Explanatory Variables of Road Traffic in Portugal

João Barata

Department of Engineering and Management, Instituto Superior Técnico

Abstract

During the last years, Portuguese passenger and goods transport has been growing at a larger rate than GDP. Also, road traffic has increased its market share as compared with other transportation means. Several factors may justify this evolution, being some on transport supply while others on transport demand. For supply, improved accessibility conditions (modals, quality, time, and cost), while for demand socioeconomic factors (population, employment, GDP, income, fuel price) seem to play a key role. Although there exists several evidence concerning which factors have been shaping demand evolution, quantification lacks research. One difficulty for this task is the nonexistence of a unique database with Portuguese road traffic statistics. Also, available data do not have the same time horizon or statistical confidence. In this study a characterization of demand evolution based on fuel sales statistics is suggested, given that his information is available for broad time horizons and is territorially disaggregated. These statistics are also compatible with socioeconomical official ones published by official entities. Model results point out per capita values of gross domestic product, gross value added, compensation of employees and employment, alongside with fuel price, as key determinants for road traffic in Portugal.

Keywords: Externalities, Fuel Demand Model, Road Traffics, Road Sector

1. Introduction

Transport is a 21st Century challenge. Whilst crucial for economic and social development of countries, it can bring more harm than benefits to societies if not carefully planned, predicted and controlled.

Even with greater knowledge resulting from several errors made in the past regarding transport planning, proper investment, transport modelling and decision making, new challenges have arisen in this century, as pollution becomes a more serious issue day by day, the number of cars circulating is increasing in fast developing countries, and global population numbers are rising fast [1]. Even with all the investments made in good transport accessibilities in developed countries, the problems of the past still arise such as congestion, pollution and road accidents.

Over recent years the Portuguese passenger and goods transportation sector has grown substantially above the GDP rate. The length of motorways increased on average 8.5% annually from 1996 to 2010, which compares to an average annual GDP growth of 1.3% [2]. Portuguese society perceives that such growth is fuelled by a larger demand for road traffic compared to pre-EU Portugal.

There are several reasons behind this evolution. Some are on the transport supply side while others are on the demand side. With regard to the former, one should mention the improved accessibility in terms of the following factors: mode, quality, time, real cost, perceived cost, utility cost, safety risk. As for demand, socioeconomic factors have had a major role: population, employment, GDP, income, fuel price, number of households.

The main objective of this dissertation is to find out the main determinants of road traffic in Portugal. Although there is some evidence about which factors are more relevant for road demand, their quantification lacks research. One of the barriers to this task is the lack of a single database on Portuguese national road traffic, and the available data does not have a unified format, statistical confidence level and time horizon.

A good proxy to characterise the demand for road traffic is statistical data concerning car fuel sales. This has already been used [3] in other literature. This data source is available for a broad time horizon and is disaggregated at municipality level. It is also easily compatible with socioeconomic statistics published by official entities.

For careful planning and implementation of a national road transport strategy, it is important to know exactly where the country's needs are more focused. Brisa is the largest supplier of motorway construction and operation in Portugal, and therefore the company needs to understand the market for passenger and goods road transportation.

The goal of this dissertation is to create a model that is able to explain the Portuguese road traffic at both national and disaggregated level, by discovering the key determinants for road traffic in Portugal and by giving the real weight to the variables that explain the demand of the Portuguese society.

This article will begin by introducing the company of interest in this study, Brisa – Auto-Estradas de Portugal, S.A., followed by a review of the literature regarding road transportation. Afterwards, a research methodology and data usage description shall be made, followed by model results and results discussion.

2. Brisa – Auto-Estradas de Portugal, S.A.

Brisa – Auto-Estradas de Portugal, S.A. is a Portuguese based transportation company whose focus is on motorway management. It was founded in 1972 with the purpose of constructing, maintaining and operating a series of motorways with a toll system. The company has grown into one of the largest motorway operators in the world and the largest one in Portugal, operating a total of 1100 km which connects the country from North to South, East to West. Brisa has a market capitalisation of approximately 3000 million Euros. Its shares are listed on the Euronext Lisbon and the company is included in the Lisbon stock market's most important index, the PSI-20. It is also part of Euronext 100 and the FTSE4Good, the reference index for social responsibility. Its main business area is the construction and operation of tolled motorways. The main focus lies in Portugal, even though the company has a share in some international subsidiaries in Holland and the United States of America. Other businesses Brisa is involved in include providing services associated with road safety and driving comfort, both in urban environments and on motorways. Their *Via Verde* product, a motorway electronic toll payment system that can also be used to pay for car fuel, car parks and some other services, is an example of the innovation culture inside the company.

3. Road Transport Policies

Due to the challenges that the road transport topic creates in developed and developing economies, it is important to review what has been done in the past in order to address the negative and positive externalities associated with road traffic.

'An efficient equilibrium is defined as a situation in which marginal social costs are equal to marginal social benefits' [4]. How to allocate resources in an efficient way, so that the extra burden brought to society is always matched with extra social benefits, is the focus of road transport policies.

Due to the importance of the transportation sector in every society, there are many studies available which address several topics, namely: statistical studies of road accidents, reviews of economic policies and their effects on mitigating the negative externalities associated with transport, studies on fuel demand modelling and estimation, the concept of induced road traffic, elasticity of demand for travel, the effect of income on car and vehicle ownership, just to quote a few of those available.

3.1 Negative Externalities of Road Transport

There is scientific consensus into which are the most important negative externalities concerning road traffic. Accidents, road damage, environmental damage, congestion and oil dependence are the major negative effects brought to society by road transport.

The accident externality exists 'whenever extra vehicles on the road increase the probability that other road-users will be involved in an accident' [5].

Externalities concerning road damage include the costs of repairing the damage caused by road use. Different types of vehicles damage roads in different proportions. The damage caused by a vehicle increases with the fourth power of the axle load, meaning that the most damage is done by heavy load vehicles, [5].

Environmental damage produced in society due to road transportation has several dimensions. These impacts can come from emission, noise and vibration, changes to landscape and townscape or the effects on biodiversity, heritage of historic resources and water [6]. Noise negatively affects human health in psychical, psychological and physiological ways. Road transport based noise affects one third of Europe's population [7]. Nitrogen oxides (NO_x) include nitrogen dioxide and nitric oxide. It contributes to the formation of atmospheric ozone, which increases respiratory diseases, and irritation of the eyes, nose and throat. Hydrocarbons (HC) are created by the incomplete combustion of fossil fuels, causing eye and throat irritation and couching [8]. Carbon monoxide (CO) interferes with human absorption of oxygen. It can also affect the central nervous and cardiovascular systems [9]. Combined with other pollutants, these effects can be exacerbated [8]. Sulphur dioxide (SO_2) affects the lining of the nose, throat and airways of the lung, especially for those who suffer from asthma and chronic lung disease [9]. It can cause bronchitis, and also has the undesirable effect of contributing to acid rain [8]. Particulate Matter (PM) is a generic term used to refer to a complex group of air pollutants that are varied in size and composition. The two main groups concerning health hazard effects are PM_{10} and $PM_{2.5}$. These particles are linked with several adverse health effects on human population, varying from increased admissions in hospitals, emergency hospital visits, respiratory symptoms, exacerbation of chronic respiratory and cardiovascular diseases, decreased lung function and premature mortality [10]. Carbon dioxide (CO_2) is the main pollutant at a global level. It is the anthropogenic greenhouse gas that most contributes to the global warming effect.

With regard to congestion, the isomorphism between travel time on a given length of motorway is a bivariate function of traffic flow and average cost [11]. This enables an adequate conversion to be made from time to cost, which combined with a demand curve, allows an economic analysis from the whole picture possible.

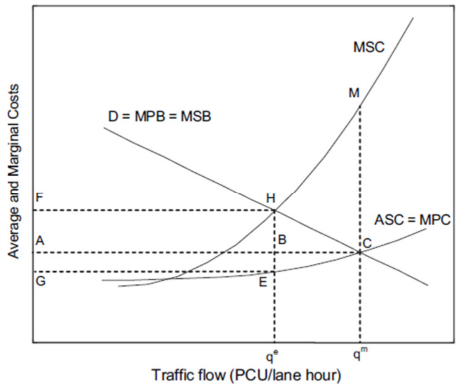

Figure 1 – Economics of Congestion – extracted from [4]

In Figure 1, road users are assumed to behave the same way, except for marginal willingness to pay for a trip, given by the inverse demand curve D, which represents marginal private and social benefits. Marginal private benefits (MPB) and Marginal social benefits (MSB) are assumed to be identical. H represents the equilibrium point, where marginal social costs (MSC) equal MSB. However, the market equilibrium is located at C, where the Average social cost (ASC) is equal to MSB. At point C, drivers are paying their ASC, not for their MSC. This creates a Marginal congestion cost (MCC), measurable by the segment MC. The deadweight loss created can be measured by the area HMC.

Oil dependence is a negative externality applicable only for oil importing countries. It is present in the effects of oil price volatility and oil price shocks. Forty-two percent of world's oil is produced by OPEC countries, and 68 percent of OPEC oil comes from Iran, Iraq, Kuwait, Saudi Arabia and United Arab Emirates [12]. OPEC, alongside Venezuela, Mexico and Norway, are willing to produce well below their capacity in order to control market prices [13].

3.2 Corrective Instruments

The application of corrective instruments and complementary policies can lean the market towards efficient equilibrium. The measures applied in road transport are Pigouvian taxes, cap-and-trade systems, land use and transport planning, incentives to use public transport and information campaigns. Furthermore, the introduction of a new technology can also shift the market equilibrium.

Applying economic policies that act as corrective instruments with the purpose of levelling marginal social costs with marginal social benefits is the proper way in theory to tackle negative externalities associated with road transport. However, it is impossible to fully do so [14].

Corrective economic measures that tackle the negative externalities of road transport are categorized into two groups: command-and-control (CAC) and incentive based (IB) [4]. IB mechanisms can be further categorised as price controls or quantity controls.

A CAC policy is a regulation that needs to be enforced by the ruling authority. Whenever an externality arises, the regulator can limit the maximum level of the activity that causes the externality, or restrain the behaviour of economic agents.

IB policies provide economic incentives to the targeted audiences, acting directly on altering private utility or benefit from a given behavioural response, making them the best instruments when the desired output is a behavioural change. These policies put a price on a good or activity, such as emissions or congestion. These can take the form of taxes or subsidies, with the ultimate purpose of reducing externalities.

Quality control IB policies usually take the form of cap-and-trade systems. A cap-and-trade system, also referred as emissions trading system, is a system based on a free market approach that attempts to control and reduce the emission of polluting substances by means of economic clean-up incentives for polluting industries [15] [16]. There are two main possible initial allocation methods: grandfathering and auctioning. In grandfathering, permits are freely allocated to each polluter, according to their emission history. In auctioning, polluters pay for the permits they wish to buy, according to the price that emerges for the auction.

While grandfathering allocates emission permits through historic data of the auctioneers, in auctioning a polluting quantity limit is imposed to the market, whereby the determinant factor for allocation is the price.

Permits, as a measure to correct externalities, always impose an extra cost on the market, raising the prices of the goods and services affected by the scheme. These costs are usually ultimately passed on to the consumers [17] [18]. Even so, the market prices of permits remain independent from the allocation method.

Grandfathering allows companies to have windfall profits, as they do not pay for the permits in a short-term period. This brings equity and implementation issues. It acts as a barrier to new entrants, because older companies did not have to pay for permits when the grandfathering was implemented [19]. Auctioning has the potential to create distributional effects, giving governments money from fuel producers that can be used in projects such as infrastructure, public transport and R&D on cleaner technologies, which can also help in correcting market externalities, because by getting the market to bid for permits, auctioning creates revenues for governments [20].

When discussing the permits allocation for the road transport sector, it is important to define whom the permits should be sold to.

If fuel producers are the target group, they should hold as many permits as needed to cover the amount of fuel they sell [9]. The administrative costs of this option would be low. However, fuel producers have few tools to reduce emissions. For that reason, it would be best to implement an additional tax on fuel instead of creating a *cap-and-trade* system, as a tax is more adjustable, less volatile and requires less monitoring [21]. An emission trading scheme that targets vehicle manufacturers is also a viable option [22] [23]. Another option would be a downstream trading scheme. Downstream trading refers to the inclusion of individual motorists in the cap-and-trade scheme. This inclusion can occur in different formats [21] [24], Even though it might be the most effective way in the polluting emissions value chain for a permit policy, is also the most difficult to implement. A large number of consumers would result in a large and liquid market for permits [19].

Even though command-and-control policies are not efficient from an economic point of view, they are widely used to regulate environmental and other types of externalities. They include fuel standards, vehicle standards, restrictions on vehicle circulation and parking restrictions.

Fuel standards are imposed by governments on the chemical constitution of motor-vehicle fuels [4]. One example is the ban on lead in petrol, which has been implemented virtually all over the world.

Vehicle standards regulate vehicle safety, tailpipe emissions and fuel efficiency. Safety standards refer to front and side impact tests that vehicles have to pass before they enter the market, compulsory fitting of head restraints and seat-belts, minimum depth of tire treads, brakes and annual safety checks [25]. Concerning tailpipe emissions, a widely known standard is the introduction and obligation of installing catalytic converters in vehicles. Vehicle emission standards are regulations imposed on car manufacturers by most of the developed countries [26].

Many historical towns in Europe have areas of restricted vehicle circulation in order to create a better environment for shoppers in the area. Such a scheme in Oxford, United Kingdom resulted in a reduction of 17 percent in the number of car trips to the centre, whilst not affecting the overall number of visitors to the city centre [27].

Parking restrictions inside city centres can reduce traffic levels indirectly, increasing the demand for public transport and reducing traffic externalities. Parking as an activity entails costs, as the land used for parking could be used for something else [28].

3.3 Taxes and subsidies in the road transport sector

There are two types of taxes: distortive and corrective taxes. They both act on society's behaviour by increasing the marginal cost of the targeted activities. The difference between them resides in the fact that distortive taxes are introduced in an otherwise efficient economy. They distort the market, by 'inserting a wedge between marginal cost and price' [20]. Corrective ones, on the other hand, are introduced in an otherwise inefficient economy, to try to make the market more efficient by changing behaviours.

Since there are several types of externalities, it is inefficient to use only one tax to internalise all the undesired outcomes of road transport. Fuel taxes are imperfect instruments to internalise all transport externalities simultaneously [29].

The literature on transport economics is critical of ownership taxes, defining them as blunt and indirect tools to address transport externalities. Nevertheless, it is also conceded that they are policy instruments that are easier to implement and which also possess higher political approval ratings [30].

Many countries tax vehicle possession and ownership. These types of taxes are a direct way to address CO_2 emissions linked to the manufacturing and disposal of vehicles. However, such emissions account for a small percentage only of the vehicle's total life emissions, which are not tackled by purchase and ownership taxes [31].

The primary impacts associated with these taxes are a reduction of vehicles in circulation and a longer car ownership [32].

For purchase taxes, it is possible to differentiate them into fuel consumption per mile, type of fuel, horsepower, engine size, weight and retail price. Model year, mileage and the presence of fuel injection are the most significant factors that contribute to emission of HC, NO_x and CO [33].

For ownership taxes, the vehicle's age is also an important factor.

Every European country levies a value added tax (VAT) on the purchase of new motor vehicles, given that vehicles are a good just like any other. VAT rates vary from 15 to 25 percent, depending on the country. Many countries also levy a registration tax [34]. Ownership taxes are levied in most countries, usually on private and commercial vehicles, with different criteria, that can include cylinder capacity, fuel efficiency, vehicle age, gross weight, CO_2 and other types of emission, in the case of private vehicles.

Subsidies are a relevant economic instrument used to shift consumer trends towards buying more fuel-efficient vehicles. Even though they do have an impact on changing customer behaviour, in a sense that subsidies sway consumers away from the second-hand market to acquire newly manufactured vehicles, they can also lead to an increase in vehicle ownership, offsetting its beneficial effect.

A Feebate, by being a self-financing system of fees and rebates, has the potential ability to shift the demand and supply of vehicles. They alter the purchase price of vehicles while at the same time encourage manufacturers to manufacture vehicles that have lower emission standards, in order to best exploit the feebate system in place. They should be considered long-term measures [35].

A disposal scheme offers an incentive to everyone who is willing to dispose of their old vehicle. Several developed countries have such schemes [4].

Usage taxes are levied on the vehicle user in line with its use, hence, if the vehicle is not used, such taxes are not issued. In this category we include fuel taxes, tolls, congestion charges and parking charges [4].

Emission taxes are the best instrument to correct emission externalities and induce behavioural change towards optimality of vehicle purchase and usage choice [25] [33]. However, direct charging every single vehicle is not a feasible option due to the lack of cost effectiveness and the impracticability of monitoring techniques [36] [37] [38].

A type of emission tax that would be almost ideal would be a carbon tax, since there are other gases that contribute to global warming besides CO_2 [39]. It has the potential to create dynamically efficient choices of 'ever cleaner technology and energy conservation' [40].

In spite of its effectiveness, political opposition is an obstacle to a broader imposition of such an economic instrument [41] [42].

Fuel taxes are applied in every country in the world, as they are a low cost and effective revenue generating instrument for governments. Even though politicians defend fuel taxes on an environmental basis [43], they have a potential role as instruments for emission reduction.

3.4 Fuel Demand Determinants

Literature points out that fuel prices, income and GDP are key determinants of fuel demand for aggregated data. Other factors include the stage of economic development, state of technology, degree of urbanisation and commuting trips. An interesting approach towards the key determinants of road traffic demand has been found [44] that models generalised cost of driving a vehicle kilometre as follows:

$$\boldsymbol{g} = \frac{\boldsymbol{p}}{\boldsymbol{s}} + \boldsymbol{k} \qquad (1)$$

Where *g* is the generalised cost of driving a vehicle kilometre, *p* is the price of fuel per litre, *s* is the number of kilometres that can be driven per litre of fuel and *k* is a non-fuel component of generalised cost.

$$s = f(p, t, Y, v),\ k = f(Y, v) \qquad (2)$$

Where *t* represents vehicle technology, *Y* represents the income of the population and *v* is the typical vehicle speed reached. From this modelling of road traffic demand, we can conclude that there are several components in road traffic demand that need to be included in our study in order for it to reflect the reality of road traffic demand in Portugal.

3.5 Fuel Price Elasticity

A plethora of studies on price elasticities have been reviewed in order to conclude that price elasticity towards fuel varies from 0.00 to -1.81, depending on the estimation technique and the data used [45]. The above mentioned model authors have observed an average long run fuel price demand elasticity of -0.77, whilst for a short run scenario that value decreases to -0.25.

4. Research Methodology and Data

4.1 Model and Data

The multiple linear regression model is now presented [46] [47], since it shall be our model methodology.

$$\boldsymbol{y} = \boldsymbol{\beta_0} + \boldsymbol{\beta_1 x_1} + \boldsymbol{\beta_2 x_2}\ \boldsymbol{\beta_3 x_3} + \cdots + \boldsymbol{\beta_k x_k} + \boldsymbol{u} \qquad (3)$$

β_0 is the intercept; β_k is the parameter associated with explanatory variable x_k for any given value of *k* and variable *u* is the error term. The model started by declaring dependent variable *y* as the amount of car fuel sold per municipality. This data was classified into type of fuel sold, municipality of purchase and time (years 1995 to 2009). Afterwards, collected data was analysed in order to find out if it qualified to become independent variable. Data assumption tests were performed through statistical software stepwise algorithm [47] [48]. A logarithmic scale was used in our multiple linear regression models in order to unlink data with original measurement scales [46]. This logarithmic scale was also useful when attempting to obtain elasticities of fuel consumption towards our modelled independent variables. The independent variable coefficient has a percentage interpretation when multiplied by 100.

4.2 Data Organization

Data sets were organized by region, time and variables. In order to study the correlations between variables throughout the years, according to a certain region, a model was created for every region to be later imported to our choice of multivariate statistics software. Each region is classified in accordance with NUTS naming. Model time span is from year 1995 up to year 2009. Variable choice was GDP, GVA, Inhabitants, Compensation of Employees, Employment, Weighted Fuel Price, Loan Interest Rates and Deposit Interest Rates.

5. Model Results

In Table 1 model results can be observed. 32 NUTS I, II and III regions were modelled to obtain the key determinants of road traffic for each region.

Table 1 – Explanatory Variables of Road Traffic in Portugal

Region	Adjusted R Square	Method	Variables	Coefficients
Continente	0,813	Enter	Weighted Fuel Price	-0,383
			Per Capita GDP	0,839
Norte	0,769	Enter	Per Capita GDP	0,994
			Weighted Fuel Price	-0,355
Minho-Lima	0,795	Stepwise	Per Capita Employment	1,979
			Weighted Fuel Price	-0,314
Cávado	0,795	Stepwise	Per Capita GDP	0,897
Ave	0,852	Stepwise	Per Capita GVA	0,503
			Per Capita Employment	1,113
Grande Porto	0,745	Stepwise	Loans	-0,05
Tâmega	0,724	Stepwise	Loans	-0,056
Entre Douro e Vouga	0,351	Stepwise	Deposits	-0,036
Douro	0,531	Stepwise	Deposits	-0,048
Alto Trás-os-Montes	0,349	Enter	Weighted Fuel Price	-0,487
			Per Capita Employment	2,697
Centro	0,549	Stepwise	Inhabitants	6,298
Centro	0,547	Stepwise	Per Capita GDP	0,552
Baixo Vouga	0,726	Stepwise	Loans	-0,032
			Per Capita Employment	-2,45
Baixo Mondego	0,611	Stepwise	Per Capita GDP	0,38
Pinhal Litoral	0,815	Stepwise	Per Capita Employment	4,036
			Weighted Fuel Price	0,279
Pinhal Interior Norte	0,701	Stepwise	Weighted Fuel Price	-0,796
Dão-Lafões	0,497	Stepwise	Per Capita Employment	1,581
Pinhal Interior Sul	0,223	Stepwise	Per Capita Employment	2,582
Serra da Estrela	0,51	Stepwise	Weighted Fuel Price	-0,363
Beira Interior Norte	0.730	Enter	Per Capita Employment	5,441
			Weighted Fuel Price	-1,098
Beira Interior Sul	0,264	Stepwise	Loans	-0,026
Cova da Beira	1	Stepwise with no constant	Per Capita GDP	1,91
			Weighted Fuel Price	-1,502
			Deposits	0,048
Oeste	0,346	Stepwise	Per Capita GDP	1,162
Médio Tejo	0,916	Stepwise	Loans	-0,106
			Per Capita Employment	-3,927
Lisboa	0.383	Stepwise	Deposits	-0,043
			Per Capita GVA	2,184
Grande Lisboa	1	Stepwise with no constant	Per Capita GVA	1,882
			Weighted Fuel Price	-1,337
			Per Capita Employment	-4,43
Península de Setúbal	0,917	Stepwise	Per Capita Compensations	0,783
Alentejo	0,402	Enter	Weighted Fuel Price	-0,18
			Per Capita GVA	0,339
Alentejo Litoral	1	Stepwise with no constant	Per Capita GVA	1,92
			Weighted Fuel Price	-1,694
Baixo Alentejo	1	Stepwise with no constant	Per Capita GDP	1,934
			Weighted Fuel Price	-1,712
Lezíria do Tejo	0,605	Stepwise	Per Capita Employment	3,924
Algarve	0,941	Stepwise	Per Capita GVA	0,93
			Weighted Fuel Price	-0,363

6. Conclusions

A review of scientific literature concerning road economics, econometrics, multivariate statistics and transport policies was conducted in order to form the basis of a multivariate statistics model concerning road traffic in Portugal. By reviewing scientific literature concerning fuel demand, an insight was achieved concerning determinants of fuel demand and its price elasticity. Income, GDP and fuel prices are key determinants for fuel demand. Several different elasticity values were obtained by different authors concerning fuel consumption demand towards fuel prices, and the trend is to assume that this relationship is inelastic. Consumers take fuel in consideration as an essential good in their lives.

A multiple regression model with logarithmic scales was used. Whenever possible, per capita values were also used to give variables a stronger explanatory power and to make up for discrepancies between different regions in geography, demographics and economics. A stepwise algorithm was firstly tested. We have obtained 32 models for 31 regions (NUTS II Centro Region had to have a second model), with 22 stepwise algorithms, 5 stepwise with no constant and 5 manual variable selection models. Weighted fuel price is the most significant and explanatory variable for road traffic in Portugal, being present in the models 15 times, followed by per capita employment with 11 times, a tie between per capita gross domestic product and per capita gross value added, since they both have been selected 8 times each.

Bank loan interest rates, has been selected 5 times, being followed by bank deposit interest rates with 3 selections, while variable inhabitants was selected once only.

Average adjusted R square model value is 0.68. This shows an average fitness of model of 68%, that is, the model explains 68% of total independent variables variance. It must be noted, though, that this average counts with 5 stepwise with no constant methods (in such method adjusted R square is assumed to be automatically equal to 1). This value shows an acceptable explanatory power of the models. However, it should be noted that 16 models have only one explanatory variable, 14 have two and only two have 3 significant explanatory variables of road traffic. Due to some data similarity, such as the case for gross domestic product with gross value added, multicolinearity situations have risen, invalidating one variable over the other. A more heterogeneous choice of variables, if feasible, would have been preferable.

Via analysing the coefficients of these explanatory variables of road traffic in Portugal it is possible, applying elasticity analysis, to realize how the nation's fuel demand is going to respond in terms of variable shifts.

By calculating the average of these coefficients, we notice that in average, fuel consumption demand is inelastic towards weighted fuel price (-0.769) and compensation of employees (0.783), while it has an elastic behaviour for per capita gross domestic product (1.08), per capita employment (1.141), per capita GVA (1.293) and Inhabitants (6.298). A 1 percentage point increase in bank loan interest rate will lead to a decrease of fuel consumption of 3.5%, while the same 1 percentage point increase in bank deposit interest rate will lead to a decrease of 4.4% in fuel consumption.

We have found results for fuel demand elasticity towards fuel price (-0.769) similar to those found in research literature.

6. References

[1] Ortúzar, Juan de Dios; Willumsen, Luis G. (2011). Modelling Transport, 4th ed., Wiley

[2] Eurostat. Length of motorways. (http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database)

[3] Fridstørm, L., Ifver, J., Ingebrigtsen, S., Kulmala, R., Thomsen, L. K., (1995). Measuring the Contribution of Randomness, Exposure, Weather, and Daylight to the Variation in Road Accident Counts. *Accid. Anal. And Prev.* 27 (1), 1-20. Elsevier Science Ltd.

[4] Santos et al. (2010). Part I: Externalities and economic policies in road transport. *Research in Transportation Economics* 28

[5] Newbery, D.M. (1990). Pricing and Congestion: Economic Principles Relevant to Pricing Roads. *Oxford Review of Economic Policy* 6 (2), 22-38

[6] UK DfT (2004). Transport Analysis Guidance (TAG) – The Environment Objective, TAG Unit 3.3.1 London: Department for Transport
[7] WHO (2007). Noise and Health. World Health Organization, Regional Office for Europe
[8] Bannister, D. (1998). *Transport Policy and the Environment*. London: Spon.
[9] UK DfT (2007). Road Transport and the EU Emissions Trading Scheme. Department for Transport
[10] Bell, M., Samet, J., and Dominici, F. (2003). Time-series Studies of Particulate Matter. *Johns Hopkins University*, Department of Biostatistics
[11] Walter, A. (1961). The Theory and Measurement of Private and Social Costs of Highway Congestion. *Econometrica* 29(4), 676-699
[12] Parry, I.W.H., and Darmstadter, J. (2003). The Costs of U.S. Oil Dependency. Discussion Paper 03-59. Washington DC: Resources for the Future
[13] Kaufmann, R., Bradford, A., Belanger, L., McLaughlin, J., and Miki, Y. (2008). Determinants of OPEC Production: Implications for OPEC Behaviour. *Energy Economics* 30(2), 333-351
[14] Verhoef, E.T. (2000). The Implementation of Marginal External Cost Pricing in Road Transport: Long Run vs. Short Run and First-best vs. Second-best. *Papers in Regional Science* 79(3), 307-332
[15] Dales, J. (1968). Pollution, Property and Prices. Toronto: University of Toronto Press
[16] Coase, R. (1960). The Problem of Social Cost. *Journal of Law and Economics* 3(1), 1-44
[17] Beamon, J.A., Leckey, T., and Martin, L. (2001). Power Plant Emission Reductions Using a Generation Performance Standard. *Energy Information Administration*
[18] Burtraw, D., Palmer, K., Bharvirkar, T., and Paul, A. (2001). The Effect of Allowance Allocation on the Cost of Carbon Emission Trading. Discussion Paper 01-30. *Resources for the Future*
[19] Watters, H., and Tight, M. (2007). Designing an Emissions Trading Scheme Suitable for Surface Transport. February – Institute for Transport Studies, University of Leeds
[20] Cramton, P., and Kerr, S. (1999). The Distributional Effects of Carbon Regulation. In T. Sterner (Ed.), *The Market and the Environment* (pp. 255-271). Cheltenham, UK: Edward Elgar
[21] Millard-Ball, A. (2008). Municipal Mobility Manager: a New Transportation Funding Stream for Carbon Trading? *Transportation Research Record*, 2079, 53-61
[22] UK DfT (2007). Transport Statistics Great Britain 2007 Edition. London: TSO: Department for Transport
[23] Millard-Ball, A. (2009). Cap-and-trade: Five Implications for Transportation Planners. Paper No. 09-2077 Washington DC: Transportation Research Board 88th Annual Meeting
[24] Raux, C., and Marlot, G. (2005). A System of Tradable CO2 Permits Applied to Fuel Consumption by Motorists. *Transport Policy* 12(3), 255-265
[25] Acutt, M., and Dodgson, J. (1997). Controlling the Environmental Impacts of Transport: Matching Instruments to Objectives. *Transportation Research Part D: Transport and Environment* 2(1), 17-33
[26] Clerides, S., and Zachariadis, T. (2008). The Effect of Standards and Fuel Prices on Automobile Fuel Economy: an International Analysis. *En. Economics* 30 (5), 2657-2672
[27] Parkhurst, G. (2003). Regulating Cars and Buses in the Cities: The case of Pedestrianisation in Oxford. *Economic Affairs* 23(2), 16-21
[28] Verhoef, E.T., Nijkamp, P., and Rietveld, P. (1995). The Economics of Regulatory Parking Policies: The (Im)Possibilities of Parking Policies in Parking Regulation. *Transportation Research Part A: Policy and Practice* 29(2), 141-156
[29] Proost, S., Delhaye, E., Nijs, E., and Van Regemorter, D. (2009). Will a Radical Transport Pricing Reform Jeopardize the Ambitious EU Climate Change Objectives? *Energy Policy* 37(10), 3863-3871
[30] Barter, P. (2005). A Vehicle Quota Integrated With Road Usage Pricing: a Mechanism to Complete the

Phase-out of High Fixed Vehicle Taxes in Singapore. *Transport Polic* 12(6), 525-536

[31] Hayashi, Y., Kato, H., and Teodoro, R.V.R. (2001). A Model System for the Assessment of the Effects of Car and Fuel Green Taxes on CO2 Emissions. *Transportation Research Part D: Transport and Environment* 6(2), 123-139

[32] Chia, N. G., Tsui, A., and Whalley, J. (2001). Ownership and Use Taxes as Congestion Correcting Instruments. Working Paper 8278 *NBER Working Paper Series*. National Bureau of Economic Analysis

[33] Johnstone, N., and Karousakis, K. (1999). Economic Incentives to Reduce Pollution From Road Transport: the Case for Vehicle Characteristics Taxes. *Transport Policy* 6(2), 99-108

[34] European Automobile Manufacturers' Association (2009). ACEA Tax Guide 2009

[35] Ben Dor, T., and Ford, A. (2006). Stimulating a Combination of Feebates and Scrappage Incentives to Reduce Automobile Emissions. *Energy* 31 (8-9), 1197-1214

[36] Fullerton, D., and Gan, L. (2005). Cost-effective Policies to Reduce Vehicle Emissions. *American Economic Review* 95(2), 300-304

[37] Fullerton, D., and West, S. (2002). Can Taxes on Cars and on Gasoline Mimic an Unavailable Tax on Emissions? *Journal of Environmental Economics and Management* 43(1), 135-157

[38] Plaut, P. (1998). The Comparison and Ranking of Policies for Abating Mobile-source Emissions. Transportation and Research Part D: Transport and Environment 3(4), 193-205

[39] Harrington, W., and McConnell, V. (2003). Motor Vehicles and the Environment. Report. Washington DC: Resources for the Future

40] Pearce, D. (1991). The Role of Carbon Taxes in Adjusting to Global Warming. *The Economic Journal* 101(407), 938-948

[41] Vehmas, J., Kaivo-Oja, J., Luukkanen, J., and Malaska, P. (1999). Environmental Taxes on Fuels and Electricity – some Experiences from the Nordic Countries. *Energy Policy* 26(6), 343-355

[42] Richardson, B. (2002). Environmental Regulation Through Financial Organisations: Comparative Perspectives on the Industrialised Nations. The Hague, London: Kluwer Law

[43] Newbery, D.M. (2005a). Why Tax Energy? Towards a Moderation Policy. *Energy Journal*, 26(3), 1-39

[44] Graham, D.J., and Glaister, S. (2005). Decomposing the Determinants of Road Traffic Demand. *Applied Economics*, 37(1), 19-28

[45] Goodwin, P., Dargay, J., Hanly, M., (2004). Elasticities of Road Traffic and Fuel Consumption With Respect to Price and Income: a Review. *Transport Reviews* 24(3), 275-292

[46] Wooldridge, J. M. (2009). Introductory Econometrics, 4th ed., South-Western CENGAGE Learning

[47] Pyndick, R. and Rubinfeld, D. (1981). Econometric Models and Economic Forecasts, McGraw-Hill.

[48] Corrar, L. J., Paulo, E., Filho, J. M. D., Rodrigues, A., Coelho, A.C., de Almeida, F.C., Bezerra, F.A., da Cunha, J. V. A., Antunes, J., Diniz, J.A., dos Santos, J., Pohlmann, M. C., Mário, P. d. C., Herdeiro, R. F. C., Nakao, S. H (2009). Análise Multivariada para os Cursos de Administração, Ciências Contábeis e Economia, Fundação Instituto de Pesquisas Contábeis, Atuariais e Financeiras. Editora Atlas