EL COLEGIO DE MÉXICO, A.C.

CENTRO DE ESTUDIOS ECONÓMICOS

"FROM THE FISCAL EVASION PROBLEM TO ENVIRONMENTAL MATTERS: SOME APPLICATIONS OF MICROECONOMIC TECHNIQUES"

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PARA OPTAR POR EL GRADO DE

DOCTOR EN ECONOMÍA

PROMOCIÓN 2004-2007

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México D.F. Agosto de 2011

EL COLEGIO DE MÉXICO

CENTRO DE ESTUDIOS ECONÓMICOS

Constancia de aprobación

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Tesis: *From the Fiscal Evasion Problem to Environmental Matters: Some Applications of Microeconomic Techniques.*

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México, D.F., 26 de agosto de 2011

A mi familia

Acknowledgments

I wish to thank:

My family, whose unconditional support and love lightened my whole educational process.

Dr. Jaime Sempere, who kindly and wisely guided me whenever I needed it, and drove me through valuable challenges.

Dr. Alejandro Castañeda and Dr. Edwin van Gameren who revised my thesis and whose useful comments substantially enriched my work.

Dr. Alejandro Guevara who has been a ‘teacher’ and a true friend.

All my teachers of *El Colegio de México* who embedded on me the high value of education.

Antonio Arellano and Carlos García for being my best friends.

Prologue

This document presents three papers, which are the result of my work done in order to obtain the Ph.D. degree on Economics by El Colegio de México. Even though, the three papers center on different topics, they all coincide in using microeconomic fundaments to analyze diverse issues. It is worth noting that this area of study of Economics have motivated all my research since the beginning of my academic life.

Economics have been proven useful to analyze a wide set of social issues. From the fiscal evasion problem to environmental matters, Economics tools represent an effective analytical framework to help policy makers in their work. Moreover, Economics is flexible enough to analyze problems from both theoretical and practical perspectives. For this, the work presented here pretends to take advantage of the knowledge I acquired in the process of my academic formation at the time of analyzing topics that have attracted me since the beginning, as the theory of games, microeconomic theory, econometrics and environmental economics.

The first paper analyzes the strategic interaction between taxpayers and the fiscal authority regarding to fiscal evasion. The existence and (local) uniqueness of Nash equilibrium are demonstrated by the best responses of players. Through a numerical analysis, it is concluded that "greater sanctions, the establishment of fiscal discipline, the improvement of monitoring processes, and less corruption, reduce fiscal evasion". Finally, it is established that, if sufficiently deep, progressivity in the tax system has a beneficial impact in collection, and - economic growth provokes both, a reduction in evasion and the improvement of social welfare.

The second and third papers take an environmental economics approach to analyze, by means of econometric modeling, two important environmental issues. First, I present an empirical estimation of the determinants of transport decisions. In particular, mode choice is analyzed. A discrete choice model is specified. One of the major tasks was to analyze a wide set of information related to people's attitudes towards environmental issues. This kind of information is scarce and consequently research has so far only led to minor conclusions in this area. In addition, several studies have analyzed this issue from a national perspective, which limits the applicability of their results. It is not the case here since I was able to use uniform data for ten countries and, consequently, results can be compared to distinguish certain country-specific effects that arise from unobservable characteristics.

The last paper analyzes fuel choice of households in the Metropolitan Zone of Mexico City. In this context, a survey was carried on in 498 households to obtain information about their consumption patterns, attitudes to environment, vehicles, and socio-demographic characteristics. With the collected information a conditional logit model was specified to analyze the determinants of fuel choices. I find that fuel choice is a somewhat technical decision that implies transaction costs which some people are not willing to pay and prefer to take the decision on the limited information they have, or to take advice on costless (or cheap) sources of information as the car manual or car agency recommendations. I also find that income can affect fuel choice, making people more likely to consume Premium gasoline as it increases, yet this effect may be outweighed if the mean age of the fleet is too high

The final objective of all three papers is to formulate policy recommendations. I consider this as an essential objective since abstract formulations, which are distinctive of economic models, are helpful as long as they can be finally translated into a sensible and comprehensible way to solve a specific social issue.

Contents

Tables and figures index

Chapter 1. The Government vs. taxpayer: the fiscal evasion game[1]

Abstract: The present paper incorporates the strategic interactions between taxpayers and fiscal authorities to the standard theory of fiscal evasion. The existence and (local) uniqueness of Nash equilibrium are demonstrated by the best responses of players. Through a numerical analysis, it is concluded that "greater sanctions, the establishment of fiscal discipline, the improvement of monitoring processes, and less corruption, reduce fiscal evasion". Finally, it is established that, if sufficiently deep, progressivity in the tax system has a beneficial impact in collection, and - economic growth provokes both, a reduction in evasion and the improvement of social welfare.

[1] A previous version of this paper was published in *Estudios Económicos*, 22(2):313-334.

1.1 Introduction

Fiscal evasion limits governments' capacity to obtain the necessary resources to fulfill their main tasks. The explanations that economic theory offers to this phenomenon lie mainly in the work of Allingham and Sandmo (1972): *Income tax evasion: a theoretical analysis*. Basically, the Allingham-Sandmo model establishes that - consumers are rational and by taking an optimal decision, will set apart a portion of their income (before taxes) that they will not declare to the fiscal administrator. The authors' main results focus on studying the effect of sanctions, the changes in tax rates and the relative aversion to risk of the taxpayers in fiscal evasion.

Under a game theory approach, Luis Corchón (1992) studies evasion using an inspection model, where the players are: one representative taxpayer and the fiscal administrator. The strategies of each player may be: evading or not evading and inspecting or not inspecting. Different concepts of solution are used in this paper and it is found that the probability of monitoring of equilibrium is the same in all of them, and that sanctions are an incentive for decreasing evasion.

On the other hand, Greenberg (1984) focuses on obtaining the best response from the fiscal administrator, with the purpose of minimizing the number of taxpayers that do not meet their fiscal obligations, for a given budget restriction and a scheme of taxes and sanctions.

Finally, through a model of game theory, Feinstein (1991) indicates that an evasion model which includes individuals that are inherently honest is more coherent with what is observed empirically. It is worth mentioning that in practice we may observe that taxpayers pay more than what would be optimal, according to the Allingham-Sandmo model.

This paper intends to extend the Allingham- Sandmo model[2] by incorporating some elements of the game theory. This approach permits considering fiscal evasion as a supply-and-demand phenomenon, assuming that the first represents the level of evasion that the fiscal administrator (the government) is willing to bear for a given level of resources that are allocated (by himself) to detect evasion, and the latter represents the level of evasion that the taxpayer decides to have taking into account the level of resources allocated by the government to detect evasion.

[2] The note made by Yitzhaki (1974) to this model is well known; however, here we part from the original model because, first, it permits us isolating the effect of sanctions in - evasion, and second, the results vary quantitatively but not qualitatively.

As it will be further observed, this way of modeling fiscal evasion will facilitate the analysis: it will be possible to know its principal determinants, analyze the effect that it has on policy shocks, understand the ways in which the fiscal administrator reacts and observe some effects in the welfare of players.

Until now, the standard theory about fiscal evasion has focused, from the theoretical point of view, on the taxpayer, but has not included the possible strategic behavior of fiscal authorities. It is important to know the responses of the fiscal administrator when he faces a certain level of evasion, because it allows us to, first, explain the differences in the magnitude of the problem among different fiscal systems, and second, establish policies that help mitigate it.

This study parts from a relatively easy theoretical framework with which the strategic behavior of the players can be described and the effect of economic variables in their decisions can be isolated. It is intended that the present study contributes to the formulation of public policies that improve tax collection of the economies.

The study is organized as follows: in the second section, the theoretical model is developed; in the third, the technical conditions that define and ensure the existence and unicity of equilibrium are established; in the fourth and fifth sections, a specific model and comparative statics exercise are developed; the sixth section comprises a social welfare analysis; the seventh stresses the implications on public policy; the seventh section, presents some thoughts about fiscal evasion in Mexico; and, finally, the last section lists the conclusions.

1.2 The Model

Suppose there is a representative taxpayer that acts rationally and has the following utility function of income:

$U : R_+ \to R$

We assume that it is concave and twice differentiable. Therefore, the strategy of this player will be a proportion of his income:[3] $\delta \in [0,1]$, which is not reported to the tax office, such that it maximizes his expected utility.

[3] Unlike the Allingham-Sandmo model, here we suppose that the evasion of the taxpayer is characterized as a proportion of his income before taxes, rather than a monetary amount.

$$\underset{\delta}{Max}\ p(h)\cdot U[Y(1-t)-s\delta Y]+(1-p(h))\cdot U[Y(1-t)+t\delta Y]$$
$$s.t.\ \delta\in[0,1] \qquad (1)$$

Where $p(h)$ is a concave function that represents the probability of detecting evasion; *Y*, the tax base; *t*, the tax rate which is proportional to the income; and *s*, the sanction for evading (as proportion of the evaded sum). Then, equation (1) is interpreted as follows: with a probability $p(h)$ evasion is detected and the taxpayer receives the utility produced by the after-tax-income, minus the sanctions derived from evasion; and in the other side, with probability $1-p(h)$ evasion is not detected and the taxpayer obtains the utility of after-tax-income, plus the fraction of evaded taxes.[4]

On the other hand, the fiscal administrator will maximize its expected tax collection by choosing a proportion of the programmed public expenditure $h\in[0,1]$ devoted to cover expenditures on evasion controls:

$$\underset{h}{Max}\ p(h)\cdot(tY+s\delta Y)+(1-p(h))\cdot(tY-t\delta Y)-f(h)G$$
$$s.t.\ h\in[0.1] \qquad (2)$$

Where $f(h)$ is a function with a domain and counter domain in the closed interval [0,1], and must meet the condition $\frac{f''(h)}{p''(h)}<(t+s)\delta\cdot\frac{Y}{G}$, which ensures that the fiscal administrator is maximizing its utility. Note that being $f(h)$ convex is sufficient to fulfill this condition; nevertheless, in some cases it is also fulfilled even when it is concave. This function reflects the transparence of the fiscal system, and represents the effective cost in monetary terms[5] of allocating certain amount of resources to detect evasion. Suppose that $f(h)=\gamma\cdot h$; a more corrupt system will have a higher value of γ. For example, if $\gamma=2$, then if the fiscal administrator allocates 4% of his resources to detect evasion, corruption will raise his real cost to approximately 8% of public expenditure. In addition, *G* represents total programmed expenditures expressed in money.

[4] Notice that implicitly we suppose that the taxpayer uses all his disposable income to consume. This is consistent with the consumer theory that indicates that the taxpayer maximizes his utility by consuming all his income.

[5] It means $f(h)G$.

So, equation (2) will be interpreted as follows: with probability $p(h)$, the fiscal administrator gets the entire collection, which derives from taxing all income, plus the fines charged to the fraction of the evaded income, and with probability $1-p(h)$, he only gets the collected amount obtained from the declaration of the taxpayer. Finally, the effective cost in terms of public expenditure is subtracted, which implies allocating *h* fraction of public expenditure to detect evasion.

1.2.1 Best response of the players

Once the payments of the players are established and supposing they are rational, each one will choose the strategy to maximize its function of payment, provided that the election of the other player[6] is given, and with the restrictions that evasion and the resources allocated to detect it are not negative, and no larger than one. From these optimization problems the next conditions for an internal solution are obtained:

$$p(h)\cdot U'(Y_A^*)s=(1-p(h))\cdot U'(Y_U^*)t \tag{3}$$

$$p'(h^*)(t+s)\delta^* Y=f'(h^*)G \tag{4}$$

where A and U denote the audited and the unaudited state, respectively. Equation (3) establishes the level of evasion that maximizes the expected utility of the taxpayer for a given amount of resources allocated with the intention to detect it. On the other hand, equation (4) is the necessary condition to determine the optimal resources that must be allocated for detecting certain level of evasion.[7]

Once this has been established, we can use the theorem of the implicit function[8] to obtain the reaction functions (or the best answer) for each player. If we differentiate (3) in respect of δ and (4) in respect of *h*, we obtain:

$$\frac{d\delta}{dh}=\frac{G}{t+s}\cdot f''(h)-\delta p''(h)>0 \text{ if equation in (3) equals zero} \tag{5}$$

[6] Mas-Colell (1995:219).
[7] The sufficient conditions for guaranteeing that the players are maximizing their payments are: $p''(h)\cdot \delta Y(t+s)-f''(h)G<0\ \forall\ h\in[0,1]$, for the fiscal administrator and $p(h)\cdot U''(Y_A)(sY)^2+(1-p(h))U''(Y_U)(tY)^2<0\ \forall\ \delta\in[0,1]$, for the taxpayer.
[8] Mas-Colell (1995:940).

$$\frac{d\delta}{dh} = \frac{1}{Y} \cdot \frac{p'(h) \cdot [U'(Y_A)s + U'(Y_U)t]}{p(h) \cdot U''(Y_A)s^2 + (1 - p(h)) \cdot U''(Y_U)t^2} < 0 \text{ if equation in (4) equals zero} \qquad (6)$$

Therefore, if evasion grows, it is optimal for the fiscal administrator to increase the resources intended to detect it and, on the other hand, if such resources are increased, the best response of the taxpayer is to reduce evasion.

Having obtained these results, we can state the following: the best responses of both players are continuous and differentiable functions in the open interval (0,1). Additionally, in the space (h, δ), the taxpayer reaction will be a non-increasing reaction and the one of the fiscal administrator, a non-decreasing one. Particularly, if corner solutions are presented, the slope of the reaction function of the taxpayer will be equal to zero in those points and the one of the fiscal administrator, infinite.[9] This is shown in Figure 1.1.

1.3 Definition of the equilibrium, existence and uniqueness

The previous arguments give us the intuitive tools to determine the existence of equilibrium in the fiscal evasion game, which is composed by the pair of strategies (h^*, δ^*), such that both players maximize their function simultaneously. It is clear that this equilibrium will be given by the intersection between the functions of the best responses of both players.

Formally, it can be demonstrated that, since the group of strategies for each player is a non-empty, compact and convex subset of R, and the functions of expected utility and collection are continuous in each point of their dominion, and both are concave functions, then there is at least one Nash equilibrium.[10]

1.3.1 Uniqueness of equilibrium

Although we know that the equilibrium exists, it is convenient to analyze its possible multiplicity.[11] Since the functions of reaction of the players have a defined sign in their entire domain and, additionally, one is positive and the other negative, they will cross only once.

[9] Those slopes can easily be inferred by analyzing the first order conditions when the restrictions of evasion and/or from resources are activated for detecting evasion.
[10] Mas-Colell (1995:246).
[11] The authority responsible of policy will face less uncertainty if he knows that the shocks in the variables under his control will have only one effect on economy.

In a one more formal sense, we may say that if $f(x)$ and $g(x)$ are two functions such that $f'(x) > 0$ and $g'(x) < 0 \; \forall \; x$, then if we denote $\varphi \equiv f(x) - g(x)$, then $\varphi' > 0 \; \forall x$. This means that it will be a strictly increasing function and it could be equal to zero, at the most, at a single point.[12]

1.4 Comparative Statics

Through the implicit function theorem, some comparative static results can be obtained, without explicitly determining the form of the functions that the model incorporates. Particularly, it can be demonstrated that:[13]

- Fiscal evasion will decrease if sanctions for evading increase.
- Increases in public expenditure will increase evasion and decrease resources allocated to detect it.
- When the taxpayer function of utility is degree *r*, fiscal evasion will be reduced and the resources allocated to the inspection will increase when the taxing base increases.

The first result confirms which has been shown by other authors such as Corchón (2002). Another finding, which seems relevant, indicates that increasing public expenditure may be a cause of fiscal evasion. Therefore, efforts in improving the efficiency of government which imply reducing public expenditure, may reduce fiscal evasion. Finally, economic growth may be beneficial in terms of reducing fiscal evasion. However, this result depends on the form of the utility function of the taxpayer and cannot be generalized.

When there is not an explicit form of the function, the effect of the tax rate in the equilibrium strategies and of the sanctions in the response of the government result ambiguous. Therefore, it is convenient to generate a specific model that, apart from solving the ambiguities, permits studying the impact of the taxpayer aversion to risk, the efficiency of the inspection process, and corruption, with the advantage of describing it in a graphical way.

[12] Notice that we could only say that the uniqueness of the equilibrium is local, because the slopes of the reaction functions were derived through the implicit function theorem that, by construction, only applies to neighborhoods on a point.

[13] This analysis consists in differentiating the first order conditions for solving an equation system, whose unknown values are the partial derivates of δ and h with respect to the parameter of interest.

1.5 Specific model of fiscal evasion

May $p(h) = h^{\varepsilon}$; $f(h) = \gamma \cdot h$; and $U(c) = c^{(1-\theta)}/(1-\theta)$, where $\varepsilon \in [0.1]$; $\gamma \in [0,1]$; $\theta \in [0,1]$. Note that when ε increases, the probability of detection is higher for a given level of *h*; i.e. ε, a higher value of implies that the probability of detection is higher for all the levels of resources allocated for detecting evasion (RADE). Intuitively, a more efficient fiscal system will have a higher inspection capacity. The parameter ε measures that efficiency. Finally, the function of utility shows a constant relative aversion to risk.[14]

The specification was based mainly on choosing functions that were algebraic tractable and which were congruent with the assumptions of the model. A sensibility test of every parameter in the model is shown in Annex 1.1. One can observe that for different combinations of values the level of fiscal evasion vary the most compared to the variation in RADE, with the exception of sanctions and ε (the parameter which affects the probability of fiscal evasion detection).

From the first order conditions in (3) and (4) we can substitute the specific functions assumed and derived the equations (7) and (8). From direct substitution we obtain:

$h^{\varepsilon} \cdot [Y(1-t) - s\delta Y]^{-\theta} s = (1-h^{\varepsilon}) \cdot [Y(1-t) + t\delta Y]^{-\theta} t$ and

$\varepsilon h^{\varepsilon-1}(t+s)\delta Y = \gamma G$

Rearranging terms we can obtain the equilibrium of the game, which is represented by the strategies:

$$\delta_T = (1-t) \cdot \frac{1-\rho(h)}{\rho(h)t + s}; \ \rho(h) = \left(\frac{h^{\varepsilon} \cdot s}{(1-h^{\varepsilon})t} \right)^{1/\theta} \tag{7}$$

$$\delta_F = \frac{\gamma}{\varepsilon} \cdot \frac{g}{t+s} \cdot h^{1-\varepsilon}; \ g = \frac{G}{Y} \tag{8}$$

for the taxpayer and for the fiscal administrator, respectively. The equilibrium will be defined when $\delta_T = \delta_F$. Nevertheless, there is no closed solution to the system, which implies

[14] Relative aversion to risk is defined as $cU''(c)/U'(c)$.

that it must be found using numeric methods. If we suppose that corruption is high[15] $(\gamma = 6)$, that the parameter $\varepsilon = .015$, that aversion to risk equals 0.5, that the tax rate is 28%, that the sanctions for evading are 20% and public expenditure (as a proportion of the tax base) is 35%, we obtain that, in equilibrium, the taxpayer will evade around 72% of its income before taxes and the fiscal administrator will allocate around 1.4% of its public expenditure for detecting evasion.[16,17]

Taking into account this result, we can now make a more exhaustive analysis of comparative static that will additionally help us answering the questions of the previous section. The methodology of such exercise will be the following: shocks for each parameter in the model are established (*ceteris paribus*), the different equilibriums are found and their behavior in the presence of shocks is analyzed. By using this methodology, the following may be observed in Annex 1.1, where the results presented next can be confirmed graphically:

OBSERVATION 1. *There is a tax rate (t_T), that maximizes fiscal evasion. Higher (lower) values of this tax rate will decrease evasion in a monotonic way. If the tax rate equals zero (or one) evasion does not exist. On the other hand, there is a tax rate ($t_F > t_T$) that maximizes the level of RADE.*

Intuitively we may say that low levels of tax rate do not generate sufficient resources for detecting evasion in an efficient way. If the rate increases, the resources increase too, but they are still insufficient; therefore, the taxpayer responds by increasing evasion (because of the decrease in the utility which makes him have a lower disposable income). Nevertheless, it comes a point where the inspection is so high, that the taxpayer decides decreasing evasion. On the other hand, the fiscal administrator will continue allocating more resources until decreasing them turns optimal, and this level is found in a higher tax rate than the one that maximizes evasion.

[15] We say 'high' in relative terms, as can be seen in Annex 1.1 a level of γ above 5 implies levels of fiscal evasion beyond 70% in equilibrium.
[16] Another useful specification is to assume that $U(c)=\ln(c)$, $\rho(h)=h$ and $f(h)=\gamma(1/2)h^2$. In this case we have a closed form solution which is congruent with the results presented here. It is worth noting that using the same values of t, s and g as the used above and assuming that the parameter γ is equal to 0.03, the equilibrium values are 58% for fiscal evasion and 1.3% for RADE. Therefore, the model permits to adopt different specifications of the functions to calibrate it to different empirical values observed.
[17] Fuentes (2010) states that the fiscal evasion rate from independent taxpayers, excluding microenterprises (*personas fisicas NO-REPECOS*) ups to 80%.

OBSERVATION 2. *An increase in sanctions will decrease, in a monotonous way, both evasion and the resources allocated to detect it.*

The expected collection of the fiscal administrator increases when sanctions increase. On the other hand, an increase in the RADE has an ambiguous effect: on one side, it increases the expected collection because of the increase in the probability of detection, and on the other, it decreases the expected collection because of its cost in terms of public expenditure. Therefore, an increase in sanctions allows the government substituting collection derived from increasing RADE with collection generated by the increase in sanctions. Consequently, in equilibrium, increases in sanctions will reduce the optimal RADE.

On the taxpayer side, he will reduce evasion because of his aversion to risk. Nevertheless, note that in equation (1), even when the agent is risk neutral, a threshold exists ($s = (1 - p(h))t / p(h)$), so that every value over this one causes that the optimal election of the taxpayer is not evading. Therefore, even if aversion to risk is absent, an increase of sanctions causes reductions on evasion.

OBSERVATION 3. *An increase in public expenditure causes increases in evasion and decreases in the RADE of equilibrium.*

If a government faces a higher public expenditure, it will not only dedicate lesser efforts to obtain the necessary collection, but the taxpayers will also be less willing to finance it.[18]

OBSERVATION 4. *Higher income causes reductions of evasion and increases in RADE.*

If income increases, taxpayers will have a higher disposition to finance the government and, consequently, the government could dedicate higher efforts to audit taxpayers.

From observations 3 and 4 we can conclude that what is important is the relative weight of public expenditure in the taxing base. If this proportion is kept constant, evasion and RADE of equilibrium will also be constant. On the contrary, if public expenditure is an increasing (decreasing) function of income, then increases in income will produce increases (decreases) in evasion and decreases (increases) of the RADE of equilibrium.

[18] It should be noted that the model supposes that there are no externalities of public expenditure in the taxpayer's utility, and from there, this result.

OBSERVATION 5. *Sustained efforts for improving efficiency of inspection of taxpayers cause reductions in evasion and in RADE.*

Simulations suggest that increases in the parameter ε, when situated in low values, causes moderate evasion rises. Nevertheless, if it keeps rising, it comes a point in which evasion becomes decreasing. On the other hand, RADE will always decrease. The economic explanation of that effect is the following: an increase in this parameter helps reaching a higher probability of detection for all levels of RADE, which generates incentives for the fiscal administrator to allocate fewer resources to detect evasion. In the beginning, such decrease causes that taxpayers evade more; however, it reaches a level where the probability of detection is so high, that evasion starts decreasing, until it disappears when $\varepsilon = 1$[19]. Therefore, if sustained efforts are dedicated to improve efficiency of inspection processes, evasion would be reduced, and the fiscal administrator would allocate less RADE.

OBSERVATION 6. *If corruption is higher in the fiscal system, evasion increases and RADE decreases.*

This case is analogous to the one corresponding to increases in public expenditure. A more corrupt system will produce higher incentives for allocating less RADE, because it is known that not all the resources will be allocated to meet the initial objective. As the taxpayer detects this, he will decide to increase evasion.

OBSERVATION 7. *An agent having a higher relative aversion to risk will decrease his evasion of equilibrium, and the fiscal administrator will make lesser efforts to detect evasion.*

Intuitively, it is clear that a taxpayer with a higher aversion to risk will be less willing to evade. As the fiscal administrator notices it, he decides to decrease RADE. This means that higher levels of aversion to risk will provoke reductions in the efforts allocated by the government to detect evasion. On the other side, the taxpayer unilaterally reduces evasion.

1.5.1 Progressive Taxes

Slemrod and Yitzhaki [20] comment that the empirical efforts for knowing determinants of evasion have had a limited success, mainly because of data problems. Nevertheless, they

[19] Notice that if $\varepsilon = 1$, then the probability of detection is equal to one, regardless of the RADE level.
[20] Slemrod and Yitzhaki (2002), pág.1440.

observe that a significant effect of the progressivity of the tax rates in the evasion has been found.

In order to study the effect of progressivity on fiscal evasion and on RADE, we will suppose that the tax rate is an increasing function of the taxing base and, particularly, that it adopts the form $T(Y) = t_{MAX} \cdot (Y / Y_{MAX})^{\rho}$, where t_{MAX} is the maximum tax rate applicable in the fiscal system, Y_{MAX} represents the lower bound of income, to which the maximum rate is applied. Based on the same methodology exposed in the previous section for variations of parameter[21] ρ, the following observation is established:

OBSERVATION 8. *There is a level of progressivity* (ρ_T) *such that evasion is maximized and other value* $(\rho_F < \rho_T)$ *that maximizes RADE. In addition, if ρ tends to be zero or infinite, evasion and RADE tend to be zero.*

Observation 8 establishes that there is a minimal threshold of progressivity such that, if it increases, evasion will decrease. As it is commented in the Slemrod and Yitzhaki (2002) study, the results of the main empirical studies do not agree in terms of the effect of progressivity on evasion; while Clotfelter (1983) finds a positive relation, Feinstein (1991) affirms that it is negative. Therefore, it is feasible that this relation is not monotonous, as it is concluded in the present model. In brief, a small increase in the progressivity of the fiscal system will reduce evasion, only if the present level is higher or equal to (ρ_T).

When comparing the results with the ones obtained for a value of the sanctions equal to 0.4 (instead of 0.2), we get a lower (ρ_T) threshold.[22] Therefore, if a more progressive fiscal system is desirable (for example, because of welfare) and other parameters of the economy are unknown (specifically information regarding to the elasticity of the probability on the detection evasion with respect to RADE, the 'level of corruption' and the level of risk aversion of the taxpayers, which are measured respectively by the parameters ε, γ, and θ and which are difficult to assign them a value on empirical grounds), an increase in sanctions will more probably make that an increase in progressivity results in reductions in evasion.

It is worth noting that T(Y) is a decreasing function in the parameter ρ, that is to say that the actual tax rate decreases as the progressivity of the fiscal system increases.

[21] Notice that if $\rho = 0$, then $T(Y) = t_{MAX}$, if $0 < \rho < 1$, the function is concave, and if $1 < \rho < \infty$, it is convex. Therefore, this parameter captures the progressivity of the fiscal system.

[22] This comparison is established because the sanctions are relatively easy to manipulate by the fiscal administrator.

Furthermore, it was shown that both evasion and RADE initially increase and then decrease as the tax rate increases. Thus, as the progressivity of the fiscal system increases (measured by the parameter ρ), one can expect both evasion and RADE to decrease. Intuitively, given some level of income, the taxpayer would be willing to choose a lower level of fiscal evasion if the tax rate is low enough.

1.6 Welfare analysis

The impact that changes in the parameters have on the functions of payments of the players constitutes a measure of welfare. Through an analysis of comparative static, which consists in evaluating the different values that the variables of the equilibrium adopt in the presence of different values of the parameters, it can be found that, except in one case, there is a *zero sum* effect among the players.[23] This means that, if one wins in terms of utility, the other loses. For example, an increase in public expenditure has a beneficial effect for the taxpayer and an adverse effect for the government.[24] However, the increase in utility of the taxpayer does not derive from some positive externality that public expenditure may have in his welfare (since that is not incorporated to the model), but from the lesser efforts to inspect of the fiscal administrator, which provoke a higher evasion of equilibrium.

The rest of the cases have a similar explanation; i.e., the positive effects on the payment of a player, is nothing but the reflection of what the other player has lost. Therefore, when referring to welfare issues, there are no Pareto improvements, in the sense that it is not possible to improve the situation of a player without affecting the other's (for example, by applying fiscal policies). However, what has been mentioned before does not occur with increases in the taxing base of the taxpayer, because they have a beneficial effect on both players. In fact, utilities of the taxpayer and of the government could increase indefinitely, whenever increases in the income are present, and the advantage is that evasion decreases in a constant way.

1.7 Implications on Public Policies

[23] The term *zero sum* is not correctly used, because it should refer to a situation in which a player loses exactly what the other wins. This does not happen in this case, because the units of measure of utility are not comparable with the ones of collection, due to the implicit subjective valuation in the functions of payment of the taxpayer.

[24] Chart 1 helps to understand these *zero sum* effects, for it summarizes the sign of the change in the equilibrium to changes in the different parameters of the model.

After considering all the above mentioned, we can establish policies to decrease fiscal evasion:

Increasing sanctions, fiscal discipline, economic growth, sustained efforts to improve efficiency of the inspection process and less corruption in the fiscal system, are determinant factors to reduce fiscal evasion.

On the other hand, with the adoption of a more progressive fiscal system, the probabilities to decrease evasion raise, if this change is complemented with rises in the sanctions to evasion.

Finally, economic growth has a positive effect in social welfare; it increases the expected utility and collection from the taxpayer and the fiscal administrator, respectively.

1.8 Brief thoughts about fiscal evasion in Mexico

Mexico is one of the countries where fiscal evasion constitutes a major problem. According to the *Global Competitiveness Report 2000-2001,* the country is located in the fifth place, from 75 countries, in terms of fiscal evasion. The main causes of evasion are associated to high levels of corruption and informal trade. According to a study issued by the Tributary Administration System (Sistema de Administración Tributaria-SAT, in Spanish), individuals performing business activities and providing professional services or individuals who get income from leasing or renting, are the groups that have the highest rates of evasion, reaching eighty and seventy percent, respectively. In contrast, juridical persons or individuals whose taxes are retained present a rate under 30%. This is closely linked to the capacity of monitoring the juridical persons and people whose income tax (Impuesto sobre la renta, ISR, in Spanish) is retained, which is relatively easy.

If we consider that public expenditure in Mexico is about 35% of the GDP, that the maximums rate of ISR is 28%, that sanctions are around 20%, and supposing that aversion to risk is about 0.5, a country's behavior, according to the described model, is consistent with a corrupted environment (γ high) and with reduced efficiency in the monitoring processes (ε low). Particularly, if these values are used, fiscal evasion is around 73% and the fiscal administrator allocates 1.4% of his resources to monitor taxpayers.

1.9 Conclusions

A model that represents a simultaneous game between a representative taxpayer and the fiscal administrator was generated. Their strategies are a proportion of the taxing base that is not declared to the government, and a proportion of public expenditure used to detect fiscal evasion, respectively. We were able to demonstrate that the taxpayer responds by decreasing fiscal evasion when resources allocated to detect evasion increase, and that the administrator increases the allocation of RADE when a lesser income is declared. These responses generate supply and demand of evasion that determine the equilibrium of Nash, whose existence and uniqueness (local) were established.

Afterwards, an exercise of compared static was made in general (without supposing a concrete form of the functions) and in particular (supposing closed forms of the functions of utility and probability of detection). By using simulations the following results were obtained: *i)* there is a rate that maximizes evasion, and there is other, bigger than the first one, that maximizes RADE, *ii)* a raise in sanctions decreases evasion and RADE, *iii)* raises in public expenditure increase evasion and decrease RADE, *iv)* economic growth generates incentives that decrease evasion and increase RADE, *v)* sustained efforts for improving efficiency of the inspection processes derive in decreases in evasion and RADE, *vi)* corruption increases evasion and provokes that the fiscal administrator allocate less RADE, *vii)* major aversion to risk causes that the taxpayer decreases fiscal evasion and the fiscal administrator allocates less RADE and *viii)* there is a threshold of progressivity such that, further increases in progressivity decrease evasion and other level of progressivity (lower than the first one) decreases RADE. Besides, it was established that economic growth increases welfare, both for the taxpayer and the government.

With the previously mentioned results a policy to decrease fiscal evasion was established: greater sanctions, fiscal discipline, economic growth, sustained efforts for improving efficiency in the inspection processes, and less corruption will decrease evasion. Besides, if a more progressive fiscal system is adopted, decreases in evasion will become more probable if it is complemented with greater sanctions. Finally, increases in income of taxpayers will have a positive effect in social welfare, and will increase the expected utility and tax collection of the players.

In brief, the model provides a framework which is rich enough to establish public policies intended to decrease fiscal evasion. It also constitutes a very useful tool to explain the differences between the countries through quantitative methods, which could be useful to make empiric estimations. Besides, it was possible to establish that if progressivity in the fiscal system is deep enough, it will have a beneficial impact on tax collection. Finally, we may conclude that economic growth increases social welfare of the players, and at the same time, reduces fiscal evasion.

Chapter 2. Mode Choice and Public Transport Use[25]

2.1 Introduction

Climate change is not solely an environmental issue that will have a strong impact on the economies of all countries in the coming decades. Climate change will also accentuate inequalities between less developed countries and developed ones. Sooner or later, productivity of agricultural activities will rise in regions which are now relatively colder, and resources will become scarcer in those parts of the world where developing countries are commonly located. However, in the long run the effects will be negative for all regions and countries (UNFCCC, 2007).

More direct and indirect evidence is found every day about the impact of human activities on climate. Governments, researchers and organizations have all recognized that greenhouse gas emissions have increased over the course of the last two centuries. The major culprit, carbon dioxide, CO_2, is responsible for approximately 80% of the impact on climate change (UNFCCC).

The transport sector is one of the major contributors to greenhouse gas emissions. According to the European Environment Agency, the transport sector's contribution to climate change is around 20% of total emissions in countries which form part of the United Nations Framework Convention on Climate Change (UNFCCC)[26]. In 15 European Union countries, greenhouse gas emissions have been decreasing in recent years in all main sectors, with the exception of transport. In fact, from 1990 to 2006 total emissions have grown by 26%, 90% of the increase is due to road transport (EEA, 2008).

According to the Stern Review Report (2006) CO_2 emissions from transport are expected to more than double in the period to 2050", which is the fastest growth ever. Reducing emissions in the transport sector is difficult because of the cost of low-carbon technologies and because reducing demand for transport affects people's welfare. One way to achieve this reduction without adverse effects is to encourage people to use travel modes

[25] Joint work with Alejandro Guevara-Sanginés.

[26] These countries are those included in "Annex 1" of the Convention, of which the industrialized countries that were members of the OECD in 1992, and some countries with economies in transition, including the Russian Federation, the Baltic States, and several Central and Eastern European States.

other than by car. Thus, to influence travel behavior it is necessary to understand how people take transport decisions.

A large number of studies have been undertaken to identify the determinants of transport decisions. This kind of research was motivated by two key factors: the relevance it has in terms of policy design and major advances in estimation techniques in recent years.

It is in this context that the OECD Environment Directorate carried out a household survey in ten member countries in order to collect individual information about environmental behavior. Thanks to this survey, a wide set of disaggregated data on transport decisions was gathered and was the primary input for the development of this work.

Our primary objective is to contribute to the knowledge of what determines transport decisions and to formulate policy recommendations to help member countries in planning and designing environmental policies. Mode choice is analyzed in this chapter. For this, a discrete choice model is specified.

One of our major tasks was to analyze a wide set of information related to people's attitudes towards environmental issues. This kind of information is scarce and consequently research has so far only led to minor conclusions in this area. In addition, several studies have analyzed this issue from a national perspective, which limits the applicability of their results. It is not the case here since uniform data are available for ten countries and, consequently, results can be compared to distinguish certain country-specific effects that arise from unobservable characteristics.

2.2 Review of the literature

Dargay (2006) reviews the main findings of recent empirical studies on personal transport decisions and focuses on the way individuals' characteristics, their residential location and the size of the transport system have an influence on their transport decisions. Whereas the author also reviews findings on car ownership and car use, here we emphasize only findings about public transport decisions.

Several authors find that as income rises, people are less likely to use public transport (Dieleman *et al*. 2002; Johansson-Stenman 2002; Dargay and Hanly 2004; Train 1980). But some others, as Golob and Hensher (1998), find a positive effect. In the case of intensity of public transport use, the results are mixed. For example, Abreu e Silva *et al.* (2006) and Johansson-Stenman (2002) find that public transport use is less intensive as income rises whereas Dieleman *et al.* and Golob and Hensher find the contrary. Nevertheless, Dargay argues that "most evidence suggests that income elasticity of public transport use is negative, implying that public transport is an inferior good".

Another common finding is that women travel shorter distances and use public transport more than men. Johansson-Stenman finds this pattern even in Sweden, a country known for its relatively high degree of gender equality, so intuitive interpretation of this result is not so clear-cut. Nevertheless, Dargay and Hanly (2004) find that between 1990 and 2000 gender differences in travel behavior have decreased. This could indicate either that gender inequality is a likely explanation (assuming that equality was greater in 2000 than in 1990) or that women select activities that require less travelling (Mannering, 1983).

With respect to the number of children in the household, Dargay and Hanly, Johansson-Stenman, Dieleman *et al.* and Simma and Auxhausen (2004) find that as this number increases, people are less likely to use public transport.

In the case of spatial characteristics, a common finding is that population density (a proxy for development), city size and easy access to public facilities (for example shops or governmental services) are associated with a more intensive use of public transport (Bhat and Koppelman 1993; Train 1980; Simma and Axhausen 2004; Giuliano and Dargay 2006; Dargay and Hanly 2004; Johansson-Stenman, 2002; Abreu e Silva *et al*. 2006).

Attitudes towards the environment are found to be significantly associated with commuting by public transport (Steg *et al.* 2001; Golob and Hensher 1998). However, the direction of causality is difficult to determine since, as Golob *et al.* (1979) out, opting for public transport may itself influence one's attitudes towards the environment by one's own experience of the mode (Dargay 2006).

As for pricing measures it has been found that demand for public transport is sensitive to changes in fares. Dargay (2006) reviews results from the Transportation Research Laboratory (2004) and Oxera Consultancy (2005), which both estimate that short-run elasticities of public transport fares range from -0.3 to -0.7 and from -0.6 to -1.1 in the long run. Litman (2005) also reviews price elasticities of public transport estimated in different studies. He concludes that the elasticity of fares ranges from -0.2 to -0.5 in the short run and from -0.6 to -0.9 in the long run. Moreover, these elasticities are greater for off-peak and leisure travel.

Finally, Dargay (2006) discusses the distributional effects of pricing measures. In particular, she cites studies by Berri (2005), Dargay (2005) and Asensio *et al.* (2002). According to Dargay, "public transport subsidies are generally progressive, especially in urban areas". But Dargay (2005) finds that bus subsidies are progressive while rail subsidies are not.

2.3 Theoretical and empirical background

Empirical research on transport decisions has been focused on analyzing the impact of several variables on households' transport choices. In this context, most studies try to explain households' decisions on the choice and use of a given transport mode.

Three main differences between models can be identified:

- The way transport decisions are measured,
- Different sets of independent variables used,
- Estimation techniques,

that are described below with an emphasis on public transport decisions.

2.3.1 Transport decisions modeling

Transport decisions can be analyzed from two perspectives: *i)* as a choice from among several modes to travel to a given destination and *ii)* as the intensity with which a certain mode is used.

In the first case, mode choice has often been modeled as a discrete choice between alternatives such as public transport, walking or driving (Train 1980; Simma and Axhausen 2004; Dargay and Hanly 2004).

In the second case, transport use has been modeled in several ways. As regards public transport, the most common way to quantify it is with the number of trips over a certain time period (Simma and Axhausen; Giuliano and Dargay; Johansson-Stenman). A different measure is found in Nolan (2002), who quantifies it with expenditures in bus fares.

2.3.2 Independent variables

Another difference between models relates to the exogenous variables included in the estimation. Four main categories of variables can be defined:

- Socio-demographic
- Economic
- Geographic
- Mode characteristics

In the first case, most studies use a set of socio-demographic variables that include head of household (HOH) and household characteristics such as gender, age, education, number of children, family size, among others.

In the case of economic variables, a measure of income is included in most studies, although it is sometimes replaced by total expenditures (Nolan 2002; Fullerton *et al.* 2004) or by dummy variables which classify households according to ranges of income (Giuliano and Dargay 2006; Dargay and Hanly 2004). Work status is also often incorporated as an explanatory variable (Simma and Axhausen 2004; Dargay and Hanly; Giuliano and Dargay). Finally, prices and capital costs are included in some analyses, for example in Fullerton *et al.* Geographic characteristics are another set of variables that has been broadly analyzed in empirical research. Common measures are population density, size of municipality, accessibility to public transport and public facilities (Simma and Axhausen; Giuliano and Dargay; Dargay and Hanly).

With respect to mode characteristics, bus frequency, distance to bus stop, car characteristics, and time spent walking are variables that are incorporated in some analyses, such as Feng *et al.* (2005) and Dargay and Hanly.

2.3.3 Estimation techniques

Mode choice is commonly modeled with discrete models which are consistent with maximization of expected utility. In particular, two models have been widely used: multinomial logit and conditional logit. Algebraically, there is equivalence between these two models, as both estimate the probability of choosing an alternative from a finite set as a function of some exogenous variables. Studies on this topic include Golob and Hensher for Australia, Dargay and Hanly for Great Britain, and Dieleman *et al.* for the Netherlands.

It is common to analyze the intensity of transport use with models that account for self-selection. This approach is considered because a proportion of individuals have no positive demand for transport (for example, if public transport use is measured as the number of trips per month, some people would have no trip at all) and it could be that those who have a positive demand are self-selected. For example, Johansson-Stenman estimates a model first specified by Cragg (1971) (also known as the double-hurdle model) and a Heckman selection model to analyze the number of trips as a function of some socio-demographic and spatial characteristics. Nolan also estimates a tobit model that accounts for heteroskedasticity.

2.4 The data

The data used in estimations were obtained from the OECD Survey on Household Environmental Behavior. The survey was carried out in February 2008 in ten OECD countries representing a total sample of 10,000 households (approximately 1,000 per country). In each country, the sample was stratified by income, age, gender and region.

Information was collected for five areas of consumption and management: waste, water, energy, transport and organic food.

The information on choices of transport mode was taken from a matrix that indicates which mode respondents usually take to travel to a given destination. Rows of this matrix specify six possible destinations, and columns six different alternatives (walking, car, public transport, bicycle, motorcycle and "not applicable"). One or more modes could be chosen by the respondent. Here, country aggregates represent the share of trips by mode and country, excluding the "not applicable" answer and merging motorcycle trips with car trips.[27, 28]

Table 2.1 presents the shares by mode of transport, by each destination, for each country. The general picture depicts that car is the preferred mode of transport in all countries. In particular, Australia and Canada are the two countries with the largest shares of trips made by car (always above 60%). In contrast, South Korea is the country with the lowest shares of trips made by this mode. Depending on the destination, trips made by public transport or by foot have the second largest shares. Particularly, South Korea is the country with the largest share of trips made by public transport in the most of cases. Netherlands show the largest shares of trips made by bicycle. Finally, motorcycle trips are very scarce in all countries, except for Italy, where the share of trips made by this mode reaches 7% in the case of commuting to and from work.

There are important differences between countries, for example, for South Korea the share of trips are more evenly distributed compared with other countries. Furthermore, there are also regional differences within countries. Appendix A.1 shows the frequency of trips

[27] The 'not applicable' option includes any of the different modes of transport, for the cases of visiting family and friends and shopping the frequency of this answer is below 4% for every country. However, for other destinations this frequency is considerable larger, particularly in the case of trips related to educational activities. Differences between countries are important as they reflect different patterns of behavior regarding the type of activities that people do. For example, in the case of commuting to and from work this frequency ups to 4% in the case of Mexico and to 36% in the case of Australia, indicating that in Mexico a larger proportion of people work than in Australia (it is important to note that the survey includes responses of different members of the household, not only the head of household). These differences may be relevant in terms estimation if the choice destination would be the object of analysis. However, this is not the case and therefore the exclusion of this alternative should not affect the results of the estimations,

[28] Trips made by motorcycle do not exceed 2% of total trips (considering all the countries). Some estimations were made including this mode as a separated one, however, any significant coefficient was obtained. Therefore, I decided to consider these trips as equivalent to trips made by car. It is worth noting that excluding or including these observations from the estimation does not reflect large differences in the estimated coefficients.

(adding up all destinations) at a subnational level. These differences reflect that fixed-effects by country are important in the econometric modelling.

Table 2.1. Share of trips by mode, by destination, for each country.

Destination	Commuting to and from work					Visiting family and friends				
Country	bicycle	public	car	walk	moto	bicycle	public	car	walk	moto
Australia	2%	15%	71%	11%	1%	1%	8%	83%	8%	1%
Canada	2%	18%	65%	15%	1%	2%	14%	73%	10%	1%
Czech Rep.	7%	30%	34%	28%	1%	7%	20%	56%	17%	0%
France	4%	17%	63%	15%	2%	2%	11%	75%	10%	2%
Italy	5%	17%	56%	15%	7%	4%	11%	70%	12%	4%
Korea	2%	45%	34%	19%	1%	1%	38%	53%	8%	1%
Mexico	1%	29%	56%	11%	2%	2%	22%	66%	10%	2%
Netherlands	32%	13%	46%	9%	1%	17%	17%	58%	7%	1%
Norway	10%	18%	53%	18%	2%	4%	15%	69%	10%	1%
Sweden	18%	21%	40%	20%	1%	8%	24%	53%	13%	1%
OECD(10)	8%	22%	51%	16%	2%	5%	18%	66%	10%	1%

Destination	Educational activities					Sports and recreational activities				
Country	bicycle	public	car	walk	moto	bicycle	public	car	walk	moto
Australia	2%	13%	70%	15%	1%	3%	10%	73%	13%	1%
Canada	3%	21%	60%	16%	1%	5%	16%	62%	16%	0%
Czech Rep.	4%	37%	31%	28%	0%	17%	22%	28%	32%	1%
France	2%	15%	48%	34%	0%	8%	11%	51%	29%	2%
Italy	5%	20%	47%	22%	6%	9%	12%	50%	23%	5%
Korea	2%	48%	26%	23%	1%	4%	36%	35%	24%	1%
Mexico	1%	28%	52%	18%	2%	6%	19%	45%	28%	2%
Netherlands	25%	23%	45%	6%	1%	39%	8%	39%	14%	0%
Norway	7%	26%	45%	20%	1%	9%	16%	53%	21%	1%
Sweden	13%	29%	40%	17%	1%	16%	20%	42%	22%	1%
OECD(10)	6%	29%	43%	21%	2%	12%	18%	46%	23%	2%

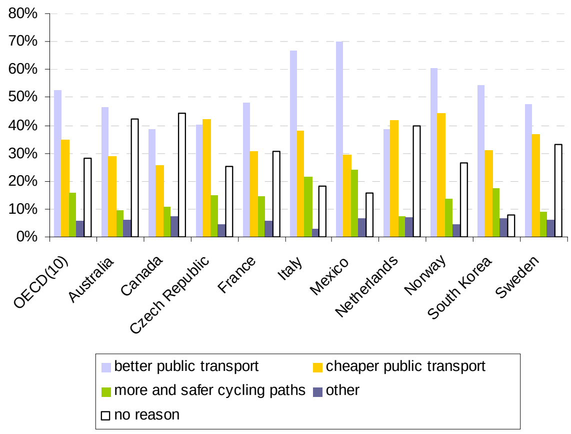
Destination	Shopping					Professional activities (independent work)				
Country	bicycle	public	car	walk	moto	bicycle	public	car	walk	moto
Australia	1%	8%	79%	12%	0%	1%	12%	77%	9%	0%
Canada	2%	12%	70%	15%	0%	2%	15%	72%	11%	0%
Czech Rep.	4%	13%	54%	28%	0%	1%	29%	62%	8%	0%
France	1%	10%	72%	16%	1%	2%	16%	63%	18%	1%
Italy	5%	14%	54%	25%	3%	1%	28%	67%	3%	1%
Korea	1%	35%	47%	16%	1%	1%	40%	51%	8%	0%
Mexico	1%	17%	67%	14%	1%	1%	28%	60%	10%	2%
Netherlands	30%	2%	44%	24%	0%	9%	25%	60%	4%	2%
Norway	4%	5%	68%	22%	0%	1%	37%	59%	2%	1%
Sweden	10%	19%	50%	20%	0%	7%	24%	56%	12%	1%
OECD(10)	6%	13%	60%	19%	1%	2%	28%	61%	8%	1%

Note: The different colors in table reflect the difference in the different shares for each mode within a country, being color red the maximum value and beige the minimum one.

2.4.1 Attitudes towards public transport

For people who commonly drive, it is possible to analyze which aspects of public transport would encourage them to drive less. Aggregated country data are presented in Figure 2.1. For Australia, Canada and the Netherlands, the percentage of people who stated they would use their cars less if public transport was better is very similar to the share of those who responded “no reason” would make them change. In contrast, in South Korea, Mexico and Italy the percentage who responded “better public transport” is around four times greater than those who answered “no reason”. A similar pattern is observed in the other countries, yet to a lesser degree. These findings may indicate that in countries like South Korea and Mexico, people are willing to use public transport if the infrastructure is improved while public transport fares are less of an issue for them. In contrast, in the Netherlands people would drive less if public transport was cheaper. In short, it seems that for some countries (such as the Netherlands, Norway and Sweden) pricing measures would be more effective than further investment in public infrastructure, and the contrary is true for countries like South Korea and Mexico.

Figure 2.1 - Which improvements in public transport and cycling paths would reduce car use



Source: 2008 OECD Household Survey on Environmental Behavior.

Figure 2.2 illustrates households’ responses with respect to the effect of having a more convenient public transport network (stops closer to home and destination) on their willingness to drive less. In general, for nine of the ten countries the largest share of people answered that they would “quite likely” reduce car use if it was more convenient.[29] The only exception is France, where a majority of respondents said that they would “very likely” reduce car use. This figure reflects a large willingness to use public transport if it was more convenient.[30] Therefore, it seems that improvements in public networks would have a positive effect on promoting public transport use, but perhaps not as great as expected. The same is true for other characteristics of public transport analyzed below.

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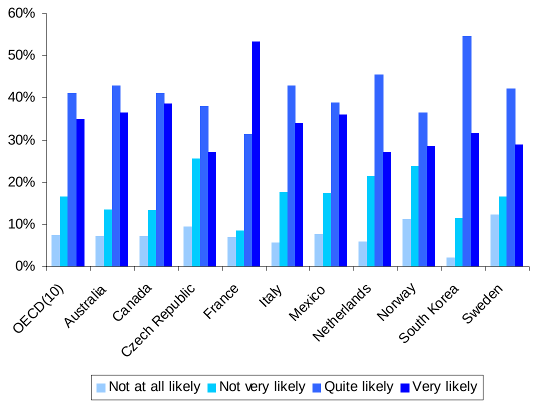
[29] A native-speaker for each country translated each questionnaire to the different languages of the respondents, thus one can expect that the interpretation of terms such as “quite likely” and “quite likely” is the same across respondents.

[30] We must take with care conclusions obtained by stated preferences as it is widely known that they sometimes do not predict accurately actual behavior.

A slightly different picture emerges from Figure 2.3 with respect to public transport reliability (fewer delays or strikes). In France, Mexico, Italy, Australia and Korea the largest share of people responded that they would "very likely" reduce car use if public transport was more reliable, which contrasts with the responses about convenience analyzed above. This difference reflects that reliability is relatively more valuable than convenience in some countries, probably a consequence of their having more accessibility to public transport: in other words, reliability is contingent upon accessibility.

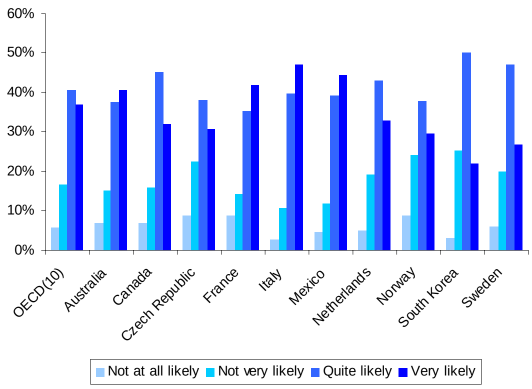
Figure 2.2 - Impact of a more convenient public transport network* on reducing car use



Source: 2008 OECD Household Survey on Environmental Behavior.

*(e.g. stops closer to home and destination)

Figure 2.3 - Impact of more reliable public transport services on reducing car use



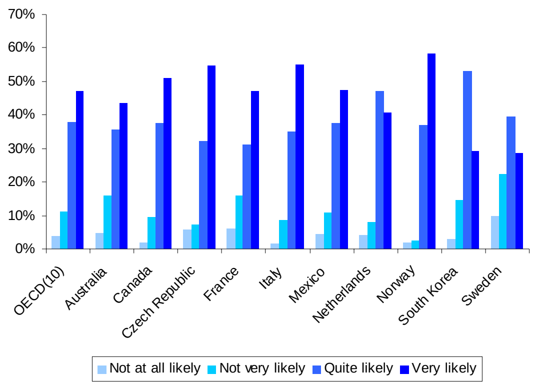
Source: 2008 OECD Household Survey on Environmental Behavior.

Having more rapid public transport services is very valuable for households as can be seen in Figure 2.4: in six of the ten countries the largest share of respondents would "very likely" drive less if public transport services were more frequent and more rapid. In fact, this feature is valued much more than convenience and reliability in several countries.

Comfort is less of an issue in some countries (Figure 2.5). A large share of respondents in Sweden, Norway and France stated that they would "very likely" reduce car use if public transport was more comfortable. However, in Mexico, South Korea and Italy people consider comfort as an important aspect that should be improved in order to reduce car use. The large differences between countries probably reflect the magnitude of demand relative to supply (crowding).

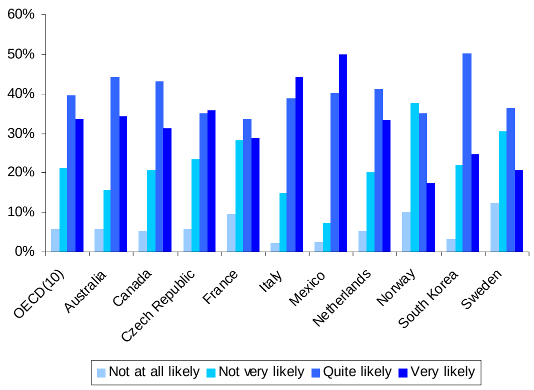
Finally, the greatest contrast between countries regards personal security transport (Figure 2.6). In the majority of European countries, this is not likely to be an issue, especially in Norway. However, in the case of Mexico and South Korea, personal security should be improved in order to reduce car use.

Figure 2.4 - Impact of a more rapid public transport on reducing car use



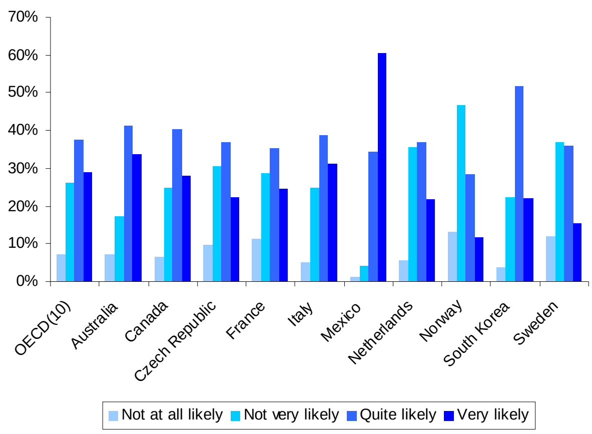
Source: 2008 OECD Household Survey on Environmental Behavior.

Figure 2.5 - Impact of a more comfortable public transport on reducing car use



Source: 2008 OECD Household Survey on Environmental Behavior.

Figure 2.6 - Impact of a more secure public transport on reducing car use



Source: 2008 OECD Household Survey on Environmental Behavior.

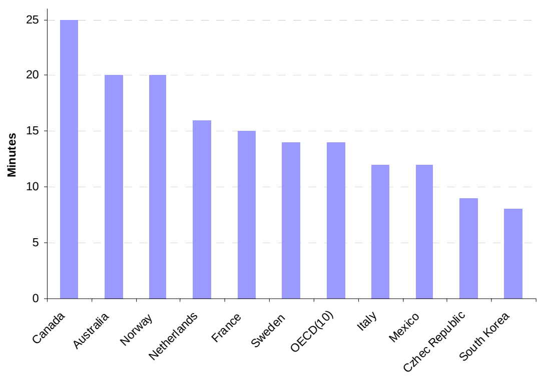
2.4.2 Public transport and car travel time

Figures 2.7 to 2.10 show the average time difference between commuting by public transport instead of driving for various purposes. There is an average difference of roughly fifteen minutes in all ten countries (except in the case of travelling to undertake educational activities, which reflect an average difference of eleven minutes). That is to say, respondents stated that on average it would take fifteen minutes more to reach their destination if they travel by public transport instead of by car.

Italy, Mexico and South Korea always rank below the average of all ten countries while Australia, Canada and Norway are above the average. These data reflect that time is an important factor for choosing a given mode because, as will be seen later, people in the former countries are more likely to use public transport. Moreover, public transport is more likely to be used for trips to educational facilities, and the average difference in time is always lower than that for other travel purposes in almost every country.[31]

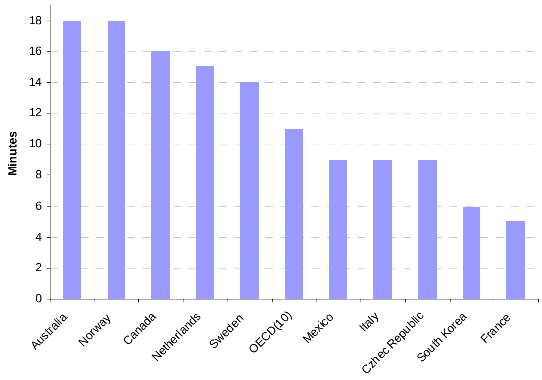
[31] We should note that these time differences are subject to perception errors because some respondents may have not actually made a certain trip once by public transport and once by car. Therefore, this information should be interpreted as a perception of the time difference between modes.

Figure 2.7 – Commuting to and from work: time spent in public transport compared to driving a car or a motorcycle (one way)



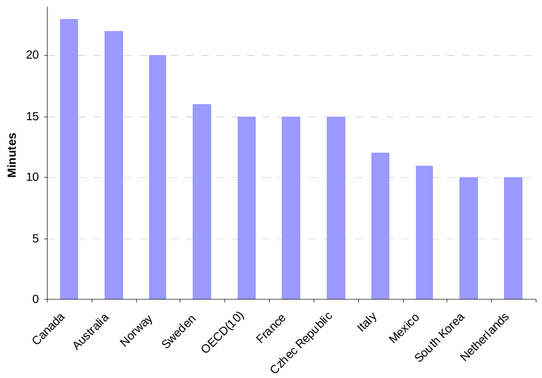
Source: 2008 OECD Household Survey on Environmental Behavior.

Figure 2.8 - Education: time spent in public transport compared to driving a car or a motorcycle (one way)



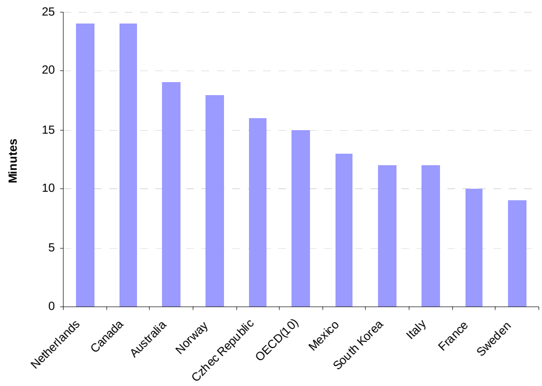
Source: 2008 OECD Household Survey on Environmental Behavior.

Figure 2.9 - Shopping: time spent in-public transport compared to driving a car or a motorcycle (one way)



Source: 2008 OECD Household Survey on Environmental Behavior.

Figure 2.10 - Professional activities: time spent in public transport compared to driving a car or a motorcycle (one way)



Source: 2008 OECD Household Survey on Environmental Behavior.

2.5 Estimation

The main purpose of this chapter is to model mode choice. For this, a discrete choice model is specified.

2.5.1 Mode choice

The estimation technique for modeling mode choice is detailed in McFadden (1973). A person chooses from a finite set of J modes of transport to a given destination. The modes of transport are walking, private car, public transport, bicycle and motorcycle. The destinations available are commuting to and from work, visiting family and friends, shopping, education, sports and cultural activities, and usual professional activities.[32]

Here, we model mode choice by specifying a model proposed by McFadden, which is known as the conditional logit. In this model it is possible to include variables that are either variant or invariant over alternatives. In extreme cases, estimations are possible even when variables differ only across individuals and not by alternative (as in the case of multinomial logit), or when variables differ only over the alternative set. Moreover, in a general case the model allows the alternatives to be non-mutually exclusive (that is, a person can choose more than one alternative), which was the case in the survey.

The dependent variable for each individual in the sample is represented by a vector containing only ones and zeros. When element j is equal to one, it means that mode j is chosen, and zero otherwise.

In principle, motorcycle was one of the modes of transport available; however, since the number of respondents using this kind of vehicle was extremely low, irrespective of the purpose of the trips, we assumed trips by motorcycle and by car as equivalent.

A vector for each respondent was constructed in the following way: the size of the vector is 4x1, each row represents a mode of transport (walking, auto, public transport or cycling), if the row j is equal to one, it means that the person transport by this mode to any of the six destinations considered. Table 2.2 presents the frequencies of observations.

[32] Refers to independent work.

Table 2.2. Mode choice frequencies.

	Choice				
Mode	**0**	**%**	**1**	**%**	**Total**
walking	5,745	0.56	4,506	0.44	10,251
car	1,490	0.15	8,761	0.85	10,251
public	5,875	0.57	4,376	0.43	10,251
bicycle	8,377	0.82	1,874	0.18	10,251

For example, 43% of respondents uses public transport for at least one of the six destinations. These vectors define the dependent variable of the model.

Formally, the theoretical framework of the model is described next: a person that faces *J* alternatives has a utility function that can be represented as follows:

$$U = V(x) + \varepsilon$$

Where x is a group of variables that may contain attributes of the alternative and/or characteristics of the person; $V(x)$ is not stochastic and reflects representative likes of the population; and ε is stochastic and represents the idiosyncrasy of the person towards the alternative j (Mc Fadden, 1973).

The person chooses the alternative that maximizes its utility such that:

$$U(x_j) > U(x_i) \quad \forall j \neq i$$

Therefore, the probability that a randomly chosen person from the population chooses the alternative j is equal to:

$$P[\varepsilon_j - \varepsilon_i < V(x_i) - V(x_j) \quad \forall j \neq i]$$

In order to estimate this probability, it is necessary to assume the form of the distribution from the stochastic part of the utility function. Mc Fadden (1978) demonstrated that if the accumulative function of distribution has a GEV (*Gumbel Extreme Value*) form, then the probability has a logistic form that can be expressed as (Train, 1980):

$$P_j = \frac{e^{x_j \beta_j}}{\sum_{i=1}^{J} e^{x_i \beta_i}}$$

Depending on the type information available, it is possible to specify different models for the estimation of the β_j coefficients. In essence, there are two models that are frequently used in literature: the multinomial *logit* and the conditional *logit*. The fundamental difference between them is the type of variables used in their estimation. In the first case, the types of variables that are used vary by individual but do not vary with the alternatives. In the latter, the variables vary per alternative. However, there is an algebraic equivalence between both models (Long, 1997), which allows us to generate an intermediate model which takes advantage of the two models.

McFadden (1973) established the general conditional *logit* estimation method. Variables that only vary per individual or variables that only vary per alternative can be used by using such model. In essence, the way in which the variables that do not vary per alternative are transformed is by interacting the variables with indicators (*dummies*) of the alternatives. A maximum likelihood method is used and in order to identify the model, it is assumed that the parameters for given alternative are equal to zero.

In addition, the McFadden model has the advantage that the person elections do not have to be mutually exclusive. That means that the dependent variable, represented by a one and zero vector, may contain more than one number one. The study also describes how the way in which a person chooses more than one alternative is weighed in the maximum likelihood function.

The general model permits to include mode-specific and individual-specific variables. However, by the nature of the data, there were not available variables of the former type. Thus the estimated probability takes the form:

$$P_j = \frac{e^{x \beta_j}}{\sum_{i=1}^{J} e^{x \beta_i}}$$

Estimation of the β is carried out by maximum likelihood as detailed in McFadden (1973).

It is important to say that it is necessary to restrict the coefficients for identification of the model. In particular, the most common way to do this is to constraint the coefficients of a certain mode equal to zero. This mode is known as the base outcome. Here we chose to consider car as the base outcome. Then, if the coefficient of variable *x*, for mode *j* is positive, it means that the as *x* increases, the odds of using mode *j* are greater than transporting by car.

The set *x* includes socio-demographic characteristics and spatial characteristics, Annex 2.2 shows summary statistics about the variables employed in the estimation.

It has been recognized elsewhere that car ownership level and choice of mode are endogenously determined. In other words, having a car determines the choice of mode, but at the same time preferences over modes of transport influence the decision of car ownership level. Several approaches have been taken to model this issue. One of the most relevant studies on the topic is found in Train (1980), who estimates the joint probability of choosing mode *j* and having a car ownership level *i*. In more recent studies, different approaches have been adopted. For example, Dargay and Hanly (2004) implicitly assume a reduced model of mode choice by excluding car ownership. Nolan (2002) estimates a model of public transport use that distinguishes between households without a car and those that own a car.

Here we present results for a conditional logit reduced model (excluding car ownership level). A reduced model is used because a structural model which explains jointly car ownership and mode choice would require information that is not available in the dataset. In particular, a nested logit model would be suitable for this purpose. However, such a model would require some alternative-variant information such as the cost of travelling by different modes or the time spent in using each mode. This kind of information is difficult to gather as it frequently implies a hypothetical situation. For example, if someone never uses public transport, it would be unreasonable to ask this person how much time he or she would spend in public transport. While it is theoretically possible to generate this information, the data are likely to be grossly wrong in a study such as this that focuses on commuting by public transport. Though a structural model would be useful, a reduced model also enables us to make predictions, which is adequate in terms or public policy.

Several specifications were tested for this work. For example, multinomial logits were estimated to compare results with those presented in the following sections. In addition, multinomial probits were also estimated. As these two models require the alternatives to be mutually exclusive, they were estimated only for the sub-sample of people who chose only one alternative. There were no significant differences in the results between models in terms of both significance and magnitude.[33]

Finally, the number of observations included in each one of the models (which are detailed in Annex 2.3) was determined by the number of respondents who chose any of the four available modes of transport. Therefore, all those cases where the "not applicable" option was chosen were excluded from the estimations.

Having explained the model specification, results from conditional logit estimations are presented next.

■ *Main findings*

Table 2.3 presents the estimated coefficients, a conditional logit was estimated for each country and for the aggregated data separately. Taking the results for all ten countries we find that income has a negative effect on the probability of choosing a mode different from by car, that married people are more likely to transport by car (this result comes by observing the significant coefficients of the variables 'living with parents', 'living alone', 'living as a single parent', 'sharing residence with familiars or friends').

Also, different to what has been observed elsewhere, it seems that being a female does not determine mode choice; however, it is observed that a male that earns the most in the household is more likely to transport by car. Furthermore, middle aged people prefer car over other modes. As the number of children is greater the likeliness to transport by a different mode than car decreases. Education does not seem to affect mode choice; however, being a full-time worker does has an impact on mode choice by making less likely to take trips by foot, by public transport or cycling. Finally, spatial characteristics of residence seem important, as households located at detached houses are more likely to travel by car, and the opposite is true for those located in urban areas.

[33] When averaging the conditional logit coefficients (when they are significant) with the significant ones from the multinomial probit estimation, a factor of 1.53 is obtained, meaning that in average the logit coefficient is 1.53 times the probit coefficient, a result that agrees with empirical findings between probit and logit coefficients.

Table 2.3 Conditional logit estimation

Variable	mode	OECD(10)	CA	NE	FR	MX	IT	CZ	SW	NW	AU	KO
lincome	walk	-0.362	-0.417	-0.565	-0.387	-0.277	-0.084	-1.314	-0.734	-1.213	-0.818	-0.078
	public	-0.415	-0.384	-0.822	-0.003	-0.434	-0.087	-1.130	-0.578	-1.283	-0.627	-0.238
	bicycle	-0.217	-0.306	-0.756	-0.222	-0.219	-0.068	-1.431	-0.718	-1.440	-0.282	0.056
q1parents	walk	0.250	0.829	1.806	-0.279	0.702	-0.051	1.336	0.245	-0.204	1.214	0.409
	public	0.789	1.598	2.021	0.079	0.942	0.358	1.874	1.060	-0.090	1.427	1.100
	bicycle	-0.149	0.637	0.056	-0.297	0.229	-0.344	0.501	0.453	0.084	0.265	1.232
q1alone	walk	1.243	1.003	1.440	0.630	0.784	1.295	2.165	1.479	1.630	0.249	1.242
	public	1.687	1.515	2.214	1.510	1.186	1.546	2.779	1.553	1.843	0.667	1.240
	bicycle	1.397	0.659	1.385	0.919	1.890	1.479	1.288	1.629	1.561	1.148	1.778
q1sparent	walk	1.237	1.032	1.500	0.466	1.860	0.604	1.595	1.219	1.264	0.810	1.257
	public	1.483	1.455	1.976	1.198	1.486	0.762	2.026	0.687	1.503	1.377	1.567
	bicycle	1.336	0.127	1.320	1.376	1.916	1.090	1.095	1.062	1.339	0.752	2.122
q1sharing	walk	1.465	2.333	1.765	0.815	0.833	1.132	3.598	1.058	2.215	0.414	1.345
	public	2.050	3.085	2.760	1.836	1.280	2.042	3.832	2.971	1.411	0.699	1.862
	bicycle	1.246	1.790	2.129	-12.653	1.558	0.446	3.332	1.385	0.906	-0.361	1.292
female	walk	0.072	-0.955	-0.580	0.081	-0.264	0.589	0.141	0.408	-0.691	0.227	0.993
	public	0.050	-0.895	-0.723	-0.337	-0.162	1.185	-0.046	-0.022	-0.473	-0.302	1.458
	bicycle	-0.259	-2.557	-0.861	-1.608	-0.063	0.499	-0.750	-0.004	-0.685	-0.562	1.154
male_earnm~t	walk	-0.356	-0.617	-0.458	-0.212	0.054	-0.736	-0.993	0.003	-0.796	-0.061	-0.004
	public	-0.600	-0.778	-0.935	-0.967	-0.182	-0.246	-1.232	-0.302	-0.850	-0.663	-0.207
	bicycle	-0.239	-0.698	-0.842	-0.437	0.672	-0.065	-1.207	-0.085	-0.515	0.465	1.347
age	walk	-0.112	0.025	-0.006	-0.041	-0.171	-0.122	-0.058	-0.111	-0.165	-0.014	-0.189
	public	-0.144	0.088	-0.033	-0.115	-0.294	-0.206	-0.112	-0.167	-0.090	-0.091	-0.279
	bicycle	-0.075	0.165	-0.089	-0.078	-0.091	-0.141	-0.059	-0.062	-0.216	-0.229	-0.077
age2	walk	0.001	0.000	0.000	0.000	0.002	0.002	0.001	0.001	0.002	0.000	0.002
	public	0.001	-0.001	0.000	0.001	0.003	0.002	0.001	0.002	0.001	0.001	0.003
	bicycle	0.001	-0.002	0.001	0.000	0.001	0.002	0.001	0.000	0.002	0.003	0.001
adults	walk	-0.020	0.016	-0.008	-0.195	-0.044	-0.016	0.050	0.505	0.421	-0.334	-0.161
	public	0.184	0.245	0.182	0.373	0.067	-0.003	0.001	0.279	0.542	0.055	-0.006
	bicycle	-0.066	-0.041	0.065	-0.076	0.346	0.092	0.022	0.447	0.488	0.391	-0.047
children	walk	-0.013	-0.066	-0.256	0.234	0.165	0.185	0.320	-0.091	-0.457	-0.122	-0.188
	public	-0.096	-0.043	-0.401	0.045	0.173	0.048	0.343	-0.090	-0.662	-0.298	-0.416
	bicycle	-0.143	-0.209	-0.031	-0.097	0.136	-0.028	0.309	-0.325	-0.551	0.101	-0.219
educated	walk	-0.258	0.227	0.196	-0.074	-0.764	-0.135	-0.024	-0.085	1.009	-0.650	-0.529
	public	0.007	0.358	0.025	-0.073	-0.701	0.429	-0.097	0.089	1.474	-0.159	-0.657
	bicycle	-0.133	-0.317	0.311	-0.322	-0.835	-0.210	-0.665	0.090	1.660	-0.507	-0.853
ws_emp_ft	walk	-0.747	-0.305	-1.611	-0.961	-0.164	-0.620	-0.043	-0.822	0.063	-0.408	-0.867
	public	-0.591	-0.310	-1.447	-0.696	-0.097	-0.423	0.002	-0.852	0.259	-0.326	-0.496
	bicycle	-0.862	-0.618	-1.264	-1.087	-0.664	-0.724	0.554	-0.789	0.738	-0.182	-0.430
detached	walk	-1.164	-1.364	-1.240	-1.715	-0.711	-0.627	-1.444	-2.242	-1.475	-1.533	0.488
	public	-1.436	-1.995	-0.752	-1.890	-1.108	-0.591	-1.438	-2.927	-1.636	-2.050	-0.341
	bicycle	-1.514	-1.139	-0.035	-0.708	-0.300	-0.769	-0.596	-1.935	-1.162	-1.752	0.891
urban	walk	0.957	1.190	0.858	1.724	-0.189	1.123	0.839	0.506	2.095	0.917	0.319
	public	0.805	1.503	0.857	1.850	-0.067	0.288	1.115	-0.042	1.202	0.411	0.214
	bicycle	0.265	1.192	0.419	1.229	-0.184	0.157	0.271	0.640	1.260	0.265	-0.035
_cons	walk	4.450	1.947	4.843	3.392	5.564	-0.163	11.394	8.003	12.974	8.017	3.094
	public	5.109	-0.292	7.436	-0.896	9.155	1.122	10.229	8.606	12.445	6.974	7.148
	bicycle	1.658	-1.857	9.370	1.563	-0.329	-0.913	11.107	6.070	14.041	2.339	-4.275

NOTE: shaded cells indicate that a coefficient is significant at the 95% level of confidence.

There are differences across countries, both in terms of magnitude of estimated coefficients and on their statistical significance. For example, the effect of income in mode choice is significantly larger than the one obtained from the full sample in the cases of Czech Republic, Sweden, Norway, Australia and The Netherlands. For Mexico this effect is similar to the coefficients of the full sample and for the other countries it seems that there is no effect of this variable on mode choice. The sign and magnitude of the coefficients for the different civil status variables show to be more consistent across countries, with the exception of Czech Republic, where it appears to be a more pronounced effect of these variables on mode choice, compared with the coefficients of the full sample. The coefficients of the two variables related to gender differ greatly from country to country; in particular, it seems to be a significant effect in Canada and Czech Republic. The age variable has coefficients with the expected sign; however, their significance varies largely across countries. The same occurs with the number of adults and of children. The effect of education on mode choice is very ambiguous; it seems to decrease the likelihood of travelling by car for Norway, decrease it in South Korea and to have no effect on the rest of the countries. Being a full-time worker has a similar effect across countries. Spatial characteristics also have the expected sign and they are found to be largely significant across countries, with the exception of South Korea, where the coefficients associated to the 'detached' variable have the opposite sign as the one expected.

Table 2.4 presents the predicted probabilities, evaluated at the mean of each variable for each country. In this table we can observe clearer the differences across countries.

Table 2.4 predicted probabilities evaluated at means values by country

	mode			
Country	**walk**	**public**	**bicycle**	**car**
OECD(10)	9%	8%	2%	81%
CANADA	6%	4%	1%	89%
NETH	9%	6%	19%	65%
FR	5%	2%	0%	92%
MX	11%	12%	1%	76%
IT	5%	5%	1%	89%
CZ	17%	12%	3%	68%
SW	12%	13%	5%	70%
NW	4%	4%	1%	91%
AU	4%	3%	0%	94%
KO	12%	37%	1%	50%

2.5.2 Mode choice and attitudes towards the environment

The Survey gathered a vast set of data related to attitudes of respondents towards the environment. It is relevant to ask if these attitudes influence actual behavior, in particular, if they affect mode choice. However, to answer this question we must take into account the potential endogeneity of these attitudes in mode choice for the latter may influence the former (Golob *et al.*, 1979). Then if we include variables that measure attitudes towards environment directly into estimations they will be biased.

Unfortunately, up to date we do not have a standard technique to deal with the endogeneity issue in non-linear models. However, the instrumental variables probit model (IV Probit) is useful to our purposes. This model is analogous to the two-stage least squares model (2sls), which consists basically in running a regression of the endogenous covariate as a function of all exogenous variables in the model and its instruments in a first stage and, in a second stage, running a regression of the dependent variable as a function of the exogenous variables, including the predicted values of the endogenous covariate as another regressor. The main difference between 2sls and IV Probit is the nature of the dependent variable, where in the first case is continuous and in the second dichotomic.

Here we specify an IV Probit by constructing an index related to attitudes towards environment. This index considers eight questions of the Survey related to the degree of concern of the respondent to different environmental issues, namely:

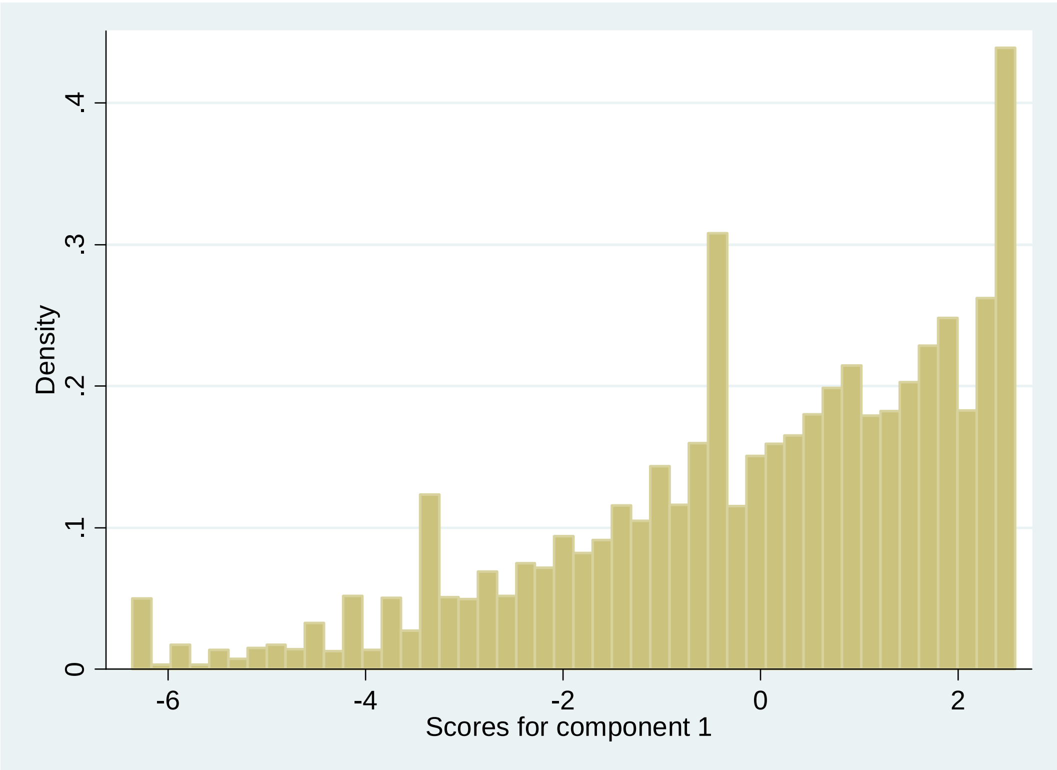
- Waster generation
- Air pollution
- Climate change
- Water pollution
- Natural resource depletion
- Genetically modified organisms
- Endangered species and biodiversity
- Noise

For each one of these issues the respondent could choose from five alternatives: 'not concerned', 'fairly concerned', 'concerned', 'very concerned' and 'no opinion'[34]
Each option was assigned a number from 1 to 4, respectively. These values are arbitrary and only reflect an ordering of the attitudes of respondents. Therefore, they only give a qualitative dimension of the attitudes of respondents. With the eight answers to each question an index was constructed by the principal components method, which basically consists in obtaining a weighted average of a set of variables by assigning a factor to

[34] The frequency of the 'no opinion' option does not exceed 2.2% of total responses in 7 of the 8 questions. In the case of the genetically modified organisms question this percentage ups to 4.7%. We chose to drop out these observations in the construction of the index because their low frequency and because including them do not change largely the estimated coefficients.

each one of them. These factors are obtained by calculating the eigenvectors and eigenvalues of the correlation matrix of the variables. Each element of the eigenvector of the largest eigenvalue represents the factor associated to each variable. In our context, the main advantage of this method is that it permits to generate a continuous variable from discrete ones; this is necessary since the IV Probit requires the endogenous regressor to be continuous. Figure 2.11 presents the histogram of this index. As can be seen the index reflects that the respondents stated a high degree of concern respect to environmental issues.

Figure 2.11. Index of attitudes towards environment.



This index was regressed against five instruments, four of them are dummies which indicate the highest degree of education attained by the respondent, namely, primary education, secondary, post-secondary and post-graduate education and one dummy which indicates if the respondent preferred not to answer the education question. The education dummies are correlated with the attitudes towards environment issues, in particular, as the level of education increases the level of concern is higher. The other regressors are the variables included in the model of mode choice, described in the previous section, excluding the 'educated' variable (which is equal to one if the respondent had post-secondary education or a higher degree).[35] The rationale to excluding it was based on the lack of significance that it showed in the model of mode choice and because it was the best proxy of the level of concern towards environmental issues available in the dataset.

The dependent variable of the IV Probit estimation is a dummy variable which is equal to one if the respondent chose car transport by any of the six destinations considered. That is, this variable is the same as the one considered in the mode choice model, yet excluding other modes.[36] Table 2.5 presents the results of estimations for both the first and second stages, for each country and for the full sample.

Table 2.5. IV Probit estimation

	First stage, OLS estimation										
dep. var. indexatt	**OECD(10)**	**CA**	**NE**	**FR**	**MX**	**IT**	**CZ**	**SW**	**NW**	**AU**	**KO**
Primary	-0.064	0.104	-0.369	-0.017		-0.193	-0.038	-0.191	-0.525	0.034	0.089
Secondary	-0.128	-0.045	-0.104	0.074	-0.010	-0.244	-0.203	-0.161	-0.406	0.064	0.117
Bachelor	0.124	0.012	-0.261	0.111	-0.026	-0.231	0.057	-0.075	-0.089	0.196	0.272
Postgrad	0.109	-0.251	0.045	0.033	-0.015	-0.821	-0.708	-0.538	0.406	0.647	0.676
nores_educ	0.017		1.615	-0.244	0.083	0.143	0.162	0.340		-0.861	-0.073
lincome	-0.398	0.035	-0.370	-0.028	0.025	-0.140	0.166	-0.433	0.109	-0.338	0.142
q1married	0.030	0.153	-0.193	0.413	0.123	0.123	-0.171	0.073	-0.092	-0.049	-0.066
female	0.354	0.308	0.158	0.142	0.327	0.388	0.530	0.783	0.376	0.438	0.270
male_earnm~t	-0.024	-0.022	-0.311	-0.095	-0.016	0.083	0.255	-0.177	-0.075	-0.122	0.243
age	0.037	0.050	-0.009	0.082	0.036	0.067	0.044	0.086	0.020	-0.007	0.062
age2	0.000	0.000	0.000	-0.001	0.000	-0.001	-0.001	-0.001	0.000	0.000	-0.001
adults	0.186	0.023	0.002	0.029	0.014	0.031	-0.070	-0.078	-0.019	-0.010	0.018
children	-0.044	-0.257	0.092	-0.271	0.024	-0.468	-0.092	0.043	-0.002	-0.126	0.087
detached	0.274	-0.187	-0.232	0.018	-0.071	0.074	0.319	-0.163	0.011	0.204	-0.175
ws_emp_ft	0.103	-0.070	-0.170	-0.023	0.025	-0.120	-0.281	0.100	0.023	0.171	0.063
urban	0.266	-0.082	0.103	-0.134	0.116	-0.042	0.034	0.135	0.043	-0.088	0.145
_cons	2.150	-1.600	2.586	-1.798	0.291	0.683	-2.363	1.199	-3.227	3.004	-2.835

[35] Even when the education level did not show relevant statistical significance in the mode choice model, the 'educated' variable in particular showed the higher significance in that model from different variables tested, for example, the model was estimated including dummies for each level of education, and the coefficients associated to the referred variable were always more significant.
[36] It is important to note that the Independence of Irrelevant Alternatives (IIA) assumption is not required by the Probit estimator, then we can estimate the choice for each mode, independently. We focus this estimation only in car choice as it is has the largest impact from an environmental point of view.

	Second stage, Probit estimation										
dep. var. Choice_car	OECD(10)	CA	NE	FR	MX	IT	CZ	SW	NW	AU	KO
indexatt2	0.301	-0.391	-0.342	0.704	-1.627	0.780	-0.155	0.019	-0.647	-0.206	0.083
lincome	0.293	0.314	0.411	0.034	0.225	0.150	0.546	0.353	0.693	0.417	0.068
q1married	0.528	0.640	0.615	0.027	0.686	0.230	0.839	0.486	0.523	0.347	0.493
female	-0.163	0.569	0.393	-0.114	0.517	-0.673	0.126	-0.039	0.361	0.321	-0.553
male_earnm~t	0.164	0.339	0.164	0.297	-0.033	0.201	0.435	0.025	0.203	0.276	0.127
age	0.027	-0.036	-0.003	0.001	0.114	0.017	-0.004	0.050	0.032	0.035	0.094
age2	0.000	0.000	0.000	0.000	-0.001	0.000	0.000	0.000	0.000	0.000	-0.001
adults	-0.008	-0.034	0.100	0.081	0.069	0.080	0.044	-0.042	-0.126	0.023	0.042
children	0.030	-0.038	0.054	-0.023	-0.116	0.044	-0.100	0.116	0.294	0.031	0.084
detached	0.443	0.505	0.085	0.554	0.217	0.146	0.592	1.080	0.549	0.799	-0.065
ws_emp_ft	0.267	-0.015	0.580	0.316	0.121	0.198	0.114	0.572	-0.040	0.238	0.190
urban	-0.382	-0.588	-0.289	-0.600	0.159	-0.150	-0.317	-0.103	-0.521	-0.232	-0.068
_cons	-2.661	-2.058	-4.745	0.687	-1.813	-0.664	-4.587	-4.534	-8.423	-4.855	-1.858

*Shaded cells indicate that the coefficient is statistical significant at the 95% level of confidence.

As it was the case with the mode choice model, the full sample coefficients show higher statistical significance than at a country-level and their sign is congruent with the results of the previous section. Regarding to the attitudes towards environment index we observe that it does not have a significant effect on the decision of transporting by car considering the full sample and for eight countries. However for Italy and Norway a significant effect is found, yet with an opposite sign. The counterintuitive sign for Italy might be explained because the lack of significance of the income coefficient; since we are considering the education level as a proxy of environmental attitudes it may be the case that what the coefficient of the 'indexatt' variable is capturing is an income effect.

In the case of Norway, the coefficient of the 'indexatt' is as expected and the income variable is significant, therefore it seems that for this country specifically, the level of concern regarding environmental issues in fact influences actual behavior, yet that is not the case for the rest of the countries.

We must highlight that the estimations of the first stage showed a very low predictive power, reflecting that the instruments were not very effective to predict the endogenous regressor. However, it is relevant the case of Norway where in the first stage two of the four education dummies are significant and also is the country with the largest number of significant coefficients at the second stage. Therefore, this might be some evidence that if education increases the level of concern towards environmental issues, then actual behavior may be affected as well.

2.6 Policy implications

In this work we found evidence that supports previous results regarding how sociodemographic and spatial characteristics influence mode choice. The main contribution of this study is to analyze a large dataset which includes information from ten countries. These data permitted to compare the effect of different variables between countries. Another relevant finding indicates that environmental attitudes do influence mode choice, we present a discussion of these results next.

Socio-demographic characteristics seem to be important in determining transport decisions. In particular, middle-aged married people in full-time employment, with larger incomes are most likely to use their car. This implies that policies should target certain segments of the population to have the greatest impact.

Differences between countries show that unobserved characteristics do have a significant impact on mode choice. At a regional level it seems that in those regions with big cities, using public transport or walking is easier. This may reflect that public transport networks are more accessible, and that the distances to given destinations are shorter. In this example, urban planning could be a key factor to promote modes other than driving.

Respondents' perceptions of public transport characteristics have been analyzed. The outcome is that many people would willingly use their car less if public transport was improved and cheaper. In contrast, improving cycling infrastructure would have a smaller impact. Moreover, rapidity is the most valued feature of public transport, with a large share of respondents stating they would "very likely" reduce car use if public transport was more rapid. Reliability is the second most appreciated feature. In third and fourth places are convenience and comfort but safety is very important in countries such as Mexico and South Korea and less important in several European countries. We can therefore recommend focusing public investment on improving certain aspects of public transport in order to attract more passengers and reduce car use.

Finally, regarding to environmental attitudes we find some evidence indicating that they indeed influence mode choice. Unfortunately, the information in the dataset was not rich enough to obtain robust results; however, it seems that, at least, people in Norway take their transport decisions influenced by their degree of concern towards environmental issues. This result suggests that not only economic policies may prove useful to influence behavior but soft policies (such as information policies, and those which promote environmentally friendly behavior) do too. Naturally, it raises the question about which of both kind of policies are more cost-effective, which is beyond the scope of this work and for the same it would be a relevant field of research for the future.

2.7 Conclusions

The transport sector is one of the major contributors to greenhouse gas emissions. According to the UNFCCC (2007) its contribution is around 20% of total emissions. Reducing emissions is one of the biggest challenges for all countries today. A key factor for adopting and designing environmental policies is first to understand how people take transport decisions.

Many studies have been undertaken with the objective of unveiling the determinants of transport decisions. Research on this topic was motivated by two key factors: the relevance it has in terms of policy design and major advances in estimation techniques in recent years.

In this chapter mode choice has been analyzed using disaggregated data obtained from the 2008 OECD Survey on Household Behavior and Environmental Policy. The survey was implemented in ten countries and responses were obtained from 10,251 households.

A conditional model was specified to analyze mode choice and a IV Probit to analyze the effect of environmental attitudes on these decisions. The set of exogenous variables includes socio-demographic characteristics, attitudes towards environmental issues, nature of the trips and attitudes towards public transport.

Choices were analyzed for four different modes: walking, car/motorcycle, public transport and bicycle. The main findings are that income has a positive and significant effect on the probability of using one’s car. People with a status other than marital or living as a couple (that is, living alone, as a single parent or sharing a house/flat with friends) are most likely to walk, use public transport or cycle. Men with the higher earnings in the household are less likely to use public transport or cycle. Middle-aged people have lower probabilities of using public transport or cycling. The probability of walking and using public transport rather than driving increases with the number of adults in the household. The number of children in the household has a negative estimated effect on the probability of using public transport. The probability of using public transport or cycling rather than driving is greater for people with a post-secondary education or a higher degree.

Full-time employees prefer not to walk and are less likely to use public transport or their bicycle and have a higher probability of driving to work.

As the size of the municipality decreases, the probability of choosing a mode other than the car is less than one.

Countries reflect large differences in fixed effects that other variables are unable to explain. This means that there are unobserved characteristics that variables in the model do not account for. These could be institutional factors, quality and scale of public transport infrastructure, the range of car expenses, public policies, among others. Some policies such as subsidies to public transport should target certain segments of the population according to their socio-demographic characteristics if they are to have the greatest impact.

Moreover, we found some evidence that indicate that environment attitudes of people in Norway have an impact on their transport decisions, making them less likely to use car as they are more concerned with environmental issues.

The main objective of environmental policies on transport decisions should be to promote the use of alternative modes, at the least possible cost (pecuniary and other). On the other hand, soft policies and pricing measures are less constraining on public sector budgets, but they imply investing sums of money that are much larger than the effects they bring.

The large differences between countries reflect unobserved characteristics that explain differences in behavior. These unobserved characteristics could be institutional factors, the extent of public transport infrastructure, different car expenses, and public policies, among others. Thus, it would be helpful to compare these factors between countries to determine which of them have the greatest potential of promoting the use of alternative modes, in addition to the effects of socio-demographic characteristics, attitudes towards environment issues, characteristics of the trips, attitudes to public transport, among others factors that were analyzed in this chapter.

The object of this chapter is to contribute to the knowledge of what determines transport decisions, which is essential for helping countries in the processes of designing and planning environmental policies. This would contribute to resolve one of today's major challenges, namely reducing polluting gases emitted by the transport sector.

Premium or Magna?

Abstract

This study analyzes fuel choice by households in the Metropolitan Zone of Mexico City. In this context, a survey was carried out in 498 households to obtain information about their consumption patterns, attitudes towards environment, vehicles, and socio-demographic characteristics. The results of the survey reflect that large differences exist between Magna and Premium users with respect to income level, schooling, number of cars owned, motivation to consume a certain type of fuel and their attitude to public transport.

With the collected information a conditional *logit* model was specified to analyze the determinants of fuel choices. The estimation results indicate that Magna users choose this fuel because of budget constraints and Premium users choose this other fuel because they want to use the right gasoline for their vehicles and because of environmental concerns.

It was also concluded that the decision of household members to do other activities to contribute to the improvement of the environment is not related to the decision of choosing a certain type of fuel. In addition, the study shows that no other socio-demographic characteristic determines such decision.

On the other hand, it seems that increasing the relative price of Magna gasoline would increase public transport use; however, it would probably not increase the probability of becoming a Premium user. Finally, the probability of being a Premium user relative to the probability of being a Magna user is very elastic to changes in the income level, yet only to those households with an income level above the average.

JEL Classification: C35, Q31, Q50,R48

Keywords: Discrete choice, fuels, environmental policy, climate change.

3.1 Introduction

Fuel use on automobiles in México presents two important challenges from an economic and environmental point of view. First, the use of fossil fuels is one of the factors that have a major impact in the global warming process. It is important to mention that fuel use in the transport sector generates 14% of carbon dioxide emissions (Stern, 2006). In addition, per capita carbon dioxide emissions are above the world average in Mexico (UNEP/GRID-Arendal, 2005).

On the other hand, the fuel market structure in Mexico has developed on a context of demand pressure and supply restrictions. As it is pointed out by the Ministry of Energy (SENER, which stands for Secretaría de Energía in Spanish), during the period 1996-2006 the average growing rate of the fuel demand was 4.1% and it is estimated that this tendency will continue during the next years, observing an annual average rate of 3.8% until 2016.

From this perspective, Mexican Oils (acronym in Spanish PEMEX) has not had the capacity to satisfy the total demand. As a result, during 2006, 38.2% of the total demand of gasoline was covered with imports. At that time, it was estimated that for the next ten years the deficit would be of around 32.6% in average (SENER, 2007).

However, the environmental and economic aspects are not independent. It also seems that the type of gasoline used is important for both. One of the required instruments to analyze together those aspects is an estimation of the demand function. This paper presents a first attempt to estimate this demand. Now it turns more evident that environmental impacts have direct effects on social and economic welfare.

Therefore, it is imperative to look for options that help us deal this problem, which has negative environmental consequences. One of these options is to promote the use of more efficient and environment-friendly fuels. However, it is not enough to overcome the technical challenges only, but also the ones raised by the market. In this context, the present work studies the fuel demand aspects analyzing the role of relative prices, information and income over people preferences, with the objective of issuing recommendations to public policies in order to promote the use of more environment-friendly fuels.

To achieve the proposed objective a survey in the Metropolitan Zone of Mexico City was carried out. Its purpose was to obtain information about consumption habits related to the two kinds of gasoline that are available in the market (Premium and Magna), and about other characteristics of the households in this zone.

With the collected information an econometric model was developed in order to identify fuel consumption determinants. In particular, a discrete choice model was specified, which is consistent with the theory of expected utility maximization.

Main findings of the survey show that the decision about the kind of gasoline to consume depends mainly on its characteristics and that Premium users have very different motivations than Magna users. In particular, it was found out that Magna users consume this fuel because of its price and Premium users choose the other because they consider that is the best gasoline for their cars. It was also concluded that Premium users are strongly motivated by environmental considerations. Finally, it seems that other characteristics of the households different to income have no influence on fuel decisions.

The structure of the chapter is as follows: section two presents some technical information and the evolution of the analyzed fuels; section three provides a short revision of existent literature; the fourth section describes sample design; section five presents descriptive data of the information obtained and the econometric estimation; the sixth section outlines policy recommendations, and in the seventh, the more relevant conclusions are presented.

3.2 Gasoline Evolution in Mexico

Currently, there are two types of gasoline on the market: Premium and Magna. Although these are the generic names with which this two fuels are known, a more detailed analysis shows that each have suffered deep changes during time and even the same denomination is used to name different gasoline formulas, depending on the geographic ambit where they are sold.

Magna Sin gasoline (actually Magna) was introduced into the market on September 1990 (PEMEX, 2000). The introduction of an unleaded gasoline allowed commercialization of automobiles with a catalytic converter since 1991; it was then possible to reduce contaminant emissions.[37] On October 1996 more rigorous technical requirements were established for Magna gasoline by the environmental authorities. Among those requirements, a more restrictive limit for sulfur content of fuels was set.

[37] It was until 1998 that trade of leaded stopped. (PEMEX, 1999)

In that same year, the Premium gasoline was introduced in the market. Its distinctive characteristic was that it had 93 octanes (six more octanes than the Magna), required for high compression motors. [38]

On May 2004 Premium gasoline was substituted by a low-sulfur Premium, which changed from 500 parts per million (p.p.m.) to an average of 250 and a maximum of 300 p.p.m. of sulfur. Again, on December 2006 a new formula of Premium gasoline was introduced, Premium UBA (Ultra Low Sulfur), which contains an average of 30 p.p.m. and a maximum of 80 p.p.m. of sulfur. On the other hand, Magna gasoline at present contains an average of 500 p.p.m. in metropolitan zones with higher number of population in Mexico and an average of 1000 p.p.m. in the rest of the country (PEMEX, 2006). It was expected that in 2009 a new gasoline, Magna UBA, which contains the same amount of sulfur than the Premium, would be introduced in the market, but until now this has not occurred.

If gasoline evolution in the latest years is analyzed, it may be observed that the efforts have been concentrated in reducing the sulfur level in the gasoline. The role that plays sulfur content in fuels is questioned then. Sulfur is a contaminant that mainly affects the respiratory system. It is estimated that in the Metropolitan Zone of Mexico City gasoline consumption contributes with around a fourth part of total sulfur dioxide emissions (GDF, 2005). This is an example of its importance in the transport sector. Furthermore, the role of sulfur in gasoline is even more relevant. It halts the adoption of technologies used to reduce emissions, such as carbon dioxide, particles, nitrogen oxide and hydrocarbons. In simple terms, the higher quantity of sulfur in gasoline the less the life of the catalytic converter, which results in the inability of the converter to reduce the above mentioned emissions.

It is important to mention that in order to empower to its maximum the capacities of a low-sulfur fuel, the correct technology should be used. Currently, there are vehicles that can guarantee minimum contaminant emissions for a distance of up to 192 thousand kilometers (Molina, 2007). Those vehicles comply with a standard set by the Environmental Protection Agency (EPA) called TIER 2. However, in order to be able to guarantee the mentioned emission levels, it is necessary to use low-sulfur fuels.

In the Mexican context, on September 2005 the Official Mexican Norm NOM-042-SEMARNAT-2003 was published. It establishes the maximum permitted limits of

[38] Further information on octanes can be consulted in (Lopez y Cardenas, 2006)

different emissions for new vehicles weighing less than 3.9 tons that use gasoline. The document recognizes that for fixing those limits (see Table 3.1), a gasoline with an average content of 30 p.p.m. of sulfur and of no more than 80 p.p.m must be fully available.

Table 3.1 Maximum permissible limits of emission for particular new gasoline-vehicles.

Durability Standard km	CO g/km	HC g/km	NOx g/km	HCev g/km	Aver./Max. sulfur p.p.m.
100,000	1.00	0.10	0.08	2.0	30/80

Hence, the introduction of Premium UBA gasoline and the planned introduction of the Magna UBA respond to technical requirements which allow taking advantage of the new automobile technologies used to reduce emissions. However, as it will be explained in the section that describes the collected information in the survey, people believe that the types of gasoline are distinguished by contaminant factors, but at the same time they perceive differences on performance and quality, among other characteristics.

It may be concluded then that there are two main differences between Magna and Premium: (i) the number of octane and (ii) the quantity of sulfur that they contain. In the first case, the number of octane reflects the antiknock capacity of the fuel; specifically a higher octane number requires a major motor compression for its detonation. Thus, the vehicles with a superior degree of compression will take better advantage of the characteristics of the Premium gasoline. According to the PROFECO (2006), an increase in the number of octane is not associated with an increase in the power. In a press release of the Secretary of Finance and Public Credit of 2006 (SHCP, 2006) it is highlighted that the Premium gasoline is adequate for sport and high performance vehicles, while other vehicles are not benefitted from a major octane content of this fuel.

In this same sense, there is a statement in the "practical advice" section of the Volkswagen which confirms the information: "A fuel with an octane content superior to the required for the motor can be used without limits. But there will not be advantages with respect to power and consumption level."[39] However, the opposite is not necessarily true. That is, a car that uses a fuel with less quantity of octane than the required could cause premature detonations, which will derive into an incorrect functioning and low performance.

As it was previously analyzed, in order to take advantage of the second difference between fuels, i.e., lower sulfur quantity, it is necessary to use Premium gasoline in vehicles that comply with the minimum standards set in the Mexican norm or other international regulations. PEMEX took an important step by introducing the fuel needed for this type of vehicles into the market. Nevertheless, the Mexican market still does not offer the ideal vehicles to take advantage of this gasoline benefits.

The introduction of these technologies is an issue whose consolidation is in process. However, an important element to take into consideration is to analyze how the gasoline market works; that is, knowing the determinants of households' decisions to consume certain type of gasoline. This is the principal topic of the present study and the rest of the sections will devote to it.

3.3 Literature Review

The literature about the determinants of the consumption of different kinds of gasoline is scarce. A closely related work to this study is found in Setiawan and Sperling (1993). The authors analyze the increase in the demand of Premium gasoline (gasoline higher than 91 octanes) that was observed in the United States during the 80´s. In the first part of their study they conclude that "…many cars do not actually need high octane gasoline, the purported performance and fuel economy benefits of premium gasoline have not been substantiated, aggregate market analyses show that premium demand is highly elastic, and our survey shows that many drivers have only a vague (and oftentimes mistaken) perception of the benefits of premium gasoline".

In the second part of their study they analyze the willingness to pay for Premium gasoline. To accomplish this objective they establish a *logit* model to analyze how income and gasoline price impact the willingness to pay. Their findings show that people is willing to pay among 4 to 8 cents of dollar for each extra octane in gasoline.

On the other hand, there is a very small number of studies that had analyzed the option of fuels, under the hypothetic situation of alternative fuels in the market. Jobs

[39] http://www.volkswagen.com.ar/servicios_consejos_practicos_1-4.asp

like Brownstone and Train's (1997) and Ahn's *et al.* (2007) use contingent valuation methods to analyze the features of the fuels that motivate the consumer to choose one of them.

Even though literature about the determinants of consumption of different kinds of gasoline is scarce, the intensive development on discrete choices models allows to adequate the different methodologies to the analyzed problem in the present study. Nowadays, there is a big number of empiric studies that were inspired by the studies of D. McFadden (1973, 1978), K. Train (1980, 2003) and T. Amemiya (1981) among others, that provide a theoretical and empiric sustain to the analysis of gasoline election.

The objective of this work is to analyze which factors determine fuel choice of households. For this, we specify an econometric model, in particular, a discrete choice one, in which the dependent variable is a fuel type and the independent variables are characteristics of the households. The data to estimate the model were obtained from a conducted survey in the Metropolitan Zone of Mexico City.

3.4 Design of the Sample

With the objective to collect information about the household preferences of fuel use for auto motors in the Metropolitan Zone of Mexico City (ZMCM for its acronym in Spanish), the sample design of the Metropolitan Survey about the Use of Fuel in Auto Motors (EMUCA for its acronyms in Spanish) was created.

Housing was considered the unity of selection, and households the unity of observation. A probabilistic and multistage type of sampling was used, because the unity of selection was selected after multiple stages.

Cartographic and demographic information corresponding to the ZMCM collected by the INEGI in the II Population and Housing Count 2005 was used as sample frame.

The primary sampling unit was determined as the group of blocks that pertain to a Basic Geostadistic Area (AGEB for its acronyms in Spanish) or to various adjacent AGEB, that have a minimum of 350 households. The secondary sampling unit is formed by one or two contiguous blocks that have a minimum of 35 habited housing.

Two blocks from each AGEB were selected and three households in each block were surveyed. The selection of the housing was made in a systematic way, taking into consideration the number of the house located in the corner with the major orientation to the south. If the three surveys could not be obtained in the block the next southern block was selected.

The sampling primary units were stratified in four areas based on the information of the Population and Housing Count 2005. The variables of the stratification were selected taking into account that no questions regarding income of people living in the household are asked in the Count. In addition, the ZMCM has particular characteristics as it is mainly an urban zone. Consequently, indicators to discriminate between households were chosen. The following variables were considered to stratify the sample:

- Percentage of people between 13 and 15 years old that do not attend school.
- Percentage of people who are 15 years or older with incomplete middle school.
- Average of approved schooling years for people who are 15 years or older.
- Average of children born alive of women between 12 and 19 years old.
- Percentage of households without a washing machine.
- Percentage of households without a refrigerator.
- Percentage of households without a paved floor.
- Percentage of households without piped water in the house.
- Average of occupants by sleeping room.

Size and Precision of the Sample

The size of the sample was calculated by the following formula:

$$n = \frac{z^2 * EF * (1-p)}{e^2 * p * (1-NR)}$$

Where:

n	Size of the sample.
z	Normal distribution value for a certain confidence level.
p	Value of the proportion of households in localities of more than 100,000 habitants that have car and that consume gasoline Premium (p = .24).

EF	Design Effect (Quotient of the variation of the design used by the random sample variance of a same size sample EF = 1.4).
NR	Maximum rate of no response (NR= .12)
e	Maximum relative error in the estimation (e = .195).

With the sample strategy shown earlier the following values were established:

z= 1.96 (95% level of confidence)
EF= 1.4
NR= .12

The result of the sample size was 495 households and a maximum allowed error of .195.

Allocation of the Sample

The sample was allocated proportionally to the population of each zone, and in them, to the proportion resulting from the primary sample units by layer.

With this methodology 82 AGEBS were selected, 40 from the Federal District and 42 from State of Mexico. Annex II shows the geographic coverage of the survey.

3.5 Empirical Results

In this section the main differences between consumer groups (Premium consumers group and Magna consumers group) are presented, according to the results of the survey obtained in the field.

In addition, the results of the econometric estimation are detailed. As it may be observed, the main differences between the groups practically concur with the variables that explain the decision to use certain kind of fuel.

The type of variables analyzed could be grouped into socio-demographic characteristics, attitudes towards the environment and attitudes towards fuel characteristics.

3.5.1 Data Description

In this section the differences of consumer groups are analyzed, separating Magna consumers from Premium consumers. This is considered relevant to determine which variables mainly distinguish each kind of consumers.

Figure 3.1 shows the distribution of the income of the different types of consumers is presented as an example of the comparisons that will be made throughout this section. It can be observed that Premium gasoline consumers have in average, a higher income than Magna consumers. This can be proved by looking at the dotted line (Magna gasoline consumers) which shows a bigger concentration in low income levels (near to the origin). On the contrary, there is a greater mass of Premium consumers in the right side of the graph, where the high income levels are located. The same analysis can be made for other information collected in the survey.

Figure 3.1. Monthly Income

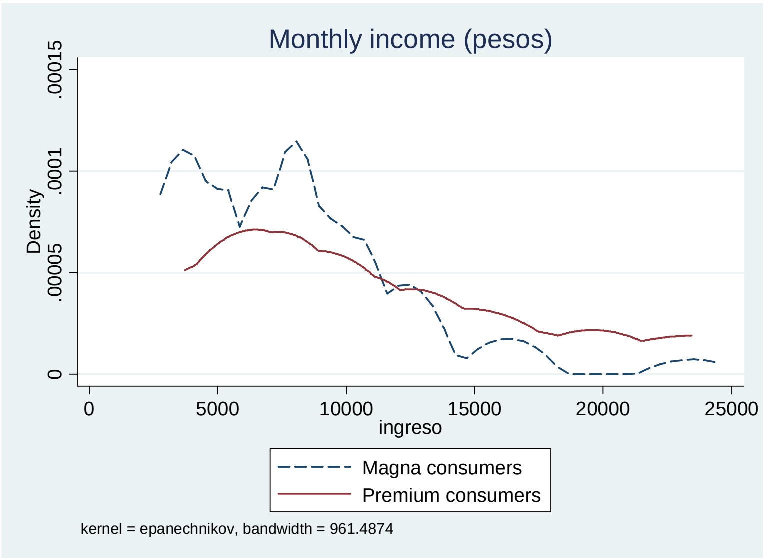
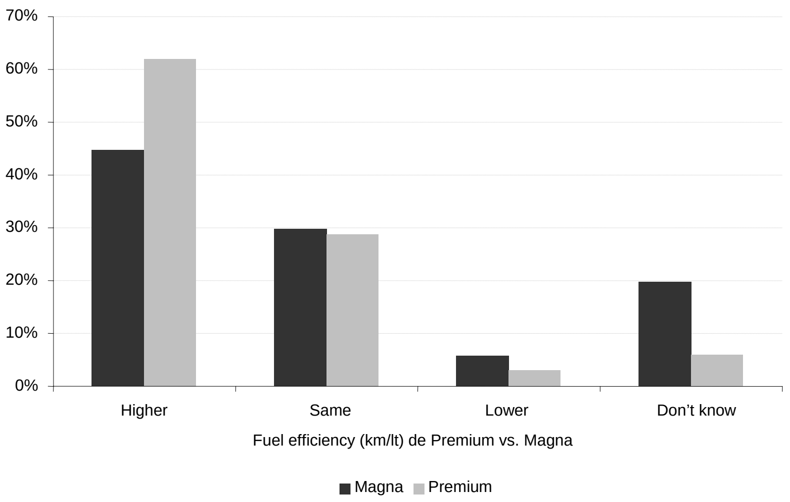


Figure 3.2. Performance Comparison (opinion)



There was a similar pattern when the consumers interviewed were asked to compare both types of gasoline in terms of octane content, power, levels of contaminants released and engine and catalytic converter life, if Premium was used instead of Magna.

The proportion of people that chose the feature favoring Premium was always the highest compared with the ones that chose the neutral option or the negative, regardless type of consumer. That means that generally Premium gasoline is perceived as the best gasoline in all senses. Nevertheless, it can also be observed that the proportion of the group of Premium consumers is always higher to the option in favor of Premium gasoline and lower in the other two cases.

Figure 3.3. Octane Content Comparison (opinion)

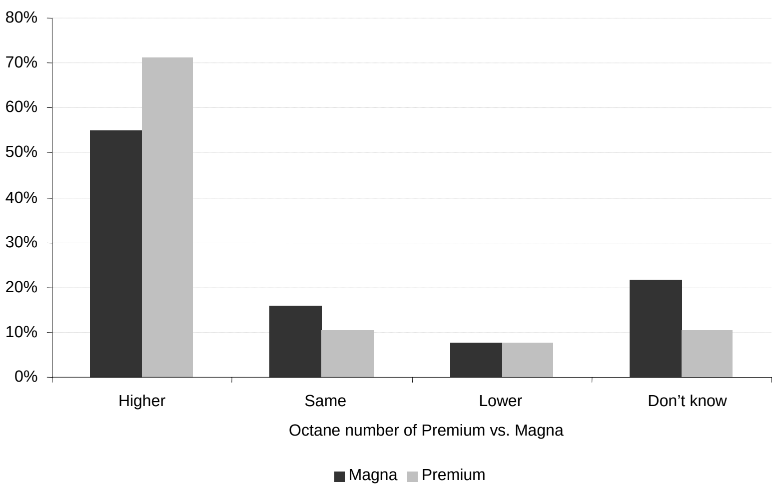


Figure 3.4. Engine power (opinion)

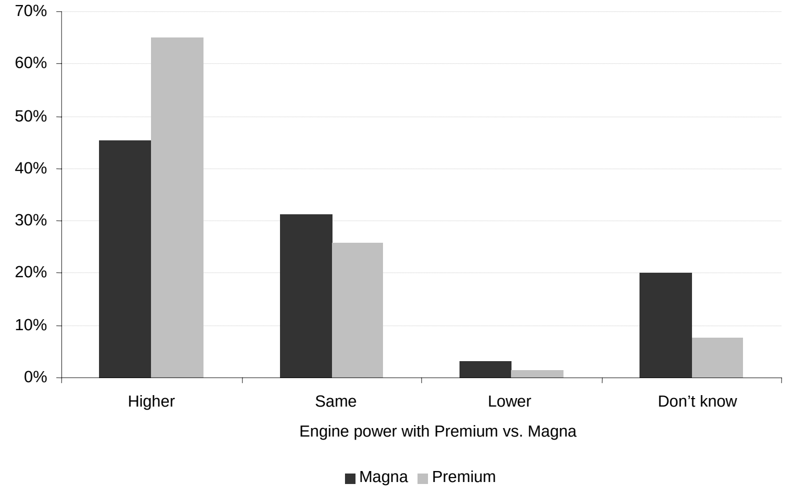
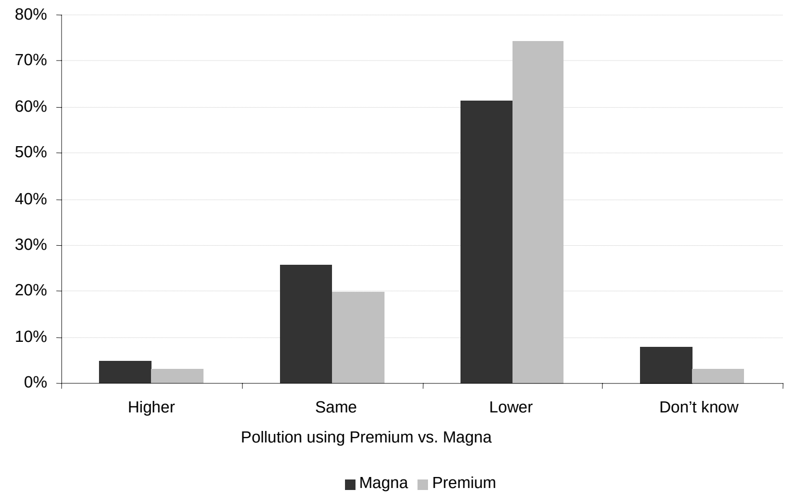


Figure 3.5. Comparison of Contaminants (opinion)



This effect is particularly deep in the cases where it was asked to compare the life of the engine and the catalytic converter. These cases show that the proportion of Magna consumers that do not perceive differences between both types of gasoline is markedly higher than the proportion of Premium consumers that have the same opinion. This suggests that even though the basic difference between both types of gasoline is their effect on the catalytic converter, Magna consumers tend to consider that the main difference between them relies on other aspects, such as power and efficiency, of which not enough evidence to prove that they really make a difference in both types of gasoline exist.

Figure 3.6. Vehicle Lifetime

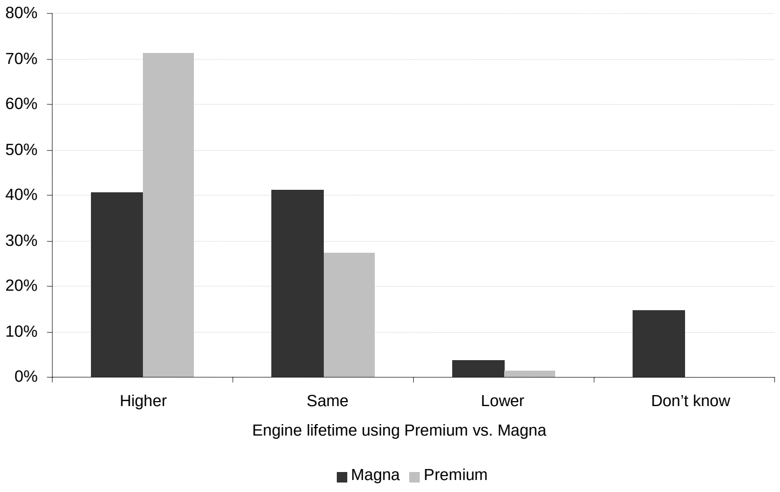


Figure 3.7. Catalytic Converter Lifetime

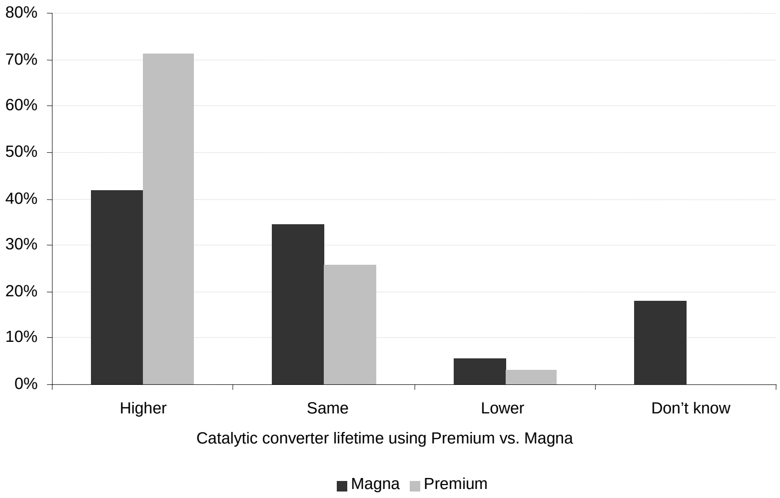
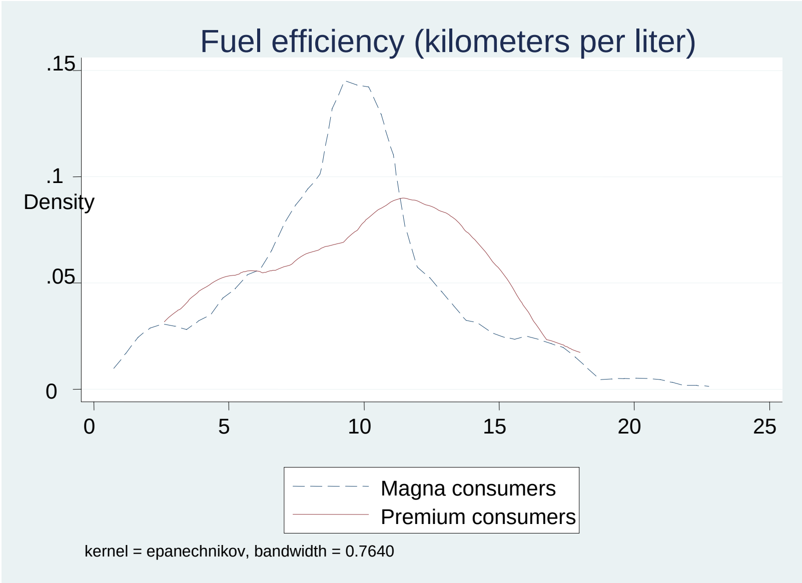


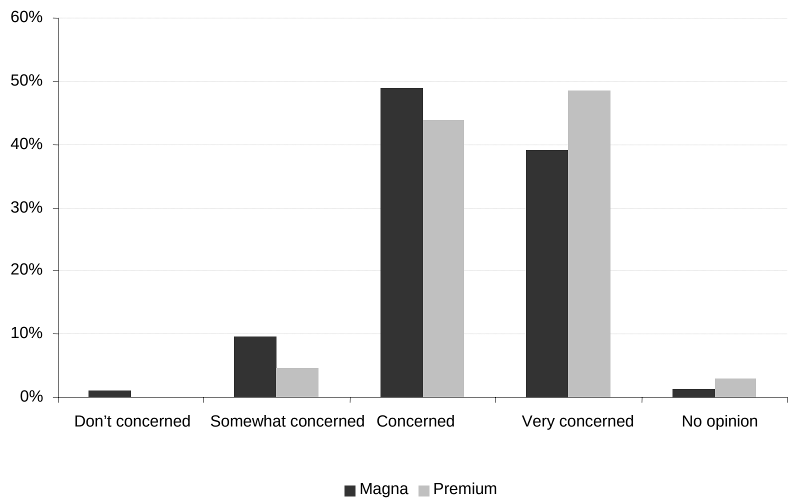
Figure 3.8. Car Efficiency



Finally, Premium consumers perceive that efficiency of their cars is higher than the efficiency perceived by Magna consumers of their own cars. This actually seems to confirm that the efficiency of a car is reduced as it becomes older.

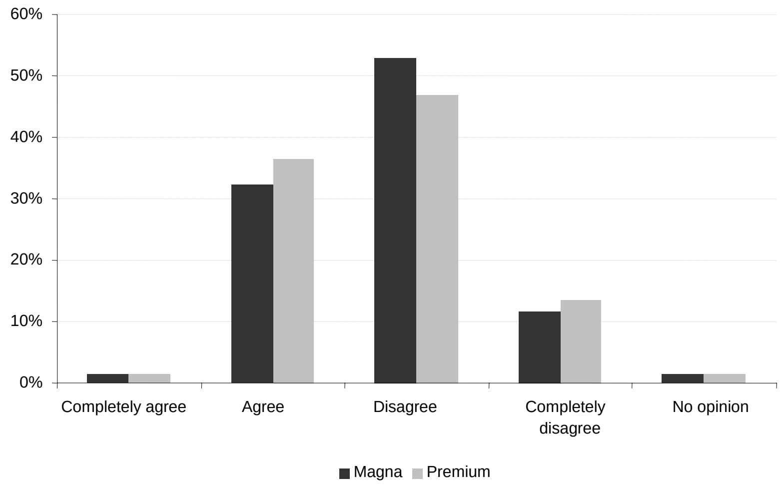
The interviewees were also asked to measure their degree of concern about air pollution. The following graph shows that Premium consumers are relatively more concerned about this environmental problem than Magna consumers.

Figure 3.9. Degree of concern about the Environment



There is no clear pattern regarding willingness to pay to solve environmental problems in the two groups of consumers. Even though the proportion of Premium consumers that agree, the proportion of consumers that highly disagrees is also high.

Figure 3.10. Willingness to Pay to Solve Environmental Problems



3.5.2 Estimation

In order to analyze the decisions of the households with respect to type of fuel consumed an econometric model of discrete election was produced. This type of models assumes that a person chooses from a group of finite alternatives that one that maximizes the expected utility.

Formally, a person that faces *J* alternatives has a utility function that can be represented as follows:

$$U = V(x) + \varepsilon$$

Where x is a group of variables that may contain attributes of the alternative and/or characteristics of the person; $V(x)$ is not stochastic and reflects representative likes of the population; and ε is stochastic and represents the idiosyncrasy of the person towards the alternative j (Mc Fadden, 1973).

The person chooses the alternative that maximizes its utility such that:

$$U(x_j) > U(x_i) \quad \forall j \neq i$$

Therefore, the probability that a randomly chosen person from the population chooses the alternative j is equal to:

$$P[\varepsilon_j - \varepsilon_i < V(x_i) - V(x_j) \quad \forall j \neq i]$$

In order to estimate this probability, it is necessary to assume the form of the distribution from the stochastic part of the utility function. Mc Fadden (1978) demonstrated that if the accumulative function of distribution has a GEV (*Gumbel Extreme Value*) form, then the probability has a logistic form that can be expressed as (Train, 1980):

$$P_j = \frac{e^{x_j \beta_j}}{\sum_{i=1}^{J} e^{x_i \beta_i}}$$

Depending on the type information available, it is possible to specify different models for the estimation of the β_j coefficients. In essence, there are two models that are frequently used in literature: the multinomial *logit* and the conditional *logit*. The fundamental difference between them is the type of variables used in their estimation. In the first case, the types of variables that are used vary by individual but do not vary with the alternatives. In the latter, the variables vary per alternative. However, there is an algebraic equivalence between both models (Long, 1997), which allows us to generate an intermediate model which takes advantage of the two models.

McFadden (1973) established the general conditional *logit* estimation method. Variables that only vary per individual or variables that only vary per alternative can be used by using such model. In essence, the way in which the variables that do not vary per alternative are transformed is by interacting the variables with indicators (*dummies*) of the alternatives. A maximum likelihood method is used and in order to identify the model, it is assumed that the parameters for given alternative are equal to zero.

In addition, the McFadden model has the advantage that the person elections do not have to be reciprocally exclusive. That means that the dependent variable, represented by a one and cero vector, may contain more than one number one. The study also describes how the way in which a person chooses more than one alternative is weighted in the maximum likelihood function.

This is particularly advantageous to the present study, because as it may be observed in this and other surveys (ENIGH, 2006; PROFECO, 2006) some households use a mix of both types of fuels in the same car. In principle, it is possible to generate a new alternative for the use of two types of fuel and analyze the impact that certain variables have in this decision. Nevertheless, the percentage of households that present this consumption pattern is small (only 16 observations and, as it will be described below, this issue limits the statistical significance of the results. A less desirable alternative would be discarding these observations, but it does not seem correct.

Given the possibility to choose more than one alternative, the previously mentioned model is used to make the estimation. Annex 3.1 details estimation large set of variables obtained from the survey. These variables are presented for the total of the sample and for each group of consumers, respectively. For each, a statistical test is presented to compare if Magna consumers distribution is different or similar to Premium consumers'. Specifically, a X^2 test is presented for dichotomic variables and a t of student test for non-dichotomic variables. It will later be evident that the significant effects in the econometric estimation correspond to the variables that have a different distribution depending on the consumer group studied.

The variables that reflect a different distribution depending on consumers group are:

(i) Income,

(ii) Proportion of people that take into account price differentials, environment or vehicle specifications as determinants of the decision to use certain type of fuel,

(iii) Proportion of people that were invited to use certain kind of fuel,

(iv) Proportion of people that consider they know which is the best fuel for their cars,

(v) Proportion of people that had looked for information about kinds of fuel,

(vi) Proportion of households that use energy-saving light bulbs,

(vii) Schooling of interviewees,

(viii) Number of cars in the household,

(ix) Number of years that the most-frequently used car has been in the household,

(x) Annual expenditure in maintenance and

(xi) Proportion of people that consider public transport as an option to travel.

Consuming Magna gasoline is taken as the base scenario in order to identify the model. We included five variables in the model. The first of them is a dummy which is equal to one if the respondent considers that using Premium gasoline increases the power of the automobile. Evaluating the marginal effects at the mean values of the variables, we found that the probability of choosing Premium instead of Magna, increases by 3.1% if a person has these beliefs. The second variable indicates if the respondent received an advice either from the car agency or the car manual related to the type of gasoline his auto should be filled with. We found that in this case the probability of choosing Premium increases by 14.9%. The age of the car was also included in the estimation, yet, no significant effect was found when income is included. However, when it is excluded this variable becomes significant. This result is natural as the age of the car may serve as a proxy of income.

Therefore, we included the interaction of income and the age of the car to distinguish the effect of each variable. This interaction has a significant effect, and is interpreted in two ways: first, for a given level of income each additional year of the car age reduces the probability of choosing Premium. For example, at the mean income, each year decreases this probability by 0.04%. Second, each additional thousand pesos on household income increases 0.34% the probability of choosing Premium gasoline; however, we must take into account the decrease in probability (0.04%) which comes from the age of the car. That is to say, the global effect of income is obtained by subtracting from 0.34% the resulting number which comes by multiplying 0.04% by the age of the car. At mean values, the whole marginal effect is negative and equal to -0.22%. In fact, there is a car age level in which the effect of the age of the car outweighs the positive effect of income. This level is at 8.4 years. In other words, if the car is sufficiently old the positive effect of income in increasing the probability of choosing Premium disappears.

Table 3.2. Summary statistics of variables used in estimation

Variable	Definition	Obs	Mean	Std. Dev.	Min	Max
Power	Respondent believe that using Premium gasoline the power of the engine increases=1	996	0.44	0.50	0	1
Recommendation	Repondent received advice to use certain type of gasoline=1	996	0.24	0.43	0	1
Income	Monthly income in pesos	992	8,945	7,080	3,722	49,480
Age of the car	Age of the car in years	996	13.94	8.27	3	51

Table 3.3. Conditional Logit estimation

Alternative-specific conditional logit							
Number of cases = 496				**Wald chi2(5) = 70.23**			
Number of obs = 992				**Prob > chi2 = 0.0000**			
Alternative variable: fuel type				**Log likelihood = -96.527969**			
Variable	**Coef.**	**Std. Err.**	**z**	**P>|z|**	**[95% Conf.**	**Interval]**	
Base outcome: Premium							
Power	1.045	0.401	2.61	0.009	0.259	1.830	
Recommendation	2.545	0.401	6.35	0.000	1.759	3.331	
Income	0.000	0.000	2.24	0.025	0.000	0.000	
Age of the car	-0.067	0.064	-1.06	0.290	-0.192	0.058	
(Income) x (age of the car)	0.000	0.000	-1.99	0.046	0.000	0.000	
Constant	-3.164	0.704	-4.49	0.000	-4.544	-1.784	

3.6 Discussion

It is important to highlight that our model is helpful to give some insights about the relevance of bounded rationality, transaction costs and imperfect information in the decision processes of agents. First, we found some evidence that indicates that individuals sometimes take decisions based on ‘self-constructed’ beliefs, which are not necessarily true. The model indicates that those who believe that Premium gasoline increases the motor power are more likely to choose this kind of fuel; however, as it was showed in previous sections, the differences between Magna and Premium are not related to this factor. This result may arise from some kind of bounded rationality effect of agents, where they take a decision limited on the information they have.

Second, it seems that imperfect information is important, as long as external advice is relevant on the decisions process. In both cases it is possible that transaction costs of acquiring information may be relevant in fuel choice. That is to say, as determining which gasoline is the best is a somewhat technical choice and is costly to obtain information, they choose either taking the decision on the limited information they have or by seeking for external advice when it comes ‘cheap’.

The third relevant result indicates that as income increases it is more likely that people choose Premium gasoline; however, this effect may be outweighed if a car is sufficiently old. Unfortunately, the mean age of cars in the sample is around 14 years, a level in which the global effect of income is negative.[40]

We tried to incorporate environmental concern variables in a similar way as in the previous chapter; however, in our sample education is not a good proxy of environmental concerns and therefore, no relevant conclusions in econometric terms could be obtained. In descriptive terms it seems that Premium consumers reflect a somewhat friendlier behavior towards environment than Magna consumers. However, this only reflects a difference between groups of consumers and not a causal relation between environmental concerns and Premium consumption.

Descriptive data also served to show large differences between groups of consumers regarding to the importance of price in fuel choice. Almost 95% of Magna consumers stated that price of fuel was determinant in their choice; in contrast, only 30% of Premium consumers think in the same way. Moreover, the survey presented an 'auction-like' question to the respondent, in which we asked how much has to be the price spread between both fuel prices in order to consume the other type of fuel. 52% of Magna consumers would switch to Premium gasoline only if the difference in prices were around 4%. Premium consumers also seem to be very reticent to switch to Magna, as 45% of them stated that they would never consume Magna no matter which was the price spread. Therefore, it seems that Magna consumers, which are the vast majority would only consume if prices of both fuels are close enough, and that Premium consumers would remain Premium consumers.

3.7 Conclusion

As a general conclusion we may state that fuel choice is a somewhat technical decision that implies transaction costs which some people are not willing to pay and prefer to take the decision on the limited information they have, or to take advice on costless (or cheap) sources of information as the car manual or car agency recommendations. That income in fact affects fuel choice, making people more likely to consume Premium gasoline as it increases, yet this effect may be outweighed if the

[40] Nevertheless, we must take into account that it is very likely that an increase in income also affects the mean car age. That is to say, as income increases it is more likely that people buy new cars. This is an issue that is beyond the scope of this work.

mean age of the fleet is too high. Finally, price spread does not seem to be a very effective way to make Magna consumers to switch to Premium.

Therefore, in terms in policy it seems that the most effective way to reduce adverse environmental effects of Magna fuel is to introduce into the market Magna fuel with low-sulfur content, since influencing behavior seems difficult.

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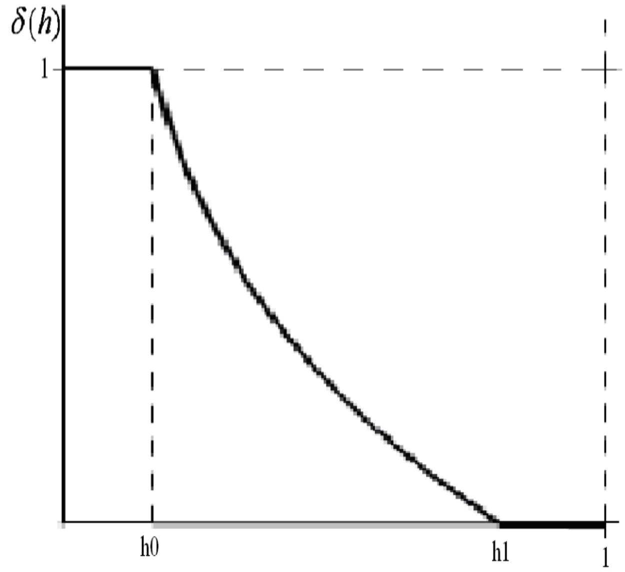
Chapter 1 annexes

Figure 1.1

a) Best responses of the taxpayer



b) Best responses of the fiscal administrator

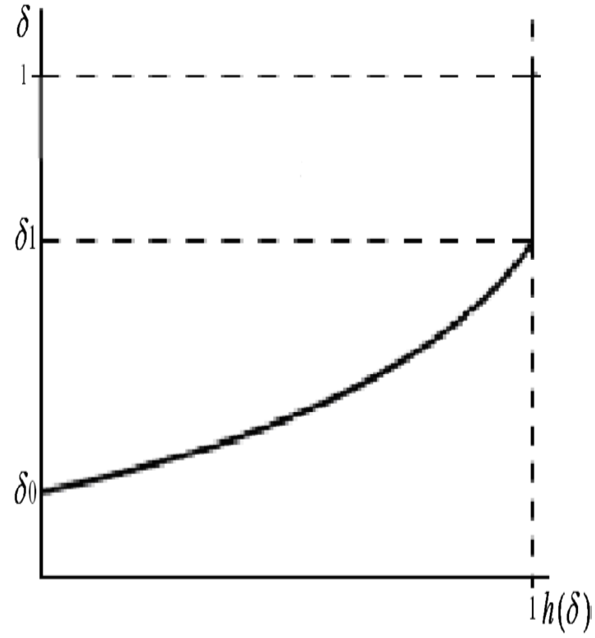
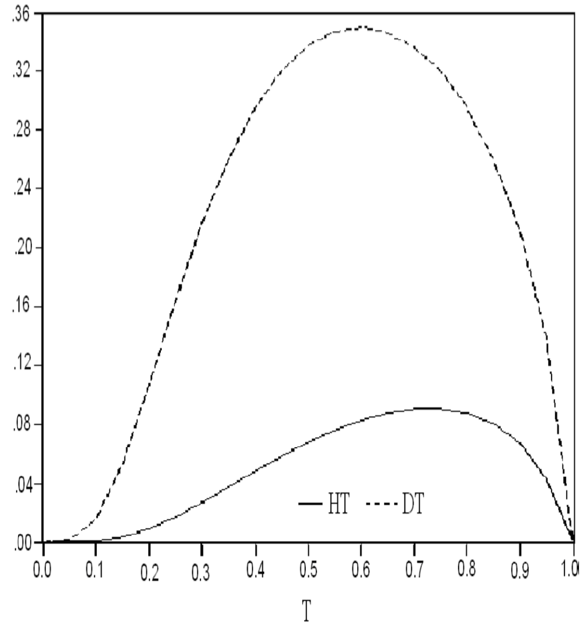


Table 1.1

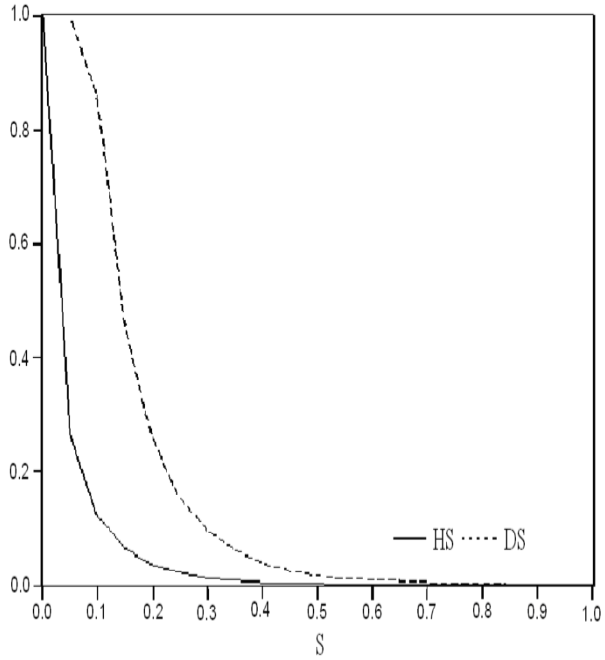
Changes in the functions of payment
because of increases in the model parameters

Parameter	*Expected Collection*	*Expected Utility*
ε	>	<
t	>	<
S	>	<
α	<	>
G	<	>
Y	>	>

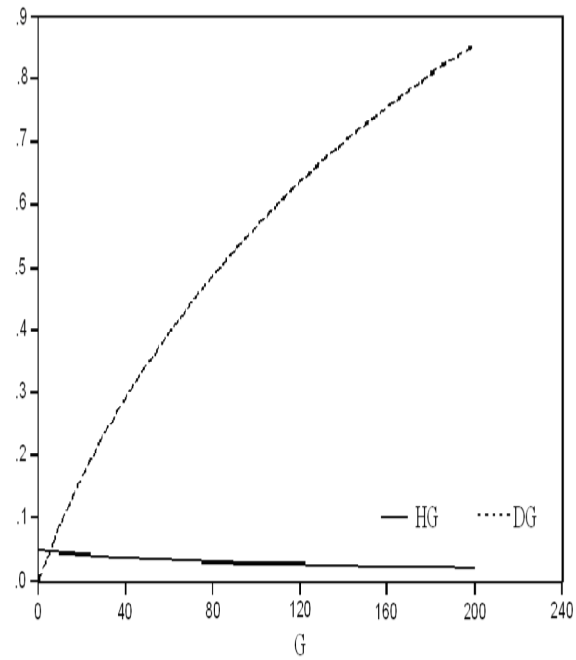
Annex 1.1
Changes in t



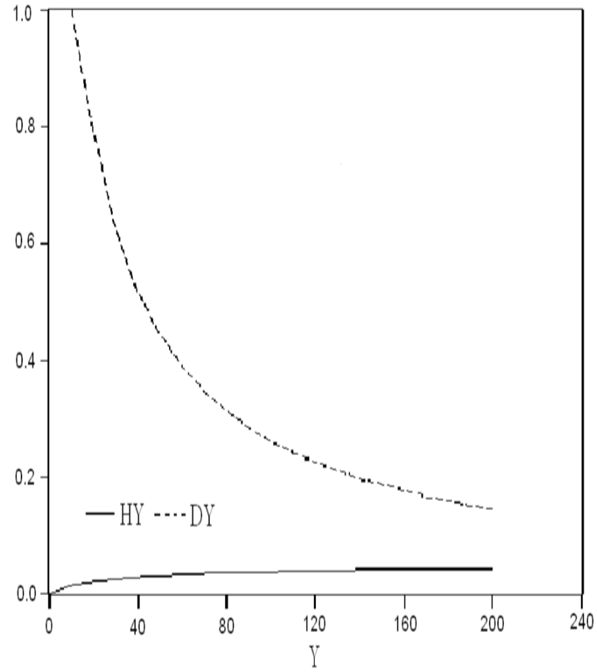
Changes in S



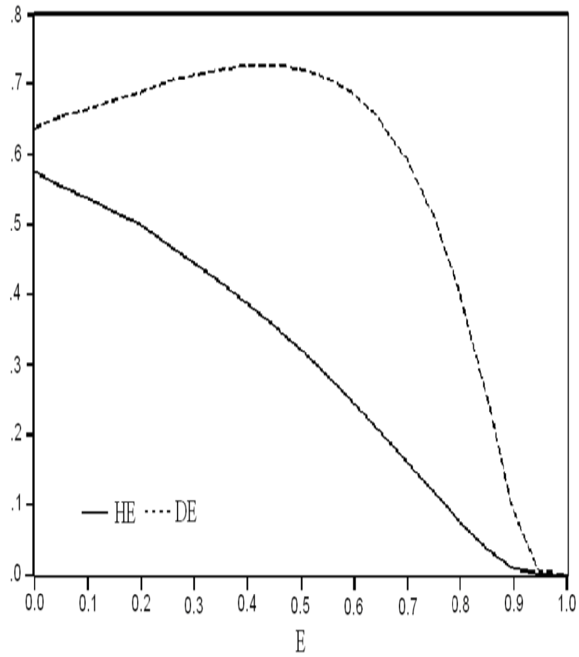
Changes in G



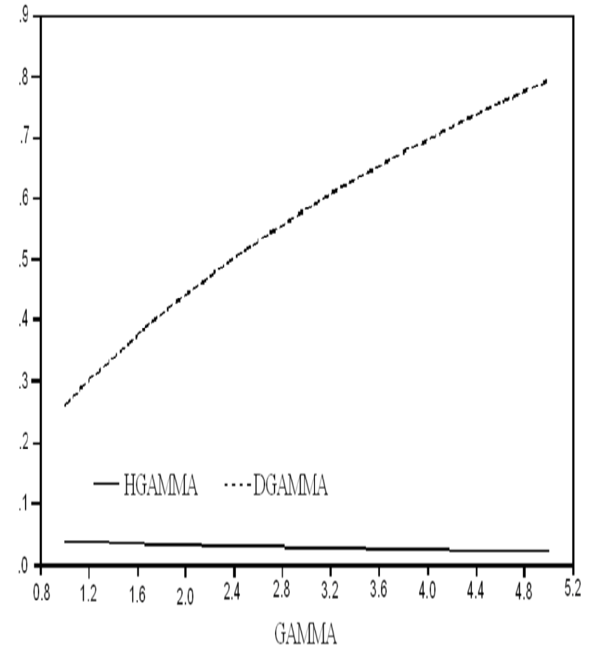
Changes in Y



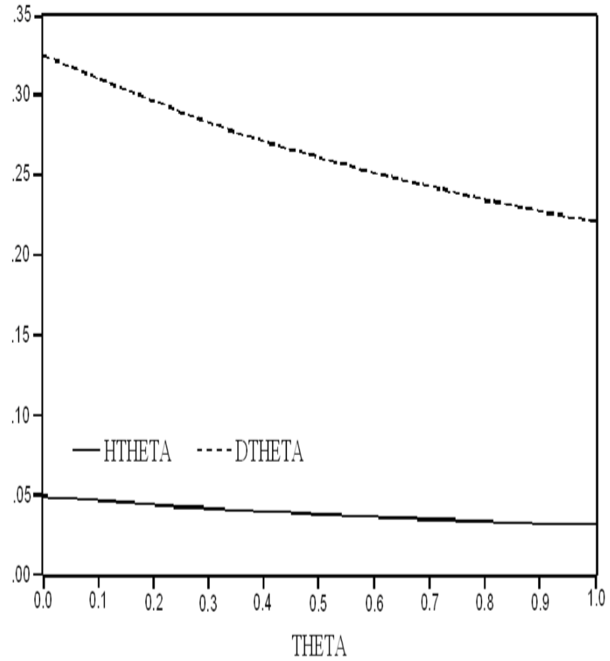
Changes in ε



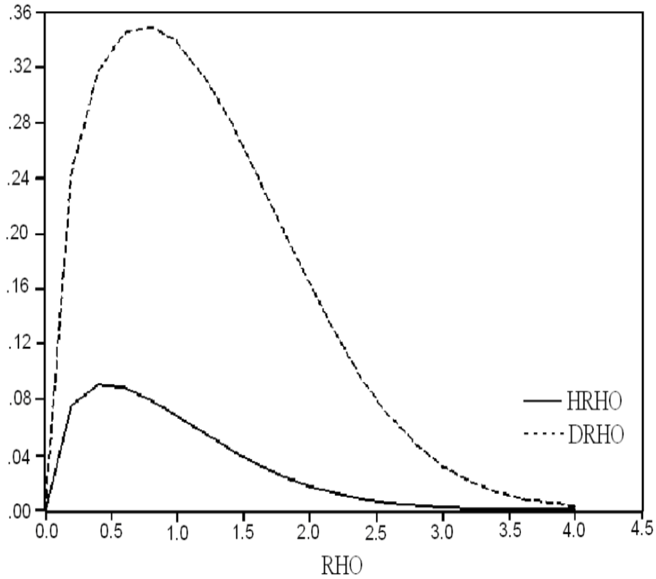
Changes in γ



Changes in θ

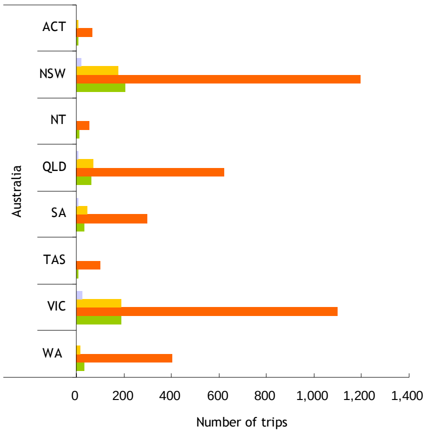


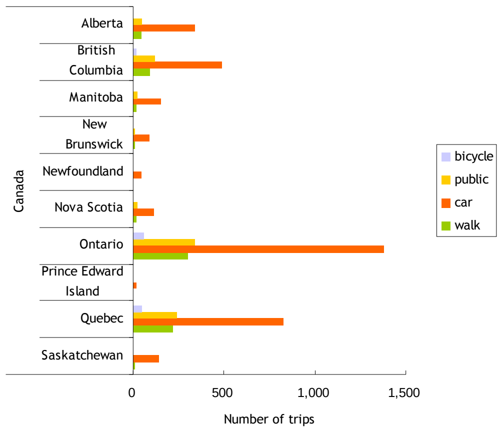
Changes in ρ

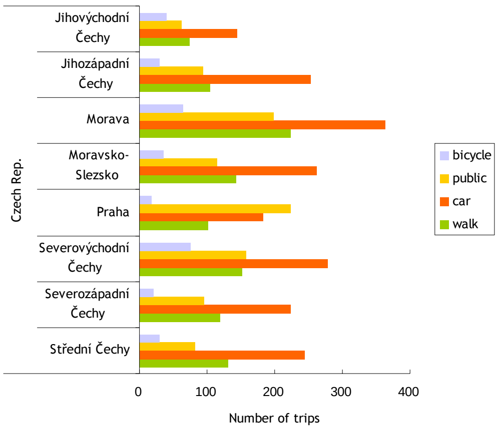


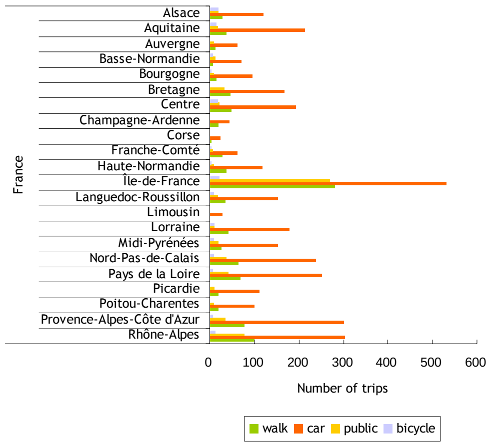
Chapter 2 annexes

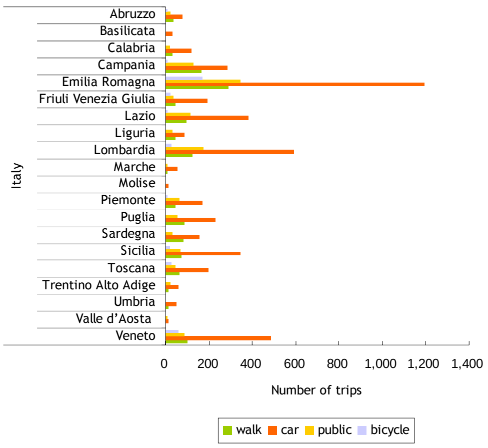
ANNEX 2.1. NUMBER OF TRIPS PER REGION AND MODE OF TRANSPORT

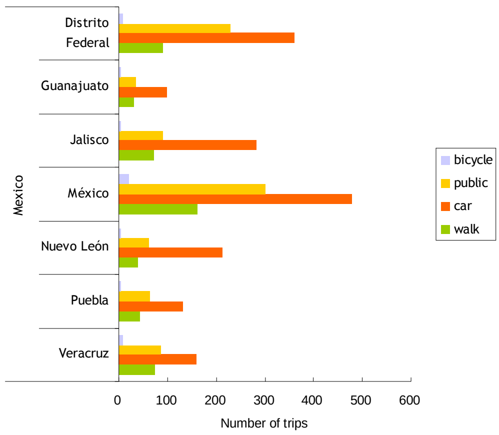




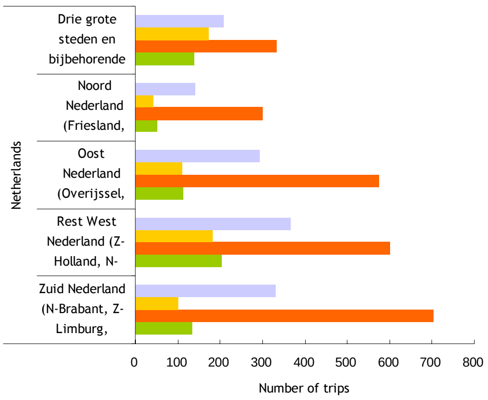


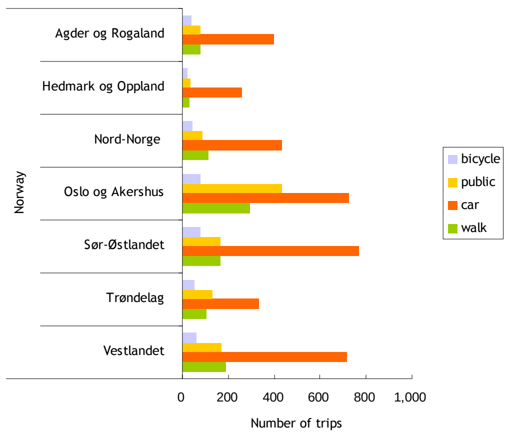


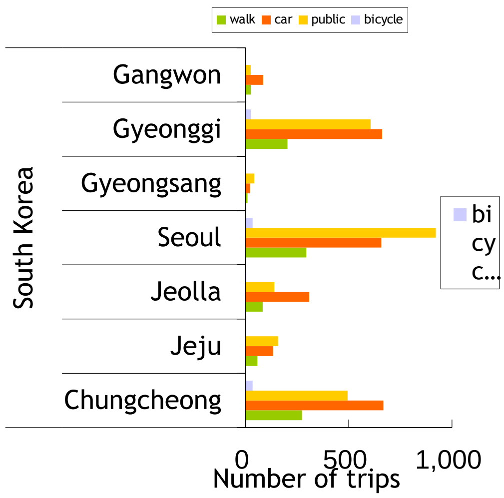


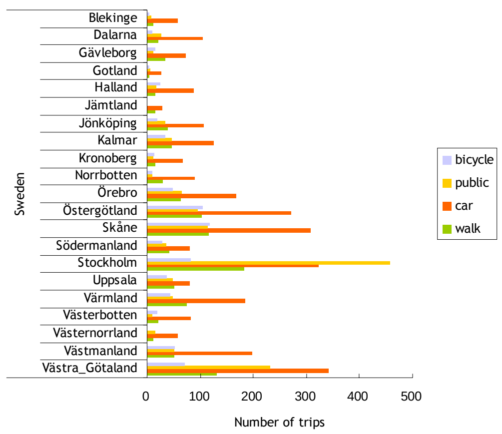


Annex 2.1. NUMBER OF TRIPS PER REGION AND MODE OF TRANSPORT (Continued)









ANNEX 2.2. DESCRIPTIVE SUMMARY

Variable	Definition	Obs	Mean	Std. dev.	Min	Max
lincome	Ln(income)	10 251	10.001	0.918	5.48	11.73
status_parents	Living with parents=1	10 251	0.132	0.339	0	1
status_alone	Living alone=1	10 251	0.160	0.367	0	1
status_sparent	Living as a single parent=1	10 251	0.056	0.230	0	1
status_sharing	Sharing a house/flat with non-family members=1	10 251	0.033	0.178	0	1
male_earnm~t	Male with the highest income in household=1	10 251	0.364	0.481	0	1
Age	Age	10 251	43.15	14.30	19	77
age^2	Age squared	10 251	2,067	1,278	361	5,929
adults	Number of adults in household	10 251	2.244	1.024	1	5
children	Number of children younger than 18 years old	10 251	0.647	0.962	0	5
educated	Post-secondary education or a higher level=1	10 251	0.606	0.489	0	1
emp_ft	Employed in a full time job=1	10 251	0.479	0.500	0	1
detached	Living in a detached house=1	10 251	0.413	0.492	0	1
urban	Urban municipality=1	10 251	0.446	0.497	0	1

Chapter 3 annexes

Annex 3.1

Variable	Definition	Consumer Type	Obs	Average	Stan. Dev.	Min	Max	Average Comp. /1	
Income	Familiar income in thousand of Mexican pesos	All	498	8.944	7.070	3.722	49.48	-19.5	***
		Magna	432	8.350	6.068	3.722	49.48		
		Premium	50	13.905	12.252	3.722	49.48		
		Both	16	9.487	3.868	3.722	16.3		
Price	The Price is a determinant factor on the decision of fuels =1	All	498	0.873	0.333	0	1	163.7	***
		Magna	432	0.942	0.234	0	1		
		Premium	50	0.300	0.463	0	1		
		Both	16	0.813	0.403	0	1		
Fuel efficiency	The performance is a determinant factor on the decision of the fuel =1	All	498	0.297	0.457	0	1	1.7	
		Magna	432	0.280	0.450	0	1		
		Premium	50	0.380	0.490	0	1		
		Both	16	0.500	0.516	0	1		
Environ_matters	The environment is a determinant factor on the decision of the fuel =1	All	498	0.175	0.380	0	1	73.6	***
		Magna	432	0.123	0.328	0	1		
		Premium	50	0.620	0.490	0	1		
		Both	16	0.188	0.403	0	1		
Specific_matters	The vehicle specifications is a determinant factor on the decision of the fuel =1	All	498	0.430	0.496	0	1	10.9	***
		Magna	432	0.405	0.491	0	1		
		Premium	50	0.660	0.479	0	1		
		Both	16	0.375	0.500	0	1		

Variable	Definition	Consumer Type	Obs	Average	Stan. Dev.	Min	Max	Average Comp. /1	
Recommendation	Some person recommended using the fuel that the household uses=1	All	498	0.474	0.500	0	1	34.1	***
		Magna	432	0.433	0.496	0	1		
		Premium	50	0.880	0.328	0	1		
		Both	16	0.313	0.479	0	1		
Know_better_fuel	Considers he knows what is the best gasoline for his car=1	All	498	0.576	0.495	0	1	10.8	***
		Magna	432	0.546	0.498	0	1		
		Premium	50	0.800	0.404	0	1		
		Both	16	0.688	0.479	0	1		
Search_info	Has searched for Information about the fuels=1	All	498	0.137	0.344	0	1	25.6	***
		Magna	432	0.109	0.312	0	1		
		Premium	50	0.380	0.490	0	1		
		Both	16	0.125	0.342	0	1		
Env_friendly_vac	Has contemplated places in contact with nature for vacations or activities for recreation =1	All	498	0.898	0.303	0	1	0.7	
		Magna	432	0.891	0.312	0	1		
		Premium	50	0.940	0.240	0	1		
		Both	16	0.938	0.250	0	1		
Recycles	Recycles or separates trash in the household=1	All	498	0.681	0.467	0	1	0.0	
		Magna	432	0.681	0.467	0	1		
		Premium	50	0.700	0.463	0	1		
		Both	16	0.625	0.500	0	1		
Efficient_lighting	There are energy efficient light bulbs in the household=1	All	498	0.765	0.424	0	1	4.9	**
		Magna	432	0.748	0.435	0	1		
		Premium	50	0.900	0.303	0	1		
		Both	16	0.813	0.403	0	1		

Variable	Definition	Consumer Type	Obs	Average	Stan. Dev.	Min	Max	Average Comp. /1	
Other_activ	Any enviromentally friendly action if carried out in the household (mainly water saving)=1	All	498	0.295	0.457	0	1	3.2	*
		Magna	432	0.269	0.444	0	1		
		Premium	50	0.400	0.495	0	1		
		Both	16	0.688	0.479	0	1		
Pollution_vconc	Very concerned for air pollution=1	All	498	0.402	0.491	0	1	1.9	
		Magna	432	0.389	0.488	0	1		
		Premium	50	0.500	0.505	0	1		
		Both	16	0.438	0.512	0	1		
WTP_env_issues	We should pay for environmental problems=1	All	498	0.343	0.475	0	1	0.2	
		Magna	432	0.338	0.474	0	1		
		Premium	50	0.380	0.490	0	1		
		Both	16	0.375	0.500	0	1		
Parents	Living with parents/relatives=1	All	498	0.147	0.354	0	1	0.2	
		Magna	432	0.144	0.351	0	1		
		Premium	50	0.180	0.388	0	1		
		Both	16	0.125	0.342	0	1		
Married	Married with children=1	All	498	0.705	0.457	0	1	0.5	
		Magna	432	0.699	0.459	0	1		
		Premium	50	0.760	0.431	0	1		
		Both	16	0.688	0.479	0	1		
emp_ft	Full time Yorker=1	All	498	0.396	0.489	0	1	0.2	
		Magna	432	0.405	0.491	0	1		
		Premium	50	0.360	0.485	0	1		
		Both	16	0.250	0.447	0	1		

Variable	Definition	Consumer Type	Obs	Average	Stan. Dev.	Min	Max	Average Comp. /1	
emp_ht	Half time employee=1	All	498	0.080	0.272	0	1	0.1	
		Magna	432	0.083	0.277	0	1		
		Premium	50	0.060	0.240	0	1		
		Both	16	0.063	0.250	0	1		
emp_ind	Independent employee=1	All	498	0.388	0.488	0	1	0.2	
		Magna	432	0.384	0.487	0	1		
		Premium	50	0.340	0.479	0	1		
		Both	16	0.625	0.500	0	1		
age	Age in years	All	498	40.959	12.427	18	81	0.0	
		Magna	432	40.897	12.243	18	74		
		Premium	50	40.818	14.475	19	81		
		Both	16	43.060	10.988	22	62		
Schooling	Categorical variable (1=without schooling, …, 5=master or doctorate)	All	496	2.712	1.075	0	5	3.5	***
		Magna	430	2.637	1.050	0	5		
		Premium	50	3.220	1.130	1	5		
		Both	16	3.125	1.088	1	4		
N_household	Number of people in the household	All	497	4.561	2.030	1	15	-0.1	
		Magna	431	4.575	2.087	1	15		
		Premium	50	4.560	1.606	2	8		
		Both	16	4.188	1.682	1	7		
N_children	Number of people younger than 18 years in the household	All	497	1.372	1.320	0	8	-0.9	
		Magna	431	1.399	1.355	0	8		
		Premium	50	1.260	1.046	0	5		
		Both	16	1.000	1.095	0	3		

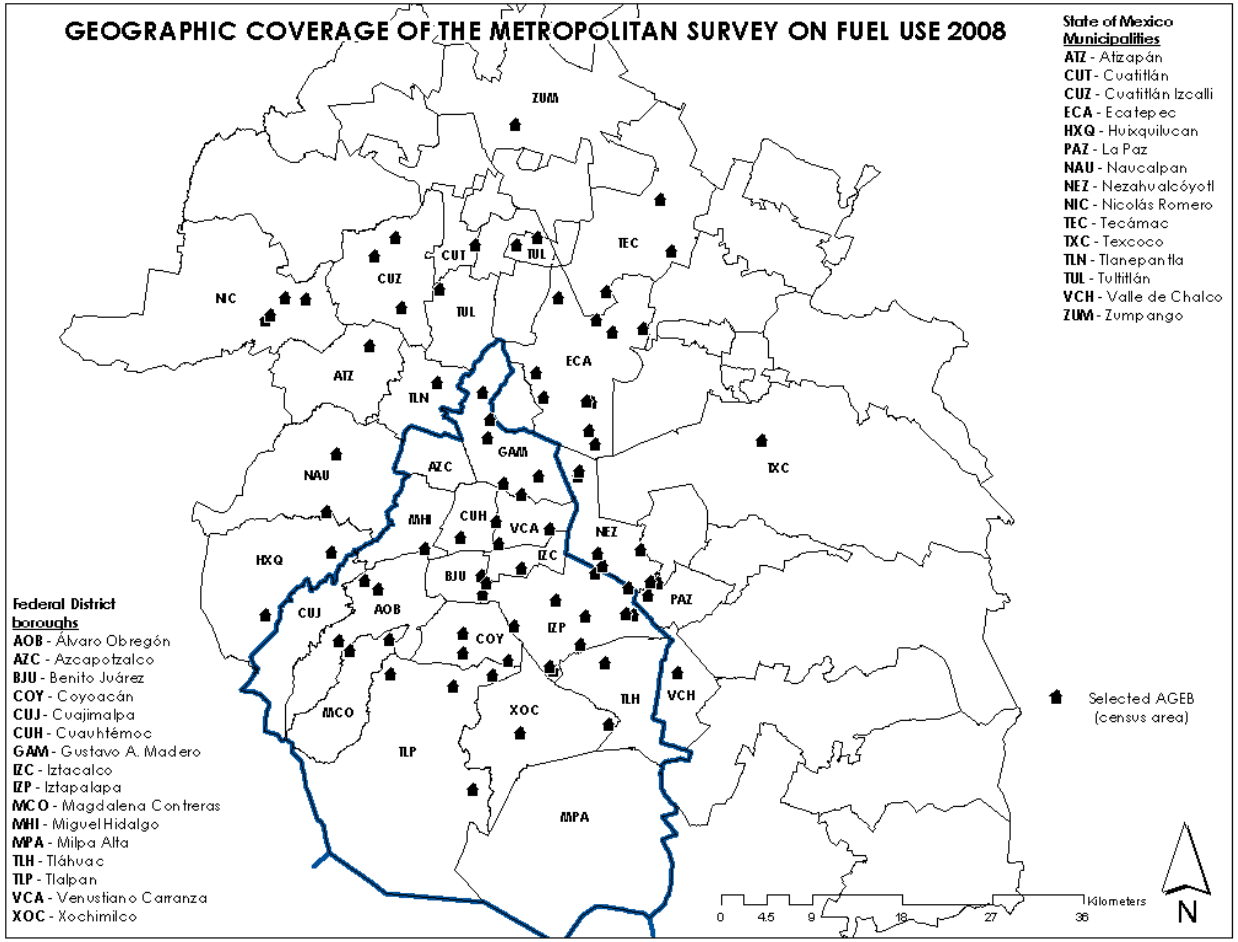
Variable	Definition	Consumer Type	Obs	Average	Stan. Dev.	Min	Max	Average Comp. /1	
Autos	Number of cars in the household	All	498	1.247	0.579	1	4	1.9	*
		Magna	432	1.227	0.557	1	4		
		Premium	50	1.420	0.702	1	4		
		Both	16	1.250	0.683	1	3		
Age of car	Number of years that the household has kept the car	All	480	5.977	7.256	0	41	-8.9	***
		Magna	414	6.616	7.457	0	41		
		Premium	50	1.300	3.364	0	15		
		Both	16	4.063	5.026	0	14		
Maintenance_exp	Annual expenditure in maintenance (thousand of Mexican pesos)	All	498	4.092	2.916	0.2	20	2.5	**
		Magna	432	3.925	2.739	0.2	20		
		Premium	50	5.389	4.026	0.6	20		
		Both	16	4.543	2.563	1.5	12		
car_commuting	Car is used to transport daily to work=1	All	498	0.534	0.499	0	1	1.6	
		Magna	432	0.546	0.498	0	1		
		Premium	50	0.440	0.501	0	1		
		Both	16	0.500	0.516	0	1		
car_long_journeys	Car is used mainly for long journeys=1	All	498	0.040	0.197	0	1	0.1	
		Magna	432	0.039	0.195	0	1		
		Premium	50	0.060	0.240	0	1		
		Both	16	0.000	0.000	0	0		
car_heavy_use	Car is used intensively for many activities=1	All	498	0.345	0.476	0	1	2.3	
		Magna	432	0.340	0.474	0	1		
		Premium	50	0.460	0.503	0	1		
		Both	16	0.125	0.342	0	1		

Variable	Definition	Consumer Type	Obs	Average	Stan. Dev.	Min	Max	Average Comp. /1	
Pub_transport	Consider that the public transportation is a feasible option to be transported =1	All	498	0.207	0.405	0	1	3.2	*
		Magna	432	0.220	0.415	0	1		
		Premium	50	0.100	0.303	0	1		
		Both	16	0.188	0.403	0	1		

/1 To compare proportions it was used the X^2 corrected test by continuity (Pirie y Hamdan, 1972). For the case of no dichotomy variables it was used the t student test. The statistical shown corresponds to the comparison of the data for Premium consumers with Magna consumers..

*** Significant on 1%; ** Significant on 5%; * Significant on 10%

Annex 3.2


GEOGRAPHIC COVERAGE OF THE METROPOLITAN SURVEY ON FUEL USE 2008
State of Mexico
Municipalities
ATZ - Atizapán
CUT - Cuatitlán
CUZ - Cuatitlán Izcalli
ECA - Ecatepec
HXQ - Huixquilucan
PAZ - La Paz
NAU - Naucalpan
NEZ - Nezahualcóyotl
NIC - Nicolás Romero
TEC - Tecámac
TXC - Texcoco
TLN - Tlanepantla
TUL - Tultitlán
VCH - Valle de Chalco
ZUM - Zumpango
Federal District
boroughs
AOB - Álvaro Obregón
AZC - Azcapotzalco
BJU - Benito Juárez
COY - Coyoacán
CUJ - Cuajimalpa
CUH - Cuauhtémoc
GAM - Gustavo A. Madero
IZC - Iztacalco
IZP - Iztapalapa
MCO - Magdalena Contreras
MHI - Miguel Hidalgo
MPA - Milpa Alta
TLH - Tláhuac
TLP - Tlalpan
VCA - Venustiano Carranza
XOC - Xochimilco
Selected AGEB
(census area)
Kilometers
0 4.5 9 18 27 36
N