** Estimation RD results of expenditure in fuel for the elderly. Income quartiles. Bandwidth +/- 5 years. (60-64 vs 65-69 years). HBS 2015- 2019. Madrid region.

| Households with MBW among 60- 64 years vs. 65-69: | | Q1 | Q2 | Q3 | Q4 |
|---|---|---|---|---|---|
| **MBW no employed** | Coef. | **-0.388*** ** | **-0.303*** | **-0.519*** ** | **-0.035** |
| | Bootstrap S.E. | (0.182) | (0.181) | (0.138) | (0.216) |
| **MBW employed** | Coef. | **-0.922** | **0.140** | **-0.510** | **0.075** |
| | Bootstrap S.E. | (1.468) | (0.306) | (0.942) | (0.202) |

See legend Table 2.

### 3.7.Conclusions and policy implications

This study analyses the impact that the subsidy for public transport (PT) received by the elderly in the Madrid Region (MR) has on the expenditure on PT and on the expenditure on automotive fuel. This is in order to assess the impact on economic well-being and equity as well as on economic efficiency of such a price transport policy. We have used the regression in discontinuity technique for the Household Budget Survey (HBS) cohorts of 2015 to 2019 to evaluate the impact for the MR. To the best of our knowledge, this is the first study tackling this issue.

As for the impact on PT expenditure, our results show that the subsidy has had a positive impact in terms of economic well-being in all the households receiving it. In that sense, all these households have reduced their expenditure on PT, thus having more disposable income to spend on other goods. As for the distributive effects of this impact, we can say that the households for which the impact has been significant are those of the quartiles 1 and 2 having a main breadwinner (MBW) not employed. In that sense, we can assert that the PT subsidy for the elderly has benefited the most vulnerable members of elderly society – those with the lowest income levels and where the MBW is not employed. These results are in line with those from other works for the case of Spain, such as Asensio et al. (2003) and Bueno-Cadena et al. (2016), which found that even for the whole population, and not specifically for the elderly, PT subsidies benefit the poorest members of society. However, the subsidy has also had a positive and significant impact on those households from quartile 4 where the MBW is employed; in fact, it is these households for which the impact has been the biggest. Thus, this policy has also had a positive impact on the economic well-being of the richest households among those having elderly people, and where the age

criterion does not correspond to retired people (the criterion of 65 is linked to the age of retirement and the supposed vulnerability of retirees). That is, households that are not economically vulnerable have been the main beneficiaries of the subsidy in terms of economic well-being. This result is in line with those of Arranz et al. (2019), that for the case of Madrid and the young population, households with medium-high income levels were those who most benefited from PT subsidies (to the young). From our results we can then conclude that the subsidy of PT prices for the elderly has reached its objectives in terms of equity because the low and medium-low households have benefited from this policy. But the results also raise doubts about the suitability of giving the subsidy only following an age criterion.

To sum up, the example of MR, which as we explained in the introduction is an excellent laboratory to analyse PT public policies, shows that from an equity perspective the subsidisation of PT to elderly people has been a necessary policy as it has had a positive impact on the economic well-being of the most economically vulnerable households among those having elderly members. However, in parallel it has also been beneficial – the richest households have received the most benefits – in terms of the economic well-being of other members of society that cannot be considered vulnerable. Hence, this kind of policy, applied in Madrid as well as in many cities in the world, might have to move from having age as the unique criterion to combining it with one based on income.

As for the impact on automotive fuel expenditure, our results show that in terms of transportation sustainability and economic efficiency, the PT subsidy to the elderly has had a positive and significant impact on subsidised households where the MBW is not employed. For quartiles 1, 2 and 3 the result is the same. In fact, subsidised households from quartile 1 spend on fuel 128 euros/year less on average than their peers from the control group, those from quartile 2 spend 174 euros/year less on average, and those from quartile 3 spend 508 euros/year less on average. Nevertheless, this measure has not had a significant impact for the richest households. Therefore, the higher relative price of automotive fuel has prompted a reduction in the use of cars in all those households except in the richest ones that are not sensitive to this price change. For the households where the MBW is employed, the results are not significant either for the whole sample or by

quartiles. This teaches us that a policy of high subsidies for PT prices has not had a significant effect on fuel consumption when the beneficiaries of the subsidy are employed. There are other factors beyond the price that seem to be more important in the choice of using a car or PT, when users do not have a free schedule as is the case of not employed people, and when they have geographical concrete mobility necessities (they live in a concrete geographical place and work in another). This is an important lesson for PT public policies aimed at promoting sustainable transport in urban areas where millions of people have to move daily from their homes to their workplace.

Finally, we want to assert that due to the demographic importance of elderly and the scarcity of works focused on analysing the impact of PT subsidies for this social group, further research is needed. In almost all developed countries, the elderly receive special subsidies for transportation, but with different degrees of subsidization, and hence it would be interesting to compare its impact in order to have a larger panorama on the issue. Also, as these subsidies are applied to urban and other kinds of means of transportation, it would also be interesting to analyse and compare the results for the different kind of means of transportation in the same country. To close this paper, we want to emphasize that the main limitations to analysing the impact of PT subsidies on the elderly are due to the fact that official data are based on households and not on individuals. To have data on individuals would permit a most accurate assessment of the redistributive impacts of such subsidies; unfortunately, these kinds of data are not available.

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## APPENDIX

**Table A1.** RD estimation results of the impact on PT expenditure. Bandwidth +/- 10 years. (55-64 vs 65-74 years). EPF 2015-2019. Madrid Region.

| | MBW not employed | MBW employed |
|---|---|---|
| **Households with MBW 65- 74 vs. 55-64 years:** | | |
| Coef. | **-0.374*** ** | **-0.952*** ** |
| Bootstrap S.E. | -3.14 | -3.1 |

Significance level: *** p<0,01; **p<0,05; *p<0,1.

**Table A2.** RD estimation results of the impact on PT expenditure for the elderly. Income quartiles . Bandwidth +/- 10 years. (55-64 vs 65-74 years). EPF 2015- 2019. Madrid region.

| QUARTILES | | | | | |
|---|---|---|---|---|---|
| **MBW 55-54 vs 65- 74 years** | | **Q1** | **Q2** | **Q3** | **Q4** |
| **MBW not employed** | Coef. | **-0.922*** ** | **-0.801*** ** | **-0.217** | **-0.102** |
| | Bootstrap S.E. | -4.780 | -4.950 | -0.830 | -0.370 |
| **MBW employed** | Coef. | **-0.957** | **-0.193** | **-1.433** | **-1.079*** ** |
| | Bootstrap S.E. | -0.740 | -0.280 | -0.940 | -2.580 |

Significance level: *** p<0,01; **p<0,05; *p<0,1

**Table A3**. Estimation RD results of expenditure in fuel for the elderly. Bandwidth +/- 10 years. (55-64 vs 65-74 years). EPF 2015- 2019. Madrid region.

| | MBW not employed | MBW employed |
|---|---|---|
| **Household with MBW 55- 64 vs 65-74 years:** | | |
| **Coef.** | **-0.412*** ** | **-0.068** |
| **Bootstrap S.E.** | 0.105 | 0.192 |

Significance level: *** p<0.01; **p<0.05; *p<0.1

**Table A4**. Estimation RD results of expenditure in fuel for the elderly. Income quartiles. Bandwidth +/- 10 years. (55-64 vs 65-74 years). EPF 2015- 2019. Madrid region.

| QUARTILES |
|---|

| MBW 55-54 vs 65- 74 years | Q1 | Q2 | Q3 | Q4 |
|---|---|---|---|---|
| **MBW not employed** | **-0.471*** ** | **-0.362*** ** | **-0.566*** ** | **-0.134** |
| | 0.150 | 0.167 | 0.135 | 0.197 |
| **MBW employed** | **-0.932** | **0.128** | **-0.565** | **0.055** |
| | 1.462 | 0.293 | 0.910 | 0.209 |

Significance level: *** p<0.01; **p<0.05; *p<0.1.

## IV. HOW BUYERS CHARACTERISTICS INFLUENCE THE CLEAN VEHICLES MARKET PENETRATION? A CASE STUDY OF SPAIN


### ABSTRACT:

This paper determines the socioeconomic and demographic characteristics of Spanish households that use a clean car (electric or hybrid), with the aim of identifying how these characteristics influence the market penetration of these vehicles. This study is one of the few in the literature that analyses the characteristics of car users based on a broad sample of data, that is representative of 11.5 million Spanish households. The data used are from the Households Budget Survey of the Spanish National Institute of Statistics for the period 2016-2019. The results allow us to identify socioeconomic challenges and opportunities regarding the goal of replacing combustion vehicles with clean vehicles. We find as the main weakness the fact that high-income households (fourth quartile) are 29% more likely to use a clean vehicle than low-income households (first quartile). The strengths are related to features like the gender and age of the household's main breadwinner: households whose main breadwinner is a male are more likely to use clean vehicles than households whose main breadwinner is a woman, and households whose main breadwinner is over 55 or under 30 years of age are more likely to use one than households with main breadwinners from the rest of the population. These results provide guidelines for a better design of public policies aimed at decarbonizing the transport sector through the replacement of conventional vehicles by clean ones. To do so it is important to consider the features of the social reality in which that objective is to be achieved.



### KEYWORDS:

Demand for Clean Cars; Households; Decarbonization; Transportation Policies; Agenda 2030; Logit Model.

## 4.1. Introduction

Transport plays an important role in climate change as it is one of the main sectors of the economy that affect air pollution and carbon emissions; furthermore, it is the only economic sector that has not reversed the trend in these emissions (White and Sintov, 2017). Thus, the transport sector is a focal point of the sustainability strategies of the European Commission (Hackbarth and Madlener, 2013). The point is that, within the global energy transition strategy of the European economy - for which each of the member countries has its own plans - the transport sector is the most sensitive sector, that is, the one that presents the greatest barriers to such a change. This is due to the characteristics of this sector, which is a diffuse sector that depends on the decisions of millions of drivers, continues to rely massively on the combustion of petroleum derivatives, and because clean technology still must improve in terms of price and autonomy. Specifically, the strategy to achieve an energy transition in the sector consists of replacing combustion engine vehicles with other types of less polluting vehicles such as electric, hybrid, and LPG (liquefied petroleum gas) vehicles. These types of vehicles have gained increasing interest, both among producers and consumers (Li et al., 2016). In addition, empirical evidence shows that these vehicles have the potential to reduce CO2 emissions and improve air quality, see for example Cox et al. (2018) for Switzerland and Knobloch et al. (2020) for 59 world regions.

From a public policy perspective, mechanisms have been implemented to encourage and facilitate the replacement of combustion vehicles with clean vehicles. Numerous scientific works also show that different types of public policies are effective in encouraging this replacement. Thus, there are studies that show that financial incentive policies can stimulate sales of clean vehicles and therefore promote their diffusion, see, for example, Münzel et al. (2019) and Wang et al. (2019). Other works have emphasized the positive effect of relief policies involving the value added tax (VAT) and other types of taxes linked to the purchase of a vehicle, or price subsidies, on the purchase of clean vehicles, see, for example, Potoglou and Kanaroglou (2007), Bjerkan et al. (2016) and Levay et al. (2017). There are also works that point out the importance of developing electric charging infrastructures to encourage the purchase of clean vehicles, see for example Fang et al. (2020).

In this context, Spain, which is the country on which this research is focused, has implemented ambitious regulations with measures and incentives to improve air quality in cities, promote the acquisition of clean vehicles, as well as to expand the installation of electricity recharging points. Among these policies, the subsidy model that the government carries out consisted in giving economic aid for the acquisition of clean vehicles. Additionally, with the aim of improving the infrastructure, there are programs that finance the costs of installing charging points. There are also tax incentives such as the exemption from the Motor Vehicle Registration Tax (IMVA) that is carried out based on the CO2 emissions of the vehicle. This incentive consists of not charging the tax for the cleanest vehicles and charging a higher rate for those vehicles with the highest CO2/km of emissions (Agencia Tributaria de España, AET, 2020). Another type of measure is the mandatory application of environmental labels on vehicles: these labels allow vehicles to be classified according to the levels of pollution that they emit and their environmental impact, and are mainly used to implement measures on circulation (allowing circulation at certain times, free parking, free access to central areas for clean vehicles, among others), especially in the largest cities where the greatest problems related to air quality are concentrated, such as the city centres of Madrid and Barcelona. On the other hand, for the renewal of the stock of vehicles, a subsidy is granted for the purchase of clean vehicles if they are replacing a car more than 10 years old, Higueras-Castillo et al. (2020). These policies are similar to the measures applied in other EU countries (European Commission, 2021).

In any case, as Higueras-Castillo et al. (2020) emphasize, the implemented measures had have a limited effect on the extension of the use of clean vehicles. Indeed, Spain is still in the initial phase of adopting clean vehicles compared to other neighbouring countries. The European market for clean cars is led by the Nordic countries, with Norway standing out, where clean vehicles represent 42%, followed by the Netherlands, where 14% of the total fleet is composed of clean vehicles (ACEA, 2020). However, in Spain, clean cars represented only 2.7% of the total in 2020[28]. Hence, according to the Spanish energy transition plan, called the National Integrated Energy and Climate Plan 2021-2030 (Ministerio de Transición Energética y Reto Demográfico, 2020), the objective set for 2030 forecasts that clean vehicles in Spain will be 16% of the total. With current data it is

[28]See, https://www.unespa.es/notasdeprensa/movil-tipos-motor-2020/

practically impossible for Spain to achieve that goal. Thus, in 2021 the European Union called this to the attention of the Spanish government for this reason[29].

The case of Spain can also be illustrative for many countries. In fact, in many economies replacing combustion vehicles with more environmentally friendly alternatives is not easy; thus clean vehicles have not yet penetrated the market to a great extent (Hackbarth and Madlener, 2013). The acquisition of these cars is not increasing as expected despite the huge public subsidies to the demand and the technological advances of the industry (Ziegler and Abdelkafi, 2022). The point is that there are still many barriers for the general population to massively acquire this type of vehicle. Among the most commonly identified barriers are the low range of autonomy (Egbue and Long, 2012; Franke et al., 2013; Schneidereit et al., 2015), the high relative prices (Adepetu and Keshav,2017; Vassileva and Campillo, 2017; Bienias et al., 2020) and the lack of infrastructure, especially the paucity of recharging points (Egbue and Long, 2012). Regarding the last factor, in Spain in the second quarter of 2021, there were barely 11,847 recharging points, a figure that is far from the objective set for the year 2022 of having between 45,000 and 48,000 points available (ANFAC, 2021).

Therefore, despite the efforts of governments to stimulate purchases, there are still barriers linked to supply that make it difficult to replace combustion vehicles with clean vehicles (Egbue and Long, 2012) and (Higueras-Castillo et al., 2021). But, in addition, there are also barriers linked to demand. Therefore, it is very important to know and characterize well all the aspects of both supply and demand that may constitute barriers to the acquisition of clean vehicles. In this sense, it is crucial to understand, among other issues, what are the socioeconomic and demographic characteristics of the buyers of this type of car.

Specifically, in this paper we are going to analyse the characteristics of Spanish households that have already purchased a clean vehicle in order to have a better understanding of the socioeconomic profile of those who, despite the existing supply barriers -high relative price, low autonomy, and scarcity of recharging points- have had a preference for buying a clean car. This will make it possible to characterize the socioeconomic and demographic factors of that demand in order to identify which socioeconomic and demographic characteristics favour and which disfavour buying a clean vehicle. Therefore, we are going to analyse to what extent, taking the

[29] See, https://www.motorpasion.com/futuro-movimiento/europa-da-tiron-orejas-a-espana-no-impulsar-coche-electrico-podria-haber-sanciones

case of Spain as an example, the current society of Western countries presents pros and cons to achieve the objectives of the 2030 Agenda linked to the transport sector. To that end, having a better understanding of the socioeconomic and demographic situation that explains the demand for clean vehicles is very important. This is something that has not been sufficiently analysed in the literature, which has mainly focused on studying supply issues, or the influence of prices on demand, or the influence of incentives, as for example in Cecere et al. (2018). In fact, understanding the opportunities and challenges that the socioeconomic reality presents to achieving the decarbonization of the transport sector is crucial if we want to achieve the goals of the 2030 Agenda for climate action, sustainable cities and communities, and affordable and clean energy for all. If the transport sector fails to decarbonize, it will be difficult to achieve these goals. For this reason, more works are needed that analyse the situation in depth and from all aspects related to supply and demand. More academic results are needed, therefore, to design effective policies in order to achieve a better balance between the transport sector and the fight against climate change. In other words, a better understanding of the situation is needed to implement policies that are realistic in relation to the social context in which they are applied, the time horizon they contemplate, and that, thus, can be effectively applied. This work, through the analysis of the case of Spain, which is interesting due to the difficulties that the penetration of clean vehicles is having in that market, represents an excellent case of an analysis to contribute to this knowledge.

To carry out the proposed analysis, a binomial logit model will be estimated for the period 2016 to 2019 using data of the Household Budget Expenditure (HBS) from the Spanish National Institute of Statistics (INE). The survey contains annual information on the nature and destination of household consumption expenses; more specifically, we will use data of households that spend on electricity for vehicles, as a proxy for the use of clean cars (hybrid and electric) and on fuel for vehicles, as a proxy for the use of conventional cars. The results obtained will help to characterize the consumers for electric and hybrid cars and will allow conclusions about the socioeconomic circumstances that may be advantageous or disadvantageous when we face the energy transition in the household automotive transport sector, or in other words, when clean cars have to penetrate in the market. The present study contributes to the literature on this subject by providing an empirical study of the socioeconomic and demographic characteristics of the consumers of clean vehicles. The results can be useful for designing transport policy measures that are realistic and effective, as at the moment such measures seem to be unsuccessful. One advantage that this work

has, compared to most of those that have addressed this topic in the academic literature, is that it uses an official database from a large sample, representative of 11.5 households, while most of the work on the subject, is based, as Oliveira and Dias (2019) point out, on their own surveys based on data from very small samples, which are therefore not very representative. Therefore, this work will provide representative results, in relation to the analysed issue, where such results are scarce. This paper is structured as follows: in the next section the existing literature is reviewed. Section 3 presents the database used in the research, the HBS, and a descriptive analysis. Section 4 presents the estimated econometric model. Section 5 presents the results of the estimates, and the last section contains the conclusions of the study.

## 4.2. Literature review

Over the last decade, all countries have implemented policies aimed at fighting air pollution in cities and fighting climate change by promoting the use of clean vehicles. For this reason, the interest in this area of research has expanded, see, for example, Oliveira and Días (2019) and Ziegler and Abdelkafi (2022). As for the works focused on analysing issues related to the demand for clean vehicles, some are focused on analysing the determinants of demand and others on analysing the specific characteristics of the buyers. In this study we will focus on the second issue. Therefore, the literature of interest for our research evaluates the socioeconomic and demographic characteristics of consumers who buy clean vehicles. We present below a review of some of the most significant work carried out on this topic.

Liao et al. (2017) conducted a review of the literature focused on examining the factors that influence the consumption of clean vehicles. They showed that most studies worldwide show that socioeconomic, demographic, and psychological factors influence the decision to purchase a clean vehicle. The most widely applied method in this type of study is the analysis of discrete choice models in which the choice of clean vehicles is described as a choice between a group of vehicle alternatives described by their characteristics or "trade attributes".

Shabanpour et al. (2017) used a logit discrete choice model to estimate the characteristics of drivers choosing electric or gasoline vehicles in the United States using data from an own survey. They found that more educated drivers, younger drivers, and those who need to commute long-distances are more likely to choose electric vehicles.

Simsekoglu (2018), using a logistic multinomial regression, compared the characteristics of drivers of electric and conventional cars in Norway. Data were obtained from a survey of 663 drivers. The results showed that electric car owners were young, highly educated, and had a high-income level. She et al. (2017), using a structural equation model, showed that, of the 476 respondents of their survey, the older ones had a more optimistic attitude towards electric and hybrid vehicles than the younger; in addition, the respondents with a second car in the family and those more concerned about the environment were more likely to adopt electric and hybrid vehicles.

Sovacool et al. (2018) showed, for the case of the Nordic countries (Denmark, Finland, Iceland, Norway and Sweden), and with data from their own survey of 5,000 respondents, that 60.2% of households that had an electric car also had a Main Breadwinner (MBW thereafter) who was single, while 85.6% of households owning an electric car had a size of four members.

Cirillo et al. (2017), using a discrete multinomial choice model, studied the case of the State of Maryland (United States) and, based on their own survey carried out over several years with 456 respondents, showed that women with a high level of education were the most likely to buy hybrid cars.

Cecere et al. (2018), using discrete choice models applied to the cases of France, Germany, Italy, Poland, Spain and the United Kingdom, and with data from a survey carried out by the European commission Joint Research Centre in 2012 for 600 respondents in each country, obtained evidence that the intention to purchase an electric or hybrid vehicle is higher for people with higher incomes and more education.

Rodrigues et al. (2021), using a mixed logit model, showed, for the case of Portugal, and with data from their own survey of 905 drivers, that those who are most likely to choose a clean vehicle are younger people, with higher incomes, those who live in urban areas and those with higher levels of education.

Oliveira and Días (2019) made a compilation of the literature related to the characteristics of the consumers of clean vehicles, and they also estimated through a statistical analysis for the case of Portugal and based on their own survey of a sample of 105 people, that consumers with higher levels of education, women and larger families are more likely to purchase alternative fuel vehicles.

In the case of Spain, the literature that deals with this type of analysis is scarce; in fact, as far as we know, there is no study that, first, deals with the analysis of the socioeconomic characteristics

of clean car buyers, understanding by clean, the electric and hybrids cars together. And second, use data from an official survey, with a very large sample, as we do in this study. However, we can highlight three works that analyse the demand for exclusively electric vehicles. Among the demand factors analysed in these works, some are socioeconomic characteristics of the buyers, and all are based on data obtained from their own surveys. Thus, Higueras-Castillo et al. (2020) analysed, through a cluster analysis, the profile of potential buyers of electric vehicles in Spain based on the data obtained in a survey of 404 respondents. They found that this profile would be defined by being a woman, being young and having a high income. Junquera et al. (2016) estimated a logit model with data from a survey of 1,245 respondents, to determine what factors influence the willingness to pay for an electric car, the only variable linked to the characteristics of consumers that was analysed is age: they found that those most likely to buy an electric car are between 24 and 45 years old. Rodríguez-Brito et al. (2018), focusing on the case of the Island of Tenerife (Spain), used data from a survey of 444 drivers and applied an analysis of principal components, clusters and a logit model to determine what factors influence the willingness to change cars for an electric one and in the willingness to pay for an electric car. Regarding socioeconomic characteristics, they found that being a man, being older, having a high income and high educational level are characteristics that determine a greater preference for electric cars than the rest of the population.

In summary, the literature seems conclusive in the positive relations between having a high level of income and other related variables, such as high educational level and household size, and buying a clean car. For other variables, such as age and gender, the literature is not conclusive.

Table 1 presents a summary of these studies, indicating the case analysed, the method used in the study, and the variables analysed.

**Table 1.** Literature about the characteristics of clean car buyers

| Author | Country | Methodology | Age | | Income | | Labor situation | Gender | | Education | | Urban areas | Household size (members (children) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Young | Old | lower | Higher | Employed | Woman | Man | Low | High | | |
| | | | | | | | | | | | | | |
| Cirillo et al (2017) | United States | Multinomial Logit model | X | | | | | X | | | X | | |
| Shabanpour et al. (2017) | United States | Mixed Logit Model | X | | | X | | | | | X | | |
| Cecere et al. (2018) | France Germany, Spain, Italy, Poland, UK | Multinomial Logit model | X | | | X | | | | | X | | X |
| Simsekoglu (2018) | Norway | Logit model | X | | | X | X | | | | X | | X |
| Sovacool et al. (2018) | Nordic Countries | Static analysis and hypothesis proves | X | | | | X | | X | | X | | X |
| | | | | | | | | | | | | | |
| Wolbertus et al. (2018) | Netherlands | Mixed Logit Model | X | | | X | X | | | | | | |
| Junquera et al. (2016) | Spain | Logit Model | X | X | | | | | | | | | |
| Higueras-Castillo et al. (2020) | Spain | Conglomerate análisis | X | | | X | | X | | | X | | |
| Rodríguez-Brito (2018) | Spain | Multinomial Logit model | | | | X | | | X | | X | | |
| Oliveira y Días (2019) | Portugal | Static analysis and hypothesis proves | | X | | | | X | | | X | | X |
| Rodrigues et al. (2021) | Portugal | Mixed Logit Model | X | | | X | | | | | X | X | |
| She et al. (2018) | China | Structural equations | | X | | X | | | | | | | X |

## 4.3. Database and descriptive analysis

The database used in this research is the Households Budget Survey (HBS) designed by the Spanish National Institute of Statics (INE). The HBS contains annual information on the nature and destination of consumption expenses of households in Spain. This survey is conducted with a representative annual sample of approximately 24,000 households that represent 18.5 million households each year. The information is presented in three files that collect information on households, household members and the expenditures they make. The survey provides socioeconomic data on households and members at the national level and at the level of the Spanish Regions. Additionally, it enables the analysis of expenditure and its distribution through 4 nomenclatures, and 12 consumption groups are distinguished. It is important to note that there are several studies in the literature that, although they differ in method, use consumer spending surveys to analyse the behaviour of transport users, for example, Burguillo et al. (2017), Arranz et al. (2019; 2022).

In our study we use the information on households that spend on automotive fuel (gasoline and diesel) as a proxy for households that have a conventional car, and on those households that spend on electricity for vehicles as a proxy for ownership of electric and hybrid cars. The information covers the period from 2016 to 2019 for the 17 Spanish Regions and the two autonomous cities of Ceuta and Melilla. Each year the sample has about 13,000 households (representative of around 11.5 million households), and the total number of observations for the 4 years of the analysis is 53,730.

Table 2 shows descriptive information about the distribution of households that spend on automotive fuel and those that spend on electricity for vehicles. As can be seen in the entire period, 94.6% of the households spent on automotive fuel, and 5.4% of them spent on electricity for hybrid or electric vehicles. In other words, we observe a very low proportion of households using clean cars in the Spanish vehicle market.

**Table 2.** Households spending on fuel or electricity for vehicles – EPF Year 2016-2019.

| YEARS | 2016 | | 2017 | | 2018 | | 2019 | | 2016-2019 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | No. | % | No. | % | No. | % | No. | % | No. | % |
| **Households spending on fuel for vehicles** | 13,209 | 95.5% | 12,752 | 92.3% | 12,802 | 96.1% | 12,088 | 94.8% | 50,851 | 94.6% |
| **Households spending on electricity for vehicles** | 617 | 4.5% | 1,070 | 7.7% | 523 | 3.9% | 669 | 5.2% | 2,879 | 5.4% |
| **Total households using cars** | **13,826** | **100%** | **13,822** | **100%** | **13,325** | **100%** | **12,757** | **100%** | **53,730** | **100%** |

Table 3 presents the descriptive statistics of the variables analysed in this work. The households that are most likely to spend on electricity for vehicles have a BMW male (70.7%), older than 55 years (44.6%), married (87.3%), employed (68,2%) and with higher education (34.4%), located in Andalusia (19.1%), with an average size of 3.2 members and on average 1.3 of their members are employed. In addition, 31.1% of these households are in the fourth quartile of income level and 77.8% among them are households located in urban areas. On the other hand, the profile of households that spend on fuel has a similar profile at the personal, work and family size characteristics. However, they differ in the income profile where those households in the first quartile are the ones that spend the most on fuel cars (32.9%) and at a regional level this expense is more distributed: not only in Andalusia, where around 11% of these households are located, but also in regions such as Catalonia, Madrid and Valencia, with around 8%-9%.

**Table 3.** Descriptive statistics of households that spend on fuel and/or electricity for vehicles. EPF - Year 2016-2019. Spain

| Variable | Households that spend on fuel | | Households that spend on electricity | |
|---|---|---|---|---|
| | Observations | Mean | Observations | Mean |
| **Gender MBW (Male=1)** | 37,402 | 0.736 | 2,035 | 0.707 |
| ***MBW age (in years)*** | | | | |
| *18 to 30* | 1,132 | 0.022 | 60 | 0.021 |

| | | | | |
|---|---|---|---|---|
| *30 to 45* | 13,342 | 0.262 | 655 | 0.228 |
| *45 to 54* | 12,426 | 0.244 | 771 | 0.268 |
| *older 55* | 22,459 | 0.442 | 1,284 | 0.446 |
| **Marital status MBW (Single =1)** | 8,515 | 0.167 | 366 | 0.127 |
| **Level of studies completed MBW** | | | | |
| *Primary* | 7,285 | 0.143 | 465 | 0.162 |
| *Secondary I stage* | 15,089 | 0.297 | 874 | 0.304 |
| *Secondary stage II* | 9,816 | 0.193 | 549 | 0.191 |
| *Higher Education (University)* | 18,661 | 0.367 | 991 | 0.344 |
| **Situation labor MBW ( Occupied =1)** | 34,349 | 0.675 | 1963 | 0.682 |
| **Number of household members** | 50,851 | 2,931 | 2,879 | 3,243 |
| **Number of employed members in the household** | 50,851 | 1,246 | 2,879 | 1,325 |
| **Number of children in the household** | 50,851 | 0.735 | 2,879 | 0.876 |
| **Income home (proxy spending )** | | | | |
| *Income Quartile 1* | 12,750 | 0.329 | 683 | 0.237 |
| *Income Quartile 2* | 12,821 | 0.251 | 611 | 0.212 |
| *Income Quartile 3* | 12,744 | 0.250 | 689 | 0.239 |
| *Income Quartile 4* | 12,536 | 0.246 | 896 | 0.311 |
| **Household residence area (Rural=1)** | 12,684 | 0.249 | 638 | 0.222 |
| **Region of residence** | | | | |
| *Andalusia* | 5,830 | 0.115 | 549 | 0.191 |
| *Aragon* | 2,252 | 0.044 | 28 | 0.010 |
| *Asturias* | 1,815 | 0.036 | 44 | 0.015 |
| *Balearic Islands* | 1,834 | 0.036 | 144 | 0.050 |
| *Canary Islands* | 2,473 | 0.049 | 210 | 0.073 |
| *Cantabria* | 1,714 | 0.034 | 116 | 0.040 |
| *Castile and Leon* | 3,056 | 0.060 | 100 | 0.035 |
| *Castile-La Mancha* | 2,945 | 0.058 | 116 | 0.040 |
| *Catalonia* | 4,385 | 0.086 | 190 | 0.066 |
| *Valencian region* | 4,133 | 0.081 | fifty | 0.017 |

| | | | | |
|---|---|---|---|---|
| *Extremadura* | 2,252 | 0.044 | 210 | 0.073 |
| *Galicia* | 3,118 | 0.061 | 190 | 0.066 |
| *Madrid region* | 4,395 | 0.086 | 183 | 0.064 |
| *Murcia* | 2,395 | 0.047 | 232 | 0.081 |
| *Navarre* | 1,618 | 0.032 | 105 | 0.036 |
| *Basque Country* | 4,593 | 0.090 | 268 | 0.093 |
| *La Rioja* | 1,517 | 0.030 | 97 | 0.034 |
| *Ceuta* | 230 | 0.005 | 28 | 0.010 |
| *Melilla* | 296 | 0.006 | 19 | 0.007 |
| ***Sample ( Households )*** | **50,851** | | **2,879** | |

**Source:** INE

## 4. 4. Econometric model

The information in the previous section allows us to know the characteristics of the distribution of Spanish households that spend on energy to use fuel or clean vehicles according to independent characteristics, but it does not consider all the factors that influence the probability of spending on energy together, for the use of electric or hybrid vehicles, since these households can also spend on fuel. In order to isolate the effect of the different determinants on these probabilities, it is necessary to carry out the estimation of an econometric model that makes it possible to explain the probability that households spend on electric or fuel vehicles, considering both personal, work, income or household size $X_{it}$. With this objective, we have proceeded to estimate the unconditional probability $p_{it}$ that a Spanish household spends on electricity for a vehicle, subject to a set of characteristics $X_{it}$ in period t:

$$p_{it} = f(\beta_1 + \beta_2 + X_{it}) (1)$$

The calculation of this probability is carried out by estimating a binomial logit model, in which the endogenous variable ($Y$) takes two values: 0 and 1. In our analysis, 1 is assigned

to the people who spend on electricity for a vehicle and 0 to those who spend on automotive fuel. Formally, the logit model is

$$Y = F(\beta_1 + \beta_2 X_{it}) + \varepsilon = \frac{1}{1+e^{-(\beta_1+\beta_2 X_{it})}} + \varepsilon \quad (2)$$

where the probability that a household spends on electricity for a vehicle in period *t* is

$$p_{it} = E(Y = 1|X_{it}) = \frac{1}{1+e^{-(\beta_1+\beta_2 X_{it})}} \quad (3)$$

The estimates have been made for all the years from 2016 to 2019 using the maximum likelihood method. The estimated models include a set of explanatory variables such as age, gender, marital status, level of studies completed and employment status of the MBW, residential area of the household, number of employed members of the household, number of children in the household, income per household and Region of residence.

### 4.5. Empirical results

Table 4 provides the results of the estimates of the probability that a household spends on electricity for its vehicle versus on fuel, for the entire sample of households. In the table, the odds ratios and the coefficients of each category are shown. If the odds ratio has a value lower (higher) than 1, this indicates that the household is less (more) likely to spend on electricity for its vehicle, compared to the reference category (spending on fuel for your vehicle).

**Table 4. Estimation of the probability that a household spends on electricity for vehicles versus spending on automotive fuel**

| *variables* | | *Coefficients* | *Odss Ratio* |
|---|---|---|---|
| ***MBW gender*** | | | |
| | *Men* | 0.035*** | 1.035*** |
| | | (0.008) | (0.008) |

| | | |
|---|---|---|
| ***MBW age groups (in years)*** | | |
| *Age between 18 - 30* | 0.216 | 1.241 |
| | (0.143) | (0.177) |
| *Age between 30 - 44* | - | - |
| *Age between 45 - 54* | 0.140** | 1.150** |
| | (0.054) | (0.061) |
| *Age over 55* | 0.255*** | 1.291*** |
| | (0.057) | (0.074) |
| ***MBW Marital Status*** | | |
| *single* | -0.201*** | 0.818*** |
| | (0.064) | (0.052) |
| ***Number of employed members*** | 0.080*** | 1.083*** |
| | (0.025) | (0.026) |
| ***Number of children*** | 0.131*** | 1.140*** |
| | (0.023) | (0.026) |
| ***Income*** | | |
| *Quartile 1* | -0.233*** | 0.791*** |
| | (0.059) | (0.046) |
| *Quartile 2* | -0.346*** | 0.707*** |
| | (0.057) | (0.040) |
| *Quartile 3* | -0.236*** | 0.790*** |
| | (0.053) | (0.042) |
| *Quartile 4* | - | - |
| ***Zone*** | | |
| *Rural zone* | -0.108** | 0.897*** |
| | (0.049) | (0.044) |
| ***Region*** | | |
| *Andalusia* | - | - |
| *Aragon* | -2.023*** | 0.132*** |
| | (0.196) | (0.025) |
| *Asturias* | -1,330*** | 0.264*** |
| | (0.159) | (0.042) |

| | | |
|---|---|---|
| *Balearic Islands , Illes* | -0.197** | 0.821** |
| | (0.098) | (0.080) |
| *Canary Islands* | -0.087 | 0.917 |
| | (0.085) | (0.078) |
| *Cantabria* | -0.325*** | 0.722*** |
| | (0.107) | 0.077 |
| *Castile and Leon* | -1.041*** | 0.353*** |
| | (0.112) | (0.039) |
| *Castilla la Mancha* | -0.849*** | 0.427*** |
| | (0.105) | (0.045) |
| *Catalonia* | -0.814*** | 0.443*** |
| | (0.087) | (0.038) |
| *Community Valencian* | -2.057*** | 0.127*** |
| | (0.149) | (0.019) |
| *Estremadura* | 0.053 | 1,054 |
| | (0.087) | (0.091) |
| *Galicia* | -0.419 | 0.657*** |
| | (0.088) | (0.057) |
| *Madrid region* | -0.879*** | 0.415*** |
| | (0.089) | (0.036) |
| *Murcia* | -0.004 | 0.990 |
| | (0.083) | (0.082) |
| *Navarre* | -0.401*** | 0.669*** |
| | (0.112) | (0.074) |
| *Basque Country* | -0.528*** | 0.589*** |
| | (0.078) | (0.046) |
| *The Rioja* | -0.369*** | 0.691*** |
| | (0.115) | (0.079) |
| *Ceuta* | 0.137 | 1.146 |
| | (0.206) | (0.236) |
| *Melilla* | -0.473** | 0.623*** |
| | (0.242) | (0.150) |

| | | |
|---|---|---|
| *Constant* | -2.551 | 0.077 |
| | (0.092) | (0.007) |

i) Standard errors are presented in parentheses,

ii ) Significance level: ***p < 0.01; **p < 0.05; *p < 0.1,

The results of Table 4 show that the households with a higher probability of spending on clean vehicles compared to conventional vehicles are the following:

Regarding gender, the probability that a household whose MBW is a man uses a clean vehicle increases by 35% compared to the probability that a household whose MBW is a woman. This result coincides with the analysis of Rodríguez-Brito et al. (2018) of the case of Tenerife. In any case, the literature is not conclusive regarding the gender, as was seen in Section 2.

The age of the MBW of the household has effects on the probability of using a clean car. In fact, the effect shows a U-shaped relation, that is, households with the youngest and oldest MBWs have a greater probability of acquiring a clean vehicle than the rest of the households. Thus, the probability that a household uses a clean vehicle is greater when the MBW is older than 55, or younger than 30. This probability compared to the probability that a household whose MBW is between 30 and 44 years old increases by 29% in the first case and 24% in the second case. In addition, that probability is 15% if the MBW is between 30-44 years old. This result agrees with other works in the literature such as that of Sovacool et al. (2018) which shows that in the Nordic countries older people and recently retired people drive short distances, have high car budgets and are less interested in design, and Simsekoglu (2018), finding, for Norway, that the youngest are those with the highest probability of buying a clean car.

Regarding marital status, the probability that a household whose MBW is single uses a clean vehicle decreases by 19% compared to the probability that a household whose MBW is married uses it. This result agrees with others in the literature, which explain that, among single people, who generally do not have children, there may be less concern for the environment and for the future (Büchs et al., 2013).

Table 4 also shows that income level is a socioeconomic factor that positively influences the acquisition of clean vehicles. Thus, the probability that low-income households (quartile 1) and medium income (quartile 3) use a clean vehicle decreases by 21% compared to high-income households (quartile 4), and the probability of low-middle income households (quartile 2) decreases by 30%. The existing literature shows that income tends to have a positive influence on the adoption of clean vehicles, and it is also in relation to this factor that the literature, as pointed out in Section 2, seems to be more conclusive. For works focused on Spain, Rodríguez Brito et al. (2016) and Higueras-Castillo et al. (2020) obtained similar results: they explain that the reason why higher incomes and the purchase of clean cars are positively related is that consumers with higher incomes can more easily bear the higher costs derived from the adoption of ecological products and produced with more advanced technology, see for example, Straughan and Roberts (1999), Tellis and Yin (2009), and Lennon et al. (2007). Also, there are works that emphasizes that high-income consumers are more likely to be aware of environmental issues, as for example, Straughan and Roberts (1999). Regarding the results by quartiles, these data would agree with those obtained by Burguillo et al. (2017) that show that Spanish households from the second quartile are more dependent on the use of fuel vehicles. This would explain why their probability of using a clean vehicle decreases more with respect to households in the richest quartile, as does also the probabilities of the 1st and 3rd quartile households.

The probability that a household with a greater number of its members employed uses a clean vehicle increases by 8.3% with respect to households that have fewer employed members. This result is common in the literature. For example, Morton et al. (2017) find that the people that are most likely to be early adopters of electric vehicles are employed full-time workers, and Gough et al. (2011) find that unemployment is negatively associated with carbon emissions.

The probability that a household with a greater number of children uses a clean vehicle increases by 14% compared to the probability of households with fewer children. The explanation is that, first it seems that families with children are more willing to pay more for environmental products due to their concerns about the negative impact of a destroyed environment on their children's future (Laroche et al., 2001). And second, it seems that

for the safety of household members, larger households appear to have more cars and are willing to pay more for them (Sovacool et al. 2018). On the other hand, the probability that a household located in a rural area uses a clean vehicle decreases by 10% compared to the probability that a household located in an urban area uses it. This result also agrees with other results in the literature, for example, Rodrígues et al. (2021) for the case of Portugal. This is logical result because in rural areas it is usually necessary to make longer and more frequent trips in private vehicles, and the problem of the autonomy of electric vehicles and the absence of the advantages that hybrids can have in urban areas (due to lower consumption of fuel) are lost in the rural context.

Finally, in relation to the results by region, we have taken Andalusia as the reference region. Thus, as can be seen in Table 4, households living in all the other regions have a lower probability of using a clean vehicle than a household in Andalusia. The regions in which the probability of using a clean vehicle decreases more compared to the probability of using it in Andalusia, are the Valencian Community and Aragón, whose probabilities decrease by 88% and 87% respectively. As for Madrid and Catalonia, the probability that clean vehicles are used there compared to Andalusia decreases by 59% and 56%, respectively.

### 4.6. Conclusions

Widespread adoption of clean vehicles can help alleviate problems like air pollution and global warming. Therefore, achieving the gradual replacement of the automobile fleet based on the combustion of petroleum derivatives for a cleaner one is very important in order to achieve three of the objectives of the 2030 agenda: climate action, sustainable cities and communities, and affordable and clean energy for all. Hence, the economic and environmental policies of developed and developing countries are focused on achieving an energy transition in the automotive sector, promoting the penetration of clean vehicles in the market to the detriment of combustion vehicles that currently lead the market throughout the world. However, in many countries the market for clean vehicles is not increasing as expected despite public subsidies and incentives, and awareness policies

such as advertising campaigns, among others, that encourage their purchase. Spain is an excellent example of that situation.

Thus, in Spain, clean vehicles represented just 2.7% of the total number of vehicles in the country in 2020, and between 2016 and 2019 only 5.4% of households using cars used a clean one. The situation at that time suggests that it will be very difficult to reach the objective set for 2030, which is to achieve a percentage of 16% of clean vehicles. This is the status quo, despite the fact that there is currently an ambitious project in Spain to achieve the energy transition of the economy. This project considers a series of measures and incentives to improve air quality in cities, promote the acquisition of clean vehicles and expand the installation of electricity recharging points for vehicles. It is true that in this last aspect the achievements have been insufficient, and the Spanish government should redouble efforts to improve the situation, as the shortage of recharging points is a significant barrier when it comes to boosting the market.

In any case, given the importance that the transport sector has in the economy as a whole, and in energy consumption in particular, achieving the decarbonization of transport is crucial if the aforementioned objectives are to be achieved by 2030. Going deeper into the knowledge of the factors that, beyond those linked to public policies, or to relative prices, explain the purchase of clean vehicles, is necessary in order to have a better understanding of the challenges and opportunities that today's society presents to adapting to the changes that the achievement of the objectives of the 2030 Agenda requires. With this purpose in mind, this paper has presented an analysis of the socioeconomic and demographic characteristics of those households that are more likely to purchase a clean vehicle in Spain. To carry out this analysis, a binomial logit model has been estimated with data from the Households Budget Survey of the Spanish National Institute of Statistics for the years 2016 to 2019, which contains annual information on the nature and destination of household consumption expenditures.

The results of this study show that the households that are most likely to spend on automotive electricity, that is, to use a clean car, are those whose socioeconomic characteristics are the following: households with a main breadwinner (MBW) over 55 years of age or under 30, who is male, and who is married; households with a high level of income, living in urban areas, with a greater number of members employed (the

average is 1.3 employed members), with a greater number of children, and who live in Andalusia. On the contrary, households whose MBW is between 31 and 44 years old, is female, is single, is a medium-low-income household (second quartile), located in a rural area, with a lower number of employed members, with a lower number of children and who live in Aragon or Valencia are less likely to have an electric or hybrid car. These results are consistent with others found in the literature analysed for various countries. These results are conclusive in the variables linked to income level, while for others, such as age or gender, there is controversy. One advantage of this study, compared to most studies in the literature, is that it uses data from an official survey for a very large sample of households, while most of the studies are based on data from surveys with relatively small samples. From these results, conclusions can be drawn about the opportunities and challenges that some of them present to achieving the decarbonization of the sector by 2030 in Spain. For example, the fact that older age is a positive socioeconomic characteristic for buying a clean car can be a help for the decarbonization of the transport sector since the number of older people in Western societies is on the rise, and so there will be a greater proportion of the population favourably disposed to buying clean vehicles. In addition, it is also favourable that the youngest, whose behaviour defines the trend of global behaviour in the future, are also likely to purchase this type of vehicle. Another positive factor could be linked to the fact that men seem more likely to use clean cars, for households with male MBW are also those with more combustion vehicles, specifically in 73.6% of households using combustion vehicles the MBW is a man (see Table 3). It is important that the largest car buyers, who according to these data are men, are also the ones who are buying to a greater extent clean cars. This fact marks a positive opportunity for the development of the clean vehicle market, since it indicates that men, who seem to have a greater preference for cars than women, also have a preference for clean vehicles. In any case, the greatest challenge outlined by these results comes from the positive relation found between the level of income and other correlated variables, and the use of clean vehicles. Indeed, from the results of this work it can be deduced that no matter how many economic incentives are given to acquire clean vehicles, in the end, as is the case in Spain, having a high level of income is key to acquiring them. This result shows that the 2030 Agenda objective of climate action, in whose achievement the

transport sector plays a fundamental role due to its dynamics of GHG emissions, can be opposed to the objective of achieving affordable and clean energy for all in 2030. In this regard, and while the automobile industry is improving technology, allowing greater autonomy of vehicles and a lower price in relation to traditional combustion vehicles, policy makers in the different countries, even continuing to implement policies both for the supply (installation of charging points) and demand (economic incentives for acquisition) sides, must have a better understanding of the socioeconomic reality in which they want to implement certain measures. These measures should be coherent with each other and feasible in the time frame in which they are proposed. This work, applied to the case of Spain, is a good example, to illustrate the opportunities and challenges that the social context presents to decarbonizing the transport sector. To sum up, this research provides useful information to policy makers so that they consider results such as these for designing realistic policies adapted to the social environment that allow a harmonious and socially acceptable balance between the transport sector and the fight against climate change. In this sense, it could also be useful to link the amount of the subsidy offered for the acquisition of a clean vehicle to the buyer's income level. In addition, the time frame for achieving the desired objectives should be redefined.

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## V. CONCLUSIONS

Several measures have been implemented worldwide to decarbonize the transport sector, one of the most atmosphere's polluting sectors. The achievement of three of the objectives set out in the 2030 Agenda: Climate Action; Sustainable Cities and Communities and Clean and Affordable Energy, largely depend on transport energy transition. In fact, there are two important premises to achieve sustainable transport and mobility: on the one hand, promoting the purchase and use of private vehicles with low emissions and, on the other hand, promoting the massive use of PT, especially in cities. Along these lines, governments have established several public policies that seek to make these means of transport more accessible to the entire population. In fact, and in relation to the promotion

of the PT, the cities allocate a large part of their public spending to subsidize it. It is necessary to have evidence of the effectiveness of this public spending in terms of equity and economic efficiency. Additionally, it is essential to know the profile of consumers of clean vehicles (electric and hybrid) as this is a key factor for implementing fair and inclusive transport energy transition policies. This PhD dissertation has focused on analyzing these points through three essays.

The first essay has analyzed the impact of the change of subsidies to PT price for the young in Madrid region on the well-being of households with at least one member beneficiary. The econometric technique Differences in Differences was used with data from the Spanish HBS for the years 2014 and 2016. The main question asked in this essay was: has the measure benefit more the households with fewer economic resources? The results of the estimates revealed that the measure evaluated has effectively reduced spending on PT travel-pass in beneficiary households. To see its distributive effect, an analysis was carried out by income quintiles, showing that this measure has mainly benefited households with medium and medium-high income levels (quintile 3 and quintile 4). However, regarding the poorest, the results show that in the households from the first quintile spending on PT has increased, which means that the reduction in price has allowed them to spend more on the travel-pass. Therefore, this measure has made PT more affordable for the poorest, achieving, in this sense, the equity objectives that can be expected from such a measure, whose fundamental objective would be to make public transport more accessible to the most vulnerable.

The second essay has analyzed the subsidies on PT price for the elderly in Madrid region with data from the Spanish HBS for the period 2015-2019. Subsidizing PT for the elderly is widespread worldwide, since this group is considered economically vulnerable. However, many people among the elderly are now financially better off than people in other age groups. This circumstance calls into question the design of such policies based solely on an age criterion. This essay analyzes on the one hand the equity of PT subsidies for the elderly, that is, whether these subsidies benefit more the poorest households with elderly main breadwinners, and on the other hand their efficiency, that is, whether the reduction of PT price has been an incentive to reduce spending on automotive fuel, therefore on the use of cars of these households. The results of the estimates reflect that this policy has benefited all the households that received it, since it has allowed them to reduce their spending on PT. When analyzing the results by income quartiles, a positive impact was observed for households with fewer resources (quartile 1 and 2) and with a non-employed main breadwinner, which corroborates that the subsidy has benefited the most vulnerable among the elderly. This subsidy policy has also had a positive and significant impact on the richest households (quartile 4) with an employed main breadwinner; in fact, those households are the biggest beneficiaries of the measure. These

results raise doubts about the appropriateness of awarding the subsidy only based on an age criterion.

Regarding the impact of the PT price subsidy policy for those over 65 years of age on economic efficiency, that is, on spending on automotive fuel, the results show that the measure has had a positive and significant impact on subsidized households where the main breadwinner is not employed. For the poorest households, with medium-low and medium-high incomes (quartiles 1, 2 and 3) the result is the same. This shows that the higher relative price of automotive fuel that results from the subsidization of the PT price has caused a reduction in car use in all households, except in the richest (quartile 4) as they have not been sensitive to the increase in the relative price of fuel. The results show that this policy of high subsidies on PT prices has not had a significant effect on fuel consumption when the beneficiaries of the subsidy are employed regardless of the level of household income. This reflects that, when users do not have free time, as is the case of non-employed people, and when they have specific geographical mobility needs (they live in a specific geographical place and work in another), there are other factors beyond the price (highly subsidized) that seem to be more important when the choice is to use a car instead of PT. This is an important lesson for PT subsidy public policies aimed at promoting sustainable transport in urban areas where millions of people must move daily from their homes to their working place.

The third essay has focused on identifying the socioeconomic and demographic characteristics of consumers of clean vehicles (hybrid and electric) in Spain. Governments worldwide have implemented a variety of public policies to stimulate the use of clean vehicles, without achieving much success so far. This is the case of Spain, in which this essay is focused. We have estimated a logistic regression to determine the probability that households spend on electricity for vehicles according to different socioeconomic and demographic characteristics. The data used came from the Spanish HBS for the period 2016-2019. The results indicate that the factors that influence the probability of spending on electricity for vehicles in Spain are the main breadwinner's gender, his or her age, his or her marital status, the income level of the household, and the location of the household. The profile of households that use clean vehicles is as follows: they are households whose main breadwinner is male, over 55 years of age or under 30, and married, they are households that have a higher income level, a greater number of employed members and a greater number of children, they are located in urban areas and in Andalucía. While households whose main breadwinner is a woman, aged between 31 and 54, and single, have lower income levels, a lower number of employed members, a lower number of children, are in rural areas and in Aragon and Valencia, are less likely to spend on electricity for vehicles. These results explain how the different socioeconomic and demographic characteristics of households influence the penetration of clean vehicles in the market. This permits to identify which of these characteristics can

have positive or negative effects on the policy measures whose objectives are focused on prompting the development of the clean cars market. This analyze is novel and important as the energy transition must lead to a generalized decarbonization of the economy, but it must be done in such a way that its costs are affordable and do not fall disproportionately on certain groups. In that sense, the results of this essay give inputs for a better design public policy aiming to encourage the penetration of clean cars. One of the positive effects of the potential buyers' characteristics is the influence of age on the choice of clean vehicles, both the older and the younger members of population are the most likely to use these vehicles, and this is an advantage given the demographic importance of the former, which is going to be growing, and the social trend that young people should mark for the future. Another positive effect is that, in a market, as the automobiles one, in which the largest buyers are men, also males are most likely to buy a clean vehicle. However, the biggest drawback comes from the positive relationship between income level and other correlated variables, and the use of clean vehicles. Indeed, from the results of this work it can be deduced that no matter how many economic incentives are given, as in the case of Spain, to acquire clean vehicles, a high level of income seems to be the key question. This shows that by the moment clean vehicles are not affordable for a large proportion of population and this is highly relevant for public policy decision-making.

To sum up, this PhD dissertation, through its three essays, has delved into research on a topic of great academic and social interest, such as the economic analysis of the use of transport and the public policies that encourage its economic, social and environmental sustainability. Besides, interesting conclusions have also been reached on different aspects related to these issues. In fact, in relation to the equity of urban public transport subsidies, the results of this PhD dissertation show that such policies meet the expected objective, since in general, the poorest groups in society benefit substantially from the subsidies, and therefore it is shown that those policies are necessary for economic equity. However, in the case of subsidies in which the eligibility criterion of the beneficiaries is the age, it would also be desirable to introduce an income criterion, because the greatest beneficiaries of these policies are households with medium-high income levels (in the case of subsidies for young people) or high-income levels (in the case of subsidies for the elderly). In relation to the economic efficiency of subsidies for urban public transport, the results show that even when the subsidies are very generous, as is the case of subsidies for those over 65 years of age, if the beneficiaries are occupied, and therefore have to move for working reasons, the increase of the relative price of fuel, derived from the policy measure analyzed, is not sufficient to encourage the substitution of private vehicle use with public transport. Thus, giving subsidies to urban public transport seem ineffective measures if the objective is to achieve a greater environmental sustainability of the transport sector in large cities. Regarding the penetration of clean vehicles in the market, beyond the barriers linked to supply, such as the high relative prices of these vehicles, their still low autonomy and the scarcity of electricity recharging points, the results of this PhD dissertation show that there are socio-economic barriers to its market

penetration that are related to the income level of potential buyers and other variables closely linked to income level. Nevertheless, there are also socio-economic characteristics that are advantageous for the growth of the clean vehicle sector, such as the age and gender of potential buyers. Public policies aiming to promote the purchase of clean vehicles should consider these results. Therefore, the objectives aiming of replacing combustion cars for clean cars can be re-designed by policy makers on the grounds of just energy transition policies, considering the influence that the characteristics of people treated by the policy should have on such objectives.