Department of Economics

# Economic Analysis of Automobile Markets

Adamos Adamou



PhD Dissertation
Submitted to the Faculty of Economics Department
of University of Cyprus
in Candidacy for the Degree of
Doctor of Philosophy

May 2011

# ΣΕΛΙΔΑ ΕΓΚΥΡΟΤΗΤΑΣ

Υποψήφιος Διδάκτορας: Αδάμος Αδάμου

Τίτλος Διατριβής: Οικονομική Ανάλυση Αγορών Αυτοκινήτων

Η παρούσα Διδακτορική Διατριβή εκπονήθηκε στο πλαίσιο των σπουδών για απόκτηση Διδακτορικού Διπλώματος στο Τμήμα οικονομικών και εγκρίθηκε στις 22 Μαρτίου 2011 από τα μέλη της Εξεταστικής Επιτροπής.

## Εξεταστική Επιτροπή

Ερευνητικός Σύμβουλος:

Σωφρόνης Κληρίδης, Αναπληρωτής Καθηγητής

Υπογραφή:

Άλλα Μέλη:

Κώστας Χατζηγιάννης, Επίκουρος Καθηγητής, Πανεπιστήμιο Κύπρου

Πάρις Κλεάνθους, Λέκτορας, Πανεπιστήμιο Κύπρου

Christos Genakos, Fellow and Director of Studies, Cambridge University

Gregory Crawford, Professor, University of Warwick

# Summary

This dissertation contains four essays addressing three research questions in the field of empirical industrial organization. A common theme running through the essays is the focus on issues related to automobile markets and more specifically on price indices and demand estimation with differentiated products.

Chapter 2, is focused on a unique experiment regarding trade liberalization that occurred in Cyprus the year 1993. This experiment gave me the opportunity to investigate the impact of used imports on the price level in small economies through the construction of several price indices. Specifically, the maximum allowable age of an imported vehicle increased from two years to five, making possible the importation of used cars from Japan into Cyprus. This led to a dramatic increase in imports of used cars; at their 1998 peak, used vehicles accounted for 72% of all car imports. The outcome indicates that the increased competition from the import of used cars lead to a significant reduction of prices of both used and new cars. In economies with a relatively high share of automobiles in CPI basket, a price reduction actually means a strong negative impact on CPI. Over a ten year period the minimum decline in the prices of new cars reached the average annual growth rate of 1.1%. For a three year period the minimum decline in the prices of used cars reached the average annual growth rate of 0.15%.

Chapter 3 is focused on the availability of auxiliary information and an idiosyncracy of the Cyprus tax system to obtain estimates of markups for automobiles in order to evaluate the performance of discrete choice models for the estimation of firms markups and to compare them with the markups estimated using discrete choice models. According to the findings, markups are similar in levels. Estimated markups obtained from discrete choice models that allow for less heterogeneity among consumers fail to generate enough dispersion in markups across different types of cars. A discrete choice model that allows for full heterogeneity among consumers generates satisfactory dispersion but not as enough as expected. The use of additional demand attributes (for the demand estimation) is essential for the estimation of markups even with the cost of lower number of observations. Finally, the correlation between the two sets of markups is found to be relatively satisfactory. Generally, the comparison of the two sets of markups shows them to be reasonably similar, which bodes well for discrete choice models.

In chapter 4 and 5, an evaluation of potential public policy interventions that could lead to the reduction of CO2 emissions of motor vehicles was carried out. Particularly, these chapters focused on numerous simulations and changes in consumer welfare, public revenues, firm mark-ups and CO2 emissions according to different policy scenarios compared to the current vehicle taxation regime in Greece and Germany. The work carried out in these chapters can be applied by policy makers for the prediction of economic and environmental changes in an automobile market for any potential policy change. For simulation purposes, a linear tax is introduced in such a way that it is positive for cars with CO2 emissions over a given emission level (the so called pivot point) and negative for cars with emissions lower than this threshold. The feebate-rebate pivot point seems to be very essential for the decision of policy makers and it should be set in reasonable levels.

# Περίληψη

Η παρούσα διατριβή περιλαμβάνει τέσσερα κεφάλαια τα οποία εστιάζονται σε τρία ερευνητικά ερωτήματα στον τομέα της βιομηχανικής οργάνωσης και συγκεκριμένα στις αγορές αυτοκινήτων. Για την ανάλυση των ερωτημάτων χρησιμοποιούνται ηδονικοί δείκτες τιμών σε ένα κεφάλαιο και μοντέλα εκτίμησης ζήτησης για διαφοροποιημένα προϊόντα στα υπόλοιπα κεφάλαια.

Στο κεφάλαιο 2, εξετάζονται οι επιπτώσεις της αλλαγής πολιτικής στις εισαγωγές μεταχειρισμένων αυτοκινήτων που έλαβε χώρα το 1993 στην Κύπρο, πάνω στο δείκτη τιμών καταναλωτή. Συγκεκριμένα, η μέγιστη επιτρεπόμενη ηλικία εισαγωγής μεταχειρισμένων αυτοκινήτων αυξήθηκε από δύο χρόνια σε πέντε, πράγμα που οδήγησε στη μαζική εισαγωγή μεταχειρισμένων αυτοκινήτων στην Κύπρο από την Ιαπωνία. Η αλλαγή πολιτικής οδήγησε στην δραματική αύξηση στις εισαγωγές μεταχειρισμένων αυτοκινήτων με αποκορύφωμα τη χρονιά 1998 όπου το μερίδιο των εισαγώμενων μεταχειρισμένων αυτοκίνητων έναντι των συνολικών εισαγωγών αυτοκινήτων ανήλθε στο 72%. Η έρευνα έδειξε ότι ο αυξανόμενως ανταγωνισμός από τις εισαγωγές μεταχειρισμένων αυτοκινήτων οδήγησε σε μείωση των τιμών όχι μόνο στα μεταχειρισμένα αυτοκίνητα αλλά και στα καινούργια. Σε οικονομίες με μεγάλο μερίδιο των αυτοκινήτων στο καλάθι του δείκτη τιμών καταναλωτή, μια μείωση στις τιμές των αυτοκινήτων συνεπάγεται σε μια μεγάλη μείωση του πληθωρισμού. Τα αποτελέσματα της μελέτης έδειξαν ότι η ελάχιστη μείωση στις τιμές των καινούργιων αυτοκινήτων είναι της τάξης του 1.1% σε όρους μέσου χρονιαίου ρυθμού ανάπτυξης, ενώ για τα μεταχειρισμένα αυτοκίνητα το ποσοστό αυτό είναι της τάξης του 0.15%.

Ο στόχος του κεφαλαίου 3 είναι να διερευνηθεί κατά πόσο τα μοντέλα διακριτής επιλογής μπορούν να εκτιμήσουν αρκετά καλά τα περιθώρια κέρδους των επιχειρήσεων/αντιπροσώπων. Για να απαντηθεί το πιο πάνω ερώτημα χρησιμοποιείται ένας εναλλαχτικός τρόπος υπολογισμού των περιθωρίων κέρδους και γίνεται σύγκριση των εκτιμημένων περιθωρίων κέδρους με τα αντίστοιχα υπολογισμένα. Η μελέτη του πιο πάνω ερωτήματος είναι εφικτή χάρις 1) σε βοηθητικές-επιπρόσθετες πληροφορίες που συλλέχθηκαν για τη μελέτη αυτή και 2) στην ιδιοσυγκρασία του Κυπριακού συστήματος φορολόγησης αυτοκινήτων. Τα αποτελέσματα έξειξαν ότι ένω τα δύο σύνολα των περιθωρίων κέρδουν είναι αρκετά κοντά σε μέσους όρους εντούτις υπάρχουν διαφορές σε θέματα διασποράς. Τα μοντέλα διακριτής επιλογής που επιτρέπουν μικρότερη ανομοιογένεια μεταξύ των καταναλωτών αποτυγχάνουν να δημιουργήσουν αρκετή διασπορά στα περιθώρια κέρδους των επιχειρήσεων, ενώ τα μοντέλα διακριτής επιλογής που επιτρέπουν πλήρη ανομοιογένεια μεταξύ των καταναλωτών δημιουργούν ικανοποιητική διασπορά αλλά όχι όση θα περιμέναμε. Επιπλέον, η χρήση πρόσθετων χαρακτηριστικών στην εξίσωση της ζήτησης που εκτιμούμε είναι ύψιστης σημασίας για την εκτίμηση των περιθωρίων κέρδους ακόμη και αν αυτό συνεπάγεται σε μείωση του αριθμού των παρατηρήσεων του δείγματος. Επιπρόσθετα, η συσχέτηση των εχτιμημένων περιθωρίων κέρδους και των αντίστοιχων υπολογισμένων είναι σχετικά ικανοποιητική. Γενικά, η σύγκριση των εκτιμημένων περιθωρίων κέρδους και των αντίστοιχων υπολογισμένων δείχνει τα δύο σύνολα πανομοιότυπα, πράγμα που σημαίνει ότι τα μοντέλα διακριτής επιλογής μπορούν να εκτιμήσουν αρκετά καλά τα περιθώρια κέρδους.

Στα κεφάλαια 4 και 5, γίνεται αξιολόγηση πιθανών αλλαγών πολιτικής που θα μπορούσαν να οδηγήσουν στη μείωση των εκπομπών διοξειδίου του άνθρακα των μηχανοκίνητων οχημάτων. Ιδιαίτερα, αυτά τα κεφάλαια εστίαζονται σε πολυάριθμες προσομοιώσεις όπου προσδιορίζονται για κάθε πιθανή αλλαγή πολιτικής οι αλλαγές στην ευημερία, στα δημόσια έσοδα, στα περιθώρια κέρδους των επιχειρήσεων και στις εκπομπές του διοξειδίου του άνθρακα (δηλαδή δίνεται έμφαση και στις περιβαλλοντικές αλλαγές αλλά και στις οικονο-

μικές αλλαγές). Η σύγκριση για τον προσδιορισμό των αλλαγών γίνεται με το ισχύον φορολογικό σύστημα της χώρας η οποία εξετάζεται. Το μοντέλο που παρουσιάζεται σε αυτά τα κεφάλαια μπορεί να χρησιμοποιηθεί από τους δημιουργούς πολιτικής για πρόβλεψη των οικονομικών και περιβαλλοντικών επιπτώσεων για οποιαδήποτε πιθανή αλλαγή πολιτικής στην αγορά αυτοκινήτων που σκέφτονται να υιοθετήσουν. Στην περίπτωση που μπορεί να εφαρμοστεί ένα σύστημα φορολόγησησ-επιδότησης με βάση ένα αριθμό ρύπων, πάνω από το οποίο να φορολογείται περισσότερο το όχημα ενώ κάτω από αυτό να επιδοτείται, η μελέτη έδειξε ότι ο αριθμός αυτός είναι σημαντικός για τις αποφάσεις των δημιουργών πολιτικής και πρέπει να τίθεται σε λογικά επίπεδα (ούτε σε πολύ μεγάλα αλλά ούτε και σε πολύ μικρά).

## Acknowledgements

First of all, I would like to express my deep gratitude to my thesis supervisor, Sofronis Clerides, for his constant orientation and encouragement. His guidance was truly inspiring not only to this thesis, but also to my career. I am also in debt with my third and fourth paper co-author, Theodoros Zachariadis. Their insights have enriched the content of this dissertation.

I am also grateful to all the participants of the 2007 ASSET, the 2010 EARIE and the 2010 Jornadas de Economía Industrial conferences, especially my discussant Consuelo Pazó, for their useful comments and suggestions.

Last but not least, I would like to thank my family, for their unconditional support.

# Contents

# List of Figures

# List of Tables

# Chapter 1

# Introduction



Empirical models of differentiated product markets have been the subject of many studies in the economic literature. Typically, these studies employ a discrete choice model (Berry, 1994; Berry, Levinsohn, and Pakes, 1995) that accounts for consumer heterogeneity on the demand side. When coupled with an assumption on firm behavior (typically Bertrand-Nash pricing), discrete choice models can produce estimates of marginal cost and therefore also of markups (defined as the absolute difference between price and marginal cost). These models are also well suited to welfare analysis and have been applied to calculate the welfare gains from product innovation (e.g. Trajtenberg (1989): a study regarding the quality improvements in CT scanners) or for the investigation of policy changes and unique experiments (e.g. Fershtman and Gandal (1998): they estimate the welfare effects of the boycott of the Israeli market by a number of automobile manufacturers and Clerides (2008): a study that exploits a unique experiment regarding trade liberalization for the small economy of Cyprus for the investigation of the welfare effects).

Perhaps the most frequently studied market in this literature is the automobile market. This is not surprising, since the automobile market is well suited to the assumptions employed in this literature. In addition, buying an automobile is probably the second most important decision of a household after the decision to buy a house. Therefore, any analysis regarding automobile markets is of great economic interest particularly with respect to matters such as trade policy and environment.

This dissertation analyzes policy questions relating to automobile markets using advanced techniques from industrial organization. In Chapter 2, I exploit a unique experiment regarding trade liberalization that occurred in Cyprus the year 1993. The maximum allowable age of an imported vehicle increased from two years to five, making possible the importation of used cars from Japan into Cyprus. This experiment gave me the opportunity to investigate the impact of used imports on the price level in small economies. The outcome indicates that the increased competition from the import of used cars lead to a significant reduction of prices of both used and new cars. In economies with a relatively high share of automobiles in CPI basket, a price reduction actually means a strong negative impact on CPI. In chapter 3, I exploit the availability of auxiliary information and an idiosyncracy of the Cyprus tax system to obtain estimates of markups for automobiles in order to evaluate the performance of discrete choice models for the estimation of firms markups. A comparison of the two sets of markups shows them to be reasonably similar, which bodes well for DCMs. In chapter 4 and 5, I evaluate potential public policy interventions that could lead to the reduction of CO2 emissions of motor vehicles. I carried out numerous simulations and I assess changes in consumer welfare, public revenues, firm mark-ups and CO2 emissions according to different policy scenarios compared to the current vehicle taxation regime. The work carried out in these chapters can be applied by policy makers for the prediction of economic and environmental changes in an automobile market for any potential policy change. An extensive summary regarding the dissertation chapters are provided in the next paragraphs below.

In the second chapter, I exploit a unique experiment in order to investigate the impact of used imports on the price level in small economies. In 1993 Cyprus relaxed restrictions on the importation of used automobiles into the country. Specifically, the policy change increased the maximum allowable age of an imported vehicle from two years to five, making possible the import of used cars from Japan to Cyprus. This led to a dramatic increase in imports of used cars; at their 1998 peak, used vehicles accounted for 72% of all car imports. This should have reduced the overall price level of automobiles for two reasons. First, increased competition from used cars must have caused a reduction of prices of new cars. Second, prices of used imports were lower than those of locally traded used vehicles. My objective is to test the validity of these theoretical predictions and to quantify the impact of used good imports on the price level.

Although there is a relatively rich literature about the introduction of new goods in the Consumer Price Index, this does not happen for the introduction of used goods in CPI. A small economy (without a local automobile industry) which is used to import only new goods, it is expected to have very large gains from the introduction of used goods (in case that there is no local market for used goods). This is happened due to the increase in competition, and not because of the product innovation. Clerides (2008) investigates the welfare effects of the introduction of used automobiles in Cyprus market by exploiting the policy change of 1993. He estimates a discrete choice model of demand and uses demand estimates to compute the consumer welfare. The results have been compared to the counterfactual scenario of no policy change. The author argues that the increase in competition was due to trade liberalization and he finds substantial welfare gains that exceeded $1,000 per purchaser in one year.

Furthermore, in chapter 2, I use hedonic price indices to investigate the impact of used imports on the price level. I compute the reduction of prices due to the policy change and similarly to Clerides's idea, I compare the results to the counterfactual scenario of no policy change. I am also able to distinguish between the change in prices that happened because of the reduction of prices of new cars (which I call the indirect effect) and the remaining effect which captures the reduction of prices due to the fact that a used product enters the market with lower quality and lower prices compared to prices of new cars (which I call direct effect). I find that the minimum decline in the prices of new cars reached an average annual growth rate of 1.1%. Regarding the direct effect, I find a decline in the prices of an average annual growth rate of 0.15%. In economies with a relatively high share of this good in CPI basket (perhaps due to high taxation, as in Cyprus), a price reduction actually means a strong negative impact on CPI. Before the entrance of Cyprus into the European Union, the commission demanded from candidate countries to have its inflation under 2.5%. Although I do not examine what the inflation would be that period if the policy change never happen, this policy change seems to help Cyprus to keep its inflation in relatively lower levels.

In chapter 3, I exploit the availability of auxiliary information and an idiosyncracy of the Cyprus tax system to obtain estimates of markups for automobiles in order to compare them with the markups estimated using discrete choice models. Discrete choice models' estimates have been used by researchers to address several questions that interest industrial organization economists, such as the impact of mergers and the measurement of market power. However, as actual markups are very rarely observed in practice, it is very rare that economists are able to compare their discrete choice models' estimates of markups with their "true" counterparts. Being able to do so (comparing the two set of markups) would be very useful as it would be a good way of assessing the performance of discrete choice models. My alternative markups can be calculated due to the availability of some auxiliary information in the Cyprus automobile market. They are computed from simple algebraic relationships and are not the outcome of econometric estimation so they are completely independent of those obtained from discrete choice models. I caution that my alternative markup estimates are not hard data. I need to make assumptions in order to compute them, therefore my estimates are not assumption-free even if they are model-free. The usefulness of this approach lies in the fact that these assumptions are very different from those made in the standard differentiated product model, hence the calculated markups can be used as a useful benchmark for comparison. Furthermore, the advantage of this procedure is that I am able to compare two set of markups and not one set of markups with a fixed percentage. Nevo (2001) compared the implications of different assumptions with some reasonable percentages. These percentages are simply the gross price-average variable cost margins. The average variable cost represents the cost of production of cereals and was computed from aggregate census of manufacturers. He found that discrete choice models perform well for the estimation of firms markups under the assumption of Bertrand-Nash pricing. Nevo's comparison was done with fixed percentages, whereas, in this chapter I am able to compare directly the set of markups obtained from discrete choice models, with the set of markups obtained from an alternative procedure (markups vary among car models).

The idiosyncracy of my data stems from the tax system. Automobiles in Cyprus are heavily taxed with a variety of different instruments. The most important ones are a consumption tax (a percentage of the vehicle's import price) and a per unit tax. Some groups and individuals that meet certain criteria can be exempt from paying taxes on automobile purchases. For a period of several years I am able to observe two prices for each model: a price with taxes and a price without them. Thus for each model I have two expressions linking marginal cost and prices but I have three unknowns: marginal cost, the markup for taxed vehicles and the markup for tax-free vehicles. By making an assumption on the relationship between the two markups I can obtain the desired estimates. The main assumption I use regarding the relationship between the two markups is reasonable according to the theory and it is supported by empirical findings (there is an extensive discussion about this assumption in chapter 3). The findings of this chapter are the following: First, I found that both set of markups are similar in levels. Second, estimated markups obtained by discrete choice models that allow for less heterogeneity among consumers fail to generate enough dispersion in markups across different types of cars. A discrete choice model that allows for full heterogeneity among consumers generates satisfactory dispersion but not as enough as expected. Third, the use of additional demand attributes (for the demand estimation) is essential for the estimation of markups even with the cost of lower number of observations. Finally, the correlation between the two sets of markups is found to be near 0.45 which is relatively satisfactory. Generally, the comparison of the two sets of markups shows them to be reasonably similar, which bodes well for discrete choice models.

In chapters 4 and 5, I evaluate potential public policy interventions that could lead to the reduction of CO2 emissions of motor vehicles and I follow the literature to carry out welfare analysis. I employ a discrete choice model that accounts for consumer heterogeneity on the demand side and using the demand parameters I estimate the existing welfare. Then, I proceed with the estimation of welfare for a number of alternative environmental policies basically through a feebate-rebate system. By taking into account that prices come from the firms profit maximization problem, these policies affect the final prices faced by the consumers and the shares of a given car model. Fershtman, Gandal, and Markovich (1999) use a similar procedure to examine a per-car tax and a tax based on engine size using data from the automobile market of Israel. Our main difference is that I am using environmental taxes and a discrete choice model that allows for more heterogeneity among consumers. Under these simulations, I estimate not only the change in welfare but also the change in public revenues, firm profits and of course CO2 emissions.

To my knowledge, this is the first study that explores the effect of CO2-based taxation in Europe with the aid of an advanced model to be empirically tested in European countries and taking into account that prices come from the firms profit maximization problem. The results of these chapters are very interesting. The feebate-rebate pivot point is proved to be very essential for the decision of policy makers. If the pivot point is very high (approaching the current average CO2 emissions per car), then it is much more difficult for policy makers to reduce CO2 emissions even if the linear tax is very high. A high pivot point may increase firm markups and consumer welfare but leads to a significant decline in public revenues. On the other hand, a very low pivot point may increase public revenues and reduce CO2 emissions effectively at the cost of a huge decline in car total sales, leading to a high drop of markups and welfare. It is very important for policy makers to choose wisely the pivot point and the tax per CO2 emission in a way that they weigh precisely both costs and benefits. For example, assume that there are two alternative environmental taxation policies that do not change public revenues. The first one decreases consumers welfare by 2% and firms markups by 5% but decreases also CO2 emissions by 5% ,whereas, the second one decreases consumers welfare by 4% and firms markups by 8% but decreases CO2 emissions by 10%. If policy makers care more for strong environmental effects compared to consumer welfare (and firms markups) they should choose the second policy, and if they care for minor environmental effects but they have strong preferences for not reducing a lot the consumer welfare and firms markups, they should choose the first policy. It is important to note that the numbers I mention above are the outcome of two simulations regarding the German automobile market.

# Chapter 2

# The Impact of Used Goods on CPI

## 2.1 Introduction

The impact of the introduction of new goods on Consumer Price Index is supported by a rich existing literature. Using the classical theory of Hicks and Rothbarth, Hausman (1997) argues that the Bureau of Labor Statistics should calculate and adjust the CPI for the introduction of completely new goods. In the above well-known paper, Hausman estimated a demand curve for what would seem to be a modestly differentiated new variety of Cheerios breakfast cereal (Apple Cinnamon Cheerios). He calculated that its introduction generated substantial additions to consumer welfare. The price that was used for the good in the pre-introduction period is the "virtual" price which sets demand to zero. Similarly, Nordhaus (1997) analyzed the cost of indoor illumination and showed that there have been dramatic reductions in the price of light, as measured in lumens, when new technologies (such as compact fluorescent bulbs) have been introduced. Obviously, both papers suggest that the CPI is missing some very large gains in consumer welfare because of the new goods bias problem. Several papers that cover this literature can be found in Bresnahan and Gordon (1997).

Although there is a relatively rich literature about the introduction of new goods in the Consumer Price Index, the same is not true for the introduction of used goods in CPI. A small economy (without a local automobile industry) which is used to import only new goods, it is expected to have very large gains from the introduction of the used goods (in case that there is no local market for used goods). Large gains are expected not because of product innovation, but because of the increase in competition.

This chapter aims to contribute to this literature by focusing on a unique natural experiment in the Cyprus Automobile Market. Specifically, in 1993 import restrictions on used cars were relaxed by increasing the maximum allowable age of an imported vehicle from two years to five. This change led to a dramatic increase in imports of used cars as it opened the gates to the mass import of used Japanese vehicles. It is important to say that before 1993, no local market for used cars existed in Cyprus. The lack of used cars local market, the absence of blue books and the hesitation of consumers to buy a used car due to the uncertainty about the quality of the products, led Cypriots to prefer buying new cars. After the vanish of the consumer hesitation, the used imports look like a "new" good for the Cypriots that is offered in lower price and similar quality with a lower remaining life.

Clerides (2008) argues that the increase in competition was due to trade liberalization. The restrictions on trade conditions were waived and the country open the gates to the mass importation of used cars. Even if those cars were older compared to the previous policy, they were in very good condition. They came with many extras, and were selling at prices considerably lower than those prevailing in the local secondary market at the time. The author investigates the welfare effects of the introduction of used automobiles in Cyprus market by exploiting the policy change of 1993. He estimates a discrete choice model of demand and uses demand estimates to compute consumer welfare. Then, he compares the results to the counterfactual scenario of no policy change. He argues that the increase in competition was due to trade liberalization and he finds substantial welfare gains that exceeded \$1,000 per purchaser in one year.

In this chapter, a number of quality-adjusted price indices for Cyprus automobile industry over the 1989-2005 time period is constructed. This period was marked by two policy changes: a) the introduction of used imports described above and b) two tax reforms. During the same period other changes occurred, such as the gradual reduction of duties after the custom union of Cyprus with the European Union.

The objective of this study is to calculate the repercussions of the 1993 police change in the consumer price index. The hedonic indices used take into account the improvement of automobile quality, the introduction of new models in the car market, the withdrawal of older models from the market and the sales of different models. I compute the reduction of prices due to the policy change and similarly to Clerides's idea, I compare the results to the counterfactual scenario of no policy change. I am also able to distinguish between the change in prices that happened because of the reduction of prices of new cars (which I call the indirect effect) and the remaining effect which captures the reduction of prices due to the fact that a used product enters the market with lower quality and prices compared to the prices of new cars (which I call direct effect). I find that the minimum decline in the prices of new cars reached an average annual growth rate of 1.1%. Regarding the direct effect, I find a decline in the prices of an average annual growth rate of 0.15%. In economies with a relatively high share of automobiles in CPI basket (perhaps due to high taxation, as in Cyprus), a price reduction actually means a strong negative impact on CPI. Before the entrance of Cyprus into the European Union, the commission demanded from candidate countries to have its inflation under 2.5%. Although I do not examine what the inflation would be that period if the policy change never happen, this policy change seems to help Cyprus to keep its inflation in relatively lower levels.

Section 2 provides more details about the two policy changes. In section 3 the price indices methodology is illustrated and discussed. Different hedonic indices are introduced and compared among them. A direct comparison between hedonic and match methods are also provided. Section 4 describes the data and provides the main statistical tests undertaken in this project. Besides, emphasis is given on the choice of the hedonic functional form. Section 5 analyzes the data and section 6 concludes.

## 2.2 Market Description

Cyprus does not produce automobiles; all vehicles are imported from abroad. The new vehicles are imported from the major car manufacturing companies. The local market operates on an exclusive dealership system. Each manufacturer designates a local dealer who is the sole distributor of his products in Cyprus and thus has substantial market power.

### 2.2.1 Policy Change of 1993

In 1993 import restrictions on used cars were relaxed by increasing the maximum allowable age of an imported vehicle from two years to five. This policy change led to a dramatic increase in imports of used cars because it opened the gates to the mass importation of used Japanese vehicles. It is important to say that before 1993, a tiny market for used cars existed in Cyprus. The lack of a large-competitive used cars local market, the absence of blue books and the hesitation of consumers to buy a used car due to the uncertainty about the quality of the products, led Cypriots buying new cars. Initially, consumers were uncertain about the quality of the imported used cars. In order to overcome consumer hesitation, used car dealers offered warranties and other incentives. Their efforts were effective and the uncertainty with regard to the quality of used imports gradually disappeared.

### 2.2.2 Taxation

Before 2003, all cars were taxed very heavily: there was a value tax which varied from 80%-130% (depending on the car size) and a proportional tax which depended on engine capacity. There was a tax reform in 2003, after which the tax was mainly calculated based on engine capacity. All taxes were paid upon registration. Import duties for cars were phased out during the 1990s, with the exception of a 10% duty on cars imported from non EU countries.

Before the tax reform of 2003, there was a mixed system of taxation based on the tariff price and the engine capacity. Specifically the proportional tax of saloon type vehicles remained the same from 1989 up to the tax reform of 2002 when it was eliminated for cars with engine capacity under 1601 cc. The value tax was calculated according to the following three categories: a) the introductive duty which was 20,5% for EU countries and 34,6% for all the others on the year 1989. This duty was gradually decreasing until 1998 when it became 10% for non EU countries b) a refugee tax which was 4% for EU countries and 4,9% for the rest of them on the year 1989. The above tax was decreasing gradually until 1998 when it was cancelled c) the consumption tax which was the same over the period 1989-2002 and varied from 80% to 130% depending on car size. For example, it was 80% for vehicles with engine capacity lower than 1000 cc and 130% for vehicles with engine capacity higher than 2500 cc. From 2002 this tax varies from 55% for cars with engine capacity up to 1600 cc to 135% for vehicles with engine capacity over 2500 cc. A significant fall of this factor can be noticed for cars with engine capacity up to 1600 cc from 80%-100% to 55%, a comparatively lower fall for cars with engine capacity of 1601-2000 cc from 100% to 85% and a small rise for cars with engine capacity over than 2500 cc from 130% to 135%.

After the tax reform of 2003, the tax is calculated only based on the engine capacity. Particularly, for cars of type saloon and SUVs the tax is calculated as follows: 0.50 Cyprus pounds (CYP) per cc for cars with engine capacity up to 1450, 0.85 CYP per cc for cars with engine capacity from 1450-1650 cc, 2.70 CYP per cc for cars with engine capacity from 1650-2050 cc, 2.85 CYP per cc for cars with engine capacity from 2050-2250 cc, 5.50 CYP per cc for cars with engine capacity from 2250-2650 cc and 8.00 CYP per cc for cars with engine capacity over than 2650 cc. There is also an additional tax of 0.01 CYP per cc for all the categories above.

### 2.2.3 The CPI Basket

The share of automobiles in the CPI basket in Cyprus during a number of years is very high and consequently, this constitutes a significant portion of the share of imported goods. It is important to mention that the 1986 and 1992 baskets included only new cars due to the relatively low shares of the used cars. After the policy change of 1993 and the change in consumers" choices, used cars were included in the 1998 basket. The respective shares of automobiles and imported goods (excluding petroleum products) in the CPI basket are shown in Table 2.1 for the three most recent base years: 1986, 1992 and 1998. The significant share of imported goods [1] in the CPI basket is a natural consequence of the smallness and openness of the Cyprus economy.

Figure 2.1 shows the particularly favorable direct impact of prices of imported goods on the overall CPI, for the period 1992-1999. Characteristically, the average monthly prices of imported goods between 1992 and 1999 increased by 0.35% compared to an overall monthly average increase of 1.87% of the CPI.

A closer look at the data, and more specifically at the components of imported

[1] Excluding final consumption of petroleum products. That period, most imports of petroleum products were processed in Cypriot refineries and were therefore considered to be intermediate products. Today Cypriot refineries are used only as storage rooms for the specific products.

Table 2.1: The share of automobiles and imported goods in the CPI basket

| Base Year | Used | New | Total | Import Goods |
|---|---|---|---|---|
| 1986 | 0% | 7.43% | 7.43% | 19.81% |
| 1992 | 0% | 11.74% | 11.74% | 23.17% |
| 1998 | | | 9.43% | 22.20% |

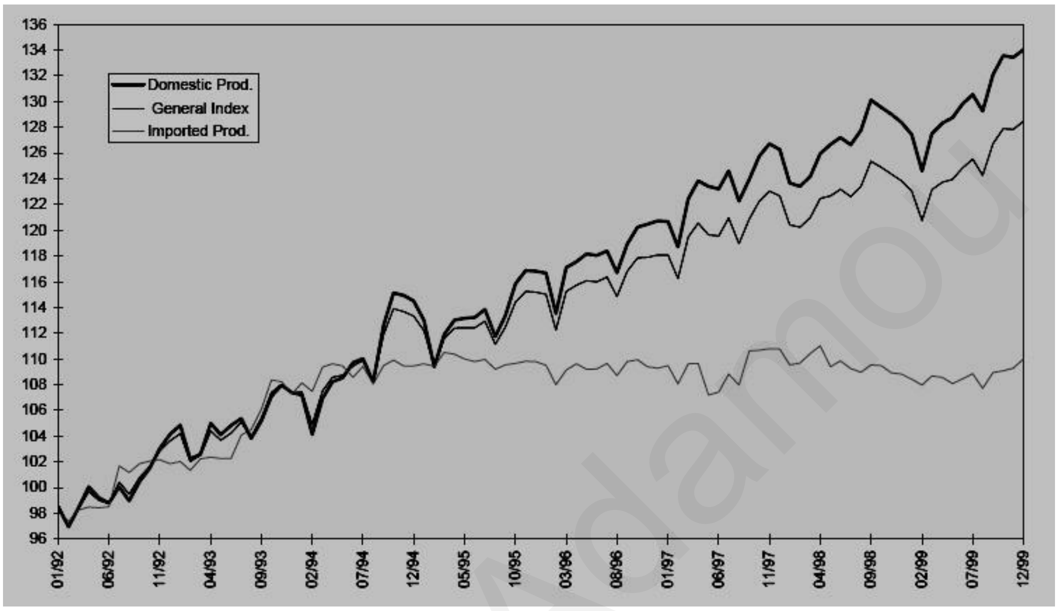



Figure 2.1: The impact of imported goods on the overall CPI

goods, indicates that the most prominent contribution to a lower CPI is attributed to the prices of automobiles which, in fact, for the period 1995-1999 recorded an absolute decline. The decomposition of prices into imported automobiles and other imported goods depicted in Figure 2.2 is quite telling. For the period 1992-1999 the prices of motor vehicles exhibited an average monthly decline of 1.29%, whereas the monthly price index of "other imported goods" (i.e. imported goods excluding petroleum products and motor vehicles) increased on average by 0.55% [2].

## 2.3 Price Indices Methodology

### 2.3.1 Match methods

Match method is based on the assumption that product characteristics remain unchanged for each model across a specific period. The price indices are constructed by a direct comparison of prices of specific products. However, by the construction of this index, it follows that when a new upgraded model appears in the market, it is considered as a new model for comparison purposes. The problem that arises here is that this method cannot provide the two-period effect before and after the upgrade of

[2]Both figures 2.1 and 2.2 are based on Cyprus Statistical services" car CPI data.

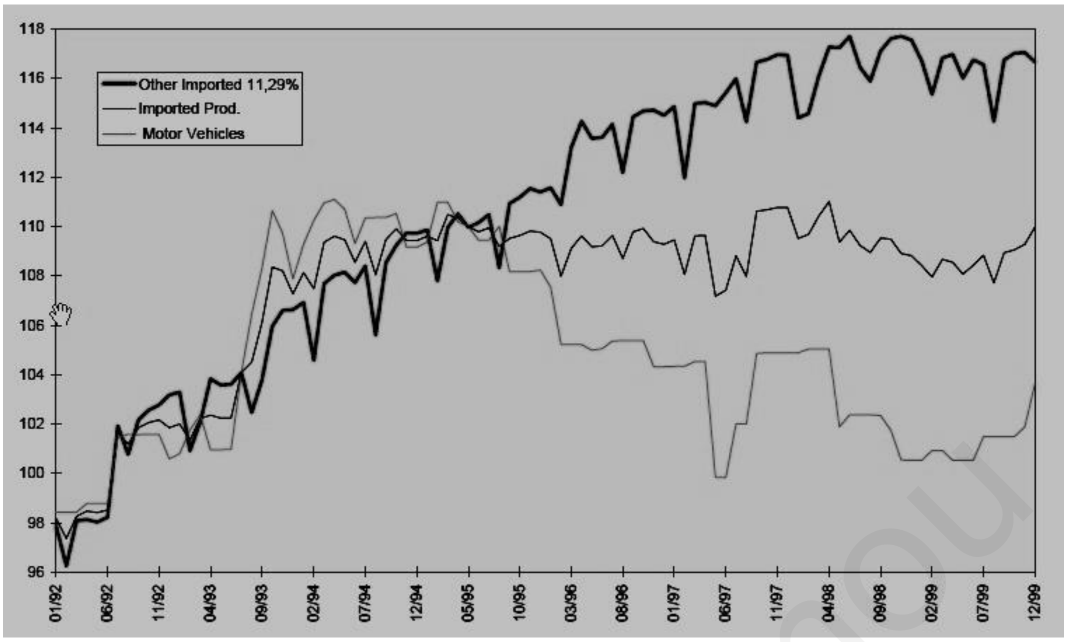



Figure 2.2: The impact of imported automobiles on imported goods

the product. If the improved quality value of the good exceeds the increase of its price then this method overestimates the real price index. Conversely, if the value of the quality improvement is lower than the price difference then this method underestimates the real price index. Additionally, if the changes in the characteristics of an upgraded model are comparatively minor, then the upgraded model is considered the same model as before and therefore this price index will ignore the changes. Finally, the database used in this study is reduced to a "selective" database for the application of the match method. According to Pakes (2010) "since the price changes of the goods that survive the comparison method are not a random sample of all price changes, the match model index incurs a selection bias". For example suppose that a model can only be sold the next period if its price is reduced a lot. But this reduction will be so significant that it would have made the good unprofitable to the market. Therefore the model exits the market and it is not included in the selective database used for the calculation of the match method. Certainly, basing only on prices of goods that do survive, the match method is given a positive selection bias.



### 2.3.2 Hedonic Function

A hedonic price index is any price index [3] that makes use of a hedonic function. A hedonic function is a relation between the prices of different varieties of a product, such as the various models of automobiles, and the quantities of their characteristics.

The hedonic model can be considered as an equilibrium model in product differentiation. The car"s price is assumed to be a function of a set of its characteristics

[3] A price index is any single number calculated from an array of prices and quantities over a period. Since not all prices and quantities of purchases can be recorded, a representative sample is used instead. For example if in period t and t+1 the quantity is one then the price index is simply $(P_{t+1}/P_t) - 1$.

or attributes. When the product price is expressed as a linear function of those characteristics, the estimated coefficients of the characteristics can be interpreted as their implicit prices (in the case of perfect competition). This technique implies that consumers buy the ideal bundle of characteristics for them and producers sell the bundles that they think to be more profitable for them. Thus, characteristics can be treated as independent goods. If two brands offer the same bundle in different prices, then consumers buy the less expensive one. Hedonic estimation residuals have an economic interpretation. Negative residuals are “bargains” as automobiles cost less than one would expect from the quantities of characteristics they contain. Conversely, positive residuals mean that automobiles cost more than the cost of the bundle of their characteristics.

Rosen (1974) developed the output theory for producers and consumer choice of product characteristics in the case of perfect competition. Inverse demand for characteristics was estimated using the estimated hedonic coefficients (the implicit prices in case of perfect competition). However, according to Pakes (2003), the coefficient from hedonic regressions generally cannot be interpreted. In the case of marginal cost pricing, the hedonic function is the marginal cost function. In Bertrand equilibrium the hedonic function is the sum of the marginal cost function and a function that summarizes the relationship between markups and characteristics. As a consequence, in Bertrand equilibrium the hedonic regression coefficients cannot be interpreted as implicit prices.

According to Hausman (2003), the price of a good under imperfect competition is an interaction of demand, cost, and competitive interaction. A hedonic regression combines these sets of factors. Under very special conditions (perfect competition), only cost may matter in the determination of price. Triplett (1987) pointed out that the perfect competition case was unrealistic for technological products such as PCs. In the most recent theoretical background, Pakes (2010) argued that for highly differentiated products, like automobiles, there are relatively few sellers, and competition among them often takes the form of product innovation. In order to find markups and gains from innovation, the models described in Berry, Levinsohn, and Pakes (1995) should be applied. Moreover, according to Griliches (1990), “the hedonic approach simply attempted to provide a tool for estimating “missing” prices, that is prices of bundles not observed in the original or later periods. It was not intended to answer whether the various observed differentials are demand or supply oriented, how the observed variety of models in the market is generated, or whether the resulting indexes have an unambiguous welfare interpretation.”

In this chapter my goal is not the application of a structural model of demand and supply in order to proposed an advance index. My primary task is to analyze the effect of the policy change of 1993 on prices and not to estimate the cost parameters. If my task was to estimate those parameters then I would apply a discrete choice model of demand as I do in the following chapters. Triplett (2006) mentioned the existence of four types of non-structural model indices: The dummy variable method, the characteristics price index method, the imputation method, and the hedonic quality adjustment method. The hedonic quality adjustment method can be estimated using a hedonic function from a prior period, whereas all the other methods requires the current period"s hedonic function as well. In fact the dummy variable method can be employed when it is feasible. However, its major liability is the difficulty in introducing weights into the dummy variable index. In this study I use two methods; the dummy variable method and the characteristics price index method. Since I have many observations, I choose not to use the fourth method. Between the second and the third method that accounts for weights, I choose to use one of them: the second. The two methods I use work very well for the purpose of this study. As Triplett (2006) argues: "there is virtue in methods that make use of all the data that can be collected, and the dummy variable method, as well as the characteristics price index method, does that."

### 2.3.3 Hedonic Indices

Below, I explain three basic hedonic price index methods. The first one is called "time dummy variable method". According to this method, the logarithm of the product price is regressed on its characteristics and time dummies. Hence, the coefficient of each dummy denotes the logarithm of the price ratio between the year of the specific dummy and the omitted year. In order to construct this index (with the omitted year as the based year), the dummy coefficients are simply exponentiated [4].

The second method is the one that Griliches (1971) called "price-of-characteristics index". According to this notion, prices are regressed on the characteristics separately for each year of the sample and then the estimated coefficients are used as "implicit prices" for the construction of price indices. For example, "implicit prices" can be estimated for year 1 and year 2. Then, the two-year price index is simply the year 2 price fitted value divided by year 1 price fitted value. The characteristics quantities that should be used for fitted value calculation is something that should be considered. If the mean of characteristics of year 1 is used, then this index is a Laspeyres price index. Similarly, if the mean of characteristics of year 2 is used, then this index is a Paasche price index. Their geometric mean is the Fisher price index and it is calculated by taking the square root of the multiplication of Laspeyres and Paasche price indices. Fisher index is an approximation to a COLI [5] "subindex" (based only on automobile

[4] However, according to Kennedy (1981) a standard bias correction is needed because the exponential of the dummy coefficient does not actually capture the real price ratio. To correct this problem, I must first subtract one-half the coefficient"s squared standard error from the estimated coefficient and then exponentiate it. This method still gives a biased estimator, but it reduces the bias.

[5] COLI is a cost of living index and it is defined in economic theory as the ratio of expenditure required to maintain a constant level of utility. In other words, it describes the welfare changes in terms of the percent of income necessary to leave the household indifferent. Consequently, it provides a unit-free measure of the change in social welfare.

characteristics). Laspeyres and Paasche indices are approximations to an upper and lower bound of a COLI "subindex" respectively.

The two methods described above were used by many researchers like Berndt, Griliches, and Rappaport (1995). Another method is the "improving matched method" which allows for product upgrading. Unfortunately, the other match method"s problem is still valid. For example, suppose that a model that was sold in year 1 is upgraded in year 2 and the prices of the older model in year 2 cannot be observed. One way to calculate this index is to regress prices on characteristics for year 1 for all observe models in order to find the implicit characteristics prices for year 1. Then the quantity of characteristics (that are observed in year 2) is multiplied with implicit prices for year 1 and the summation is computed for the creation of an estimated car price for the upgraded car for year 1. After that, a comparison of the estimated price of year 1 with the normal price of year 2 can be made. The other way is to regress log of prices on characteristics for all the models and years and save the coefficients. Then those coefficients can be multiplied with characteristics ratio (e.g. engine capacity of year2 divided with engine capacity of year1). After summing and computing the exponential, this result (1+g) minus one is defined as the percentage of the quality improvement between the old and new model. By multiplied this result (1+g) with the price of the older model at year 1, then an estimated price for the upgraded model for year 1 can be recorded. Consequently, a comparison of year 1 estimated prices and year 2 actual prices can be made. Diewert (2003) pointed out that this method can give more or less the same results as the first two methods provided that the amount of matching is relatively large and that traditional superlative indices should be used [6]. For this reason this method will not be applied here. However, all three methods are described mathematically in the appendix.

In section 5, seven indices are presented. These are the following: a) the "arithmetic mean index" which completely ignores the effects of characteristics b) the "match index" which is based on the classic match method [7] c) the "pooled time dummy variable index" which is the first hedonic prices index method described in this section d) the "two-period dummy variable index" which is a modification of "pooled time dummy variable index" as I allow for a change in characteristics coefficients across years [8] e) the "Laspeyres price index" f) the "Paasche price index" and g) the "Fisher price index". The last three indices are the "price-of-characteristics indices" that I denote above.

---

[6] According to Silver and Heravi (2001) a geometric average of the Laspeyres and Paasche indices yields a superlative fisher index. Superlative indices are some indices named by Diewert (2003) that corresponds to flexible functional forms which are second order approximations to the underline utility function of consumers. That is, superlative indices like the Fisher can do the job.

[7] I made an assumption that a model remains the same if its characteristics do not change less or more than 1%.

[8] Wald test reject the stability of characteristics or attributes coefficients but I present this index for comparisons. For more information, you can look at the next section.

## 2.4 Data and Empirical Issues

Information on car sales was obtained from the Cyprus Road Transport Department, which keeps track of vehicle registrations. Figure 3 shows annual registrations of new and used cars for the period 1989-2005. Data on new automobile prices are obtained from a local car magazine called “Driver & Car”. The magazine has been publishing monthly prices of most major car makes and models since 1989. Various vehicle characteristics (such as horsepower, weight, fuel efficiency, etc.) are also reported starting in 1995 [9]; only engine capacity and number of doors were reported prior to that. It is important to note that, all past issues of the magazine were unable to be located, so data are missing for some months, mostly in the earlier years. The number of models listed per month ranges from 25 to 57. Unfortunately, this magazine went out of circulation in June 2002. Consequently data from a second source was obtained, which is another local magazine called “4 wheels”. Prices of used automobiles are not as easy to come by. In many countries, market prices of used vehicles are reported in magazines or special publications (widely known as ”blue books”). Unfortunately, no such publication exists in Cyprus. Nonetheless, some information on the prices of used imports were collected from two individual dealers. This information is used for the construction of price indices for both new and used imports. No information on the prices of local used cars was found.

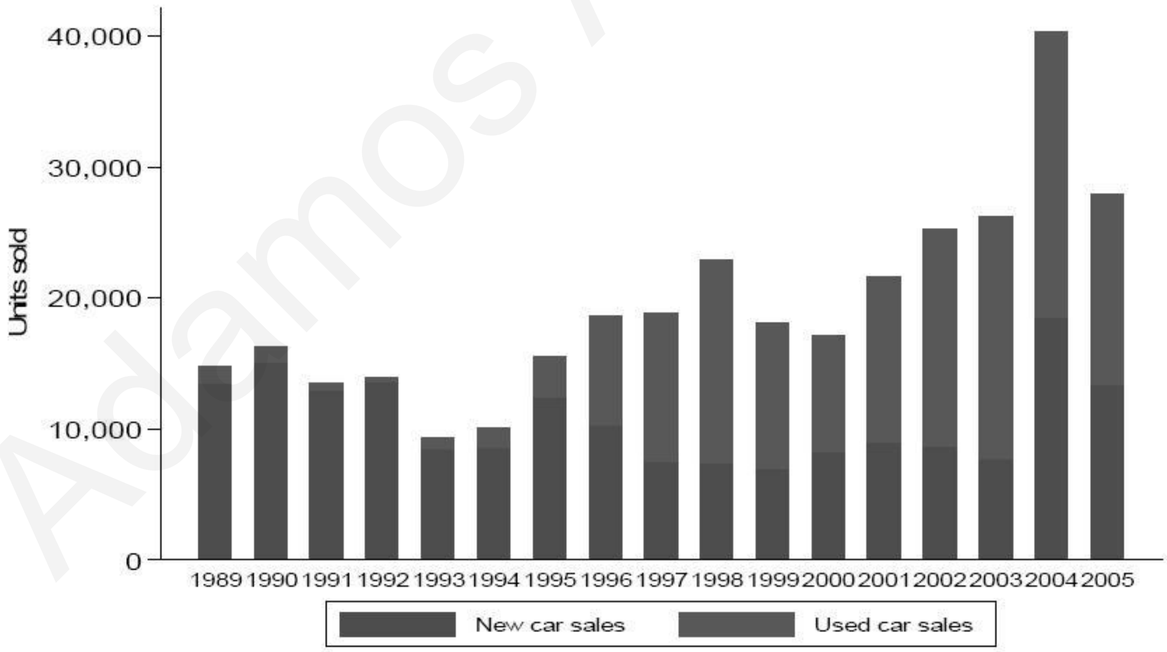



Figure 2.3: Sales of new and used automobiles

The price data provide some informal evidence on the reported quality increase. For example, Alfa Romeo’s “Alfa 146L” appears in the dataset under that name until July

[9] In order to have indices that take account of the quality of the characteristics before that period, I create “virtual characteristics” from 1989 to 1995 and they were numerically the same as their first real observation. As a result, the indices show the lower bound before December of 1995 period because the real quality was actually in lower levels than the one I imposed.

1995; starting in August 1995 it appears as "Alfa 146L A/C", with the price remaining unchanged. Apparently at that point in time the dealer made air-conditioning part of the standard package. Similarly, the Ford Ka gets the "A/C" at the tail of its name starting in December 1997; the Mitsubishi Charisma in February 1996 (the price rises in this case, only to fall below the original price by September of the same year); the Mitsubishi Lancer in February 1996; and the Seat Ibiza in November 1994 (with price increase).

For the construction of the indices, common characteristics are needed for the regressions. The data contains performance variables such as acceleration and fuel consumption and physical characteristics such as horsepower and weight. Ohta and Griliches (1976) pointed out that manufacture effects capture omitted variable effects, so I also include automobile company dummies (when the theory of the construction of an index allows me to do that). Specifically, the independent variables of this study are automobile company dummies, engine capacity, fuel"s consumption at 90 kms, maximum speed, acceleration, frame (length multiplied by width), horsepower, torque, weight and technology. The last variable is a variable that measures the technology due to an upgrade of a model [10]. Additionally the number of doors and a dummy for sport utility vehicles are used as independent variables.

### 2.4.1 Testing for functional forms

The theory of hedonic functions illustrates that the hedonic functional form is entirely an empirical matter. Rosen (1974) showed conclusively why in general theory cannot specify the appropriate functional form for hedonic functions, and why the hedonic functional form is purely an empirical issue to be determined from analysis of the data. Thus, one should choose the functional form that best fits the data empirically.

The dominant functional form that has been widely used in hedonic research for all products is the semi-log function. For PCs, double log and linear functions were also used. The standard econometric test for choosing functional forms is the "Box-Cox test". The test involves adding nonlinear parameters on both sides of the hedonic function equation. Depending on these estimated parameters, the function may collapse to either logarithmic or linear on either side. So, this test is a good tool for the decision regarding to the best functional form (from the set of the three most popular functional forms that I mentioned above). However, this test was inconclusive for this study as all forms were statistically rejected. Therefore, a more appropriate test should be used.

In order to choose between the three functional forms, I follow MacKinnon, White,

[10] The value of this variable changes when an upgrade happens. E.g. The Seat Ibiza for New Automobile Market has upgraded 3 times during 1989-2005: the years 1994, 1998 and 2004. This variable takes the value one from 1989 to 1993, the value 6 from 1994-1997 (1994 is the 6th year in the sample), the value 10 from 1998 to 2003 and 16 for 2004 and 2005.

Table 2.2: The correlation coefficients among characteristics

| Characteristics | Engine Capacity | Fuel Cons. | Max. Speed | Accel. | Frame | HP | Torque | Weight |
|---|---|---|---|---|---|---|---|---|
| Eng. Cap. | 1.000 | | | | | | | |
| Fuel Cons. | 0.464 | 1.000 | | | | | | |
| Max. speed | 0.463 | 0.248 | 1.000 | | | | | |
| Acceleration | -0.325 | -0.198 | -0.846 | 1.000 | | | | |
| Frame | 0.663 | 0.278 | 0.587 | -0.334 | 1.000 | | | |
| HorsePower | 0.742 | 0.386 | 0.816 | -0.711 | 0.659 | 1.000 | | |
| Torque | 0.262 | 0.126 | 0.203 | -0.169 | 0.205 | 0.307 | 1.000 | |
| Weight | 0.778 | 0.324 | 0.406 | -0.226 | 0.700 | 0.655 | 0.276 | 1.000 |

and Davidson (1983) [11]. The test can be applied to any combination of two functional forms. It rejects either both of the two functional forms or only one of them. Considering the three functional forms, three possible combinations could be done. Between double-log and linear functions, the test rejects both functions; between double-log and semi-log, the test rejects double log; between linear and semi-log, the test rejects the linear function. Consequently, semi-log seems to fit best to the data among the set of these three functions [12].

### 2.4.2 Other Testing

Multicollinearity is tested through correlation coefficients among the independent variables. The highest correlation, -84.61% is between acceleration and maximum speed. The other correlations are shown in table 2.2. Heteroskedasticity seems to be present as the white test rejects the homoskedasticity null hypothesis. Thus, heteroskedasticity-robust inferences after OLS estimations are applied. In order to test the stability of the characteristic coefficients, I create time-characteristics dummy variables and I use a Wald test to test the case that all dummy coefficients are zero. The test rejects the stability of the coefficients [13].

## 2.5 Results

Seven indices with and without weighting with sales are constructed. In addition, data from the new automobile market and from the whole automobile market are used. The difference between “new automobile indices” and “whole automobile indices” is

[11]This test is provided in details in appendix.

[12]Just for comparisons the R squared between the three functions: linear, semi-log and double-log is 0.7999, 0.8333 and 0.8218 respectively.

[13]All these “other” tests are based on the semi-log function as I found that it is the optimal functional form among the three dominant hedonic functional forms. My results in section V are based also in semi-log function.

the direct used cars effect [14]. I should also mention that since the semi-log hedonic functional form better fits the data, the use of this function to create the "price-of-characteristics indices" (Laspeyres, Paasche and fisher indices) is important. Moulton, LaFleur, and Moses (1998) also use the semi-log functional form to construct "price-of-characteristics indices".

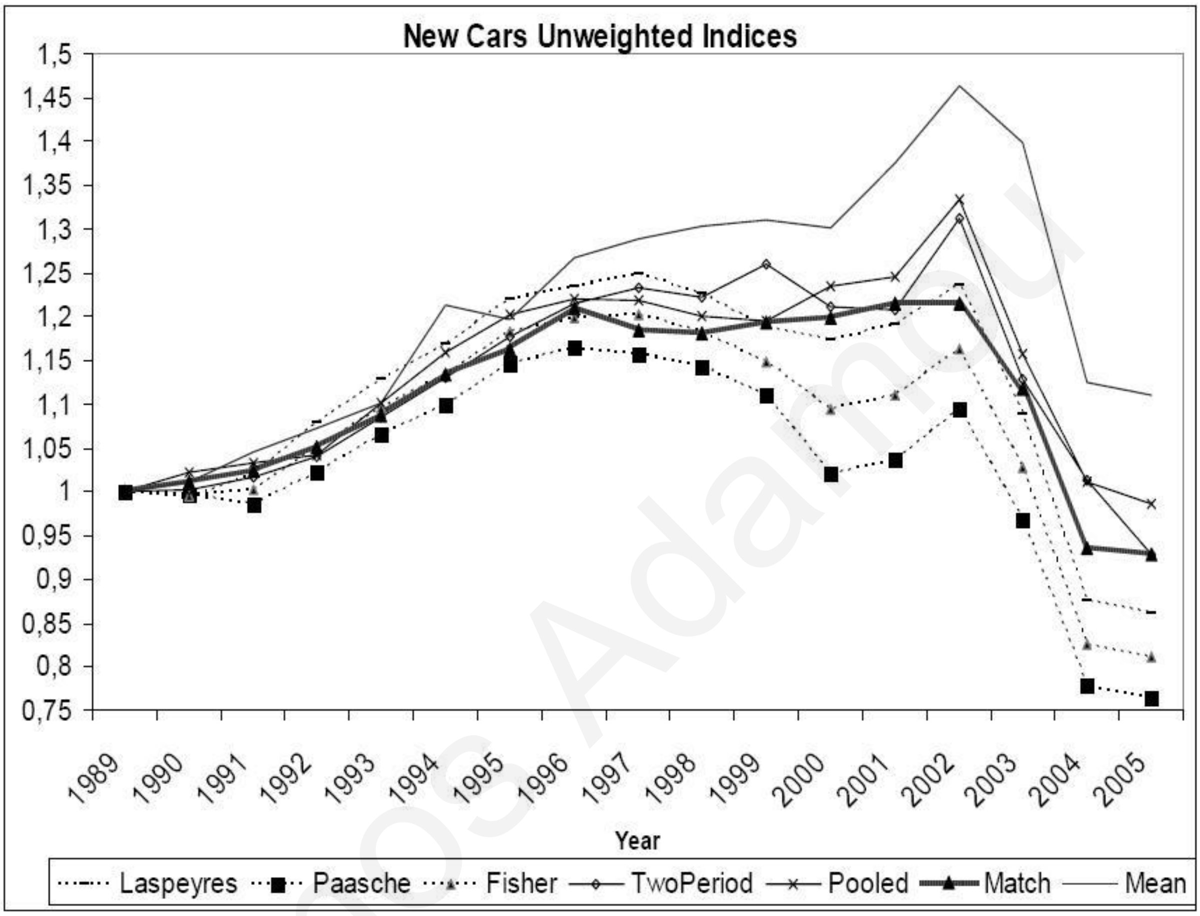



Figure 2.4: The unweighted Indices for new automobile market

Figure 2.4 shows the new automobile indices without weighting with sales. The "mean index" is the upper bound, as was expected, because it ignores quality improvements. The "pooled time dummy variable index" is very close to the "two period dummy variable index". The "two period dummy variable index" provides the minimum constraint on characteristics coefficients, which is compatible with the dummy variable method. That is, the characteristic coefficients are assumed to remain constant for two periods. Multi-period hedonic regressions should normally be avoided, unless it can be shown empirically that coefficients have not changed over time. Unfortunately, the appropriate test rejects the stability of the coefficients. By construction, the Fisher index is located between "Laspeyres price index" and "Paasche price index". "Laspeyres price index" is above "Fisher price Index" and "Paasche price index" is

[14] The used car"s observations are comparatively low and exist only for the years 1997-2002 and 2004-2005. That"s why I prefer this method for used cars direct effect in prices. The percentage of used cars observations to new cars observations varies from 7.41% to 17.87%. In order to distinguish new from used cars, I use an age variable in which a new car takes the zero value.

Table 2.3: The sales weighted Indices for new automobile market: Percentages change from previews years (gr) and averages annual growth rates (aagr)

| Rates-Year | Laspeyres | Paasche | Fisher | Twoperiod | Pooled | Match | Mean |
|---|---|---|---|---|---|---|---|
| gr1990 | -13.70 | -10.70 | -12.20 | -1.86 | -1.85 | -1.32 | -1.44 |
| gr1991 | 0.94 | 3.97 | 2.45 | 3.88 | 0.09 | -0.72 | 3.60 |
| gr1992 | 6.78 | 7.30 | 7.04 | 11.10 | 7.44 | 7.43 | 6.21 |
| gr1993 | 2.42 | 1.82 | 2.12 | -0.98 | 1.14 | 5.19 | -1.97 |
| gr1994 | 1.63 | 0.51 | 1.07 | 5.98 | 8.16 | 6.30 | 14.80 |
| gr1995 | 8.63 | 9.60 | 9.11 | 7.56 | 7.06 | 4.24 | 4.63 |
| gr1996 | -0.84 | -4.35 | -2.61 | 1.04 | 0.95 | 1.20 | 6.76 |
| gr1997 | -1.82 | -1.97 | -1.90 | -2.17 | -2.58 | -2.40 | 6.47 |
| gr1998 | -4.61 | -6.31 | -5.46 | -2.53 | -2.71 | -0.99 | -0.05 |
| gr1999 | -7.46 | 6.43 | -0.76 | 5.31 | -2.86 | 0.54 | -1.38 |
| gr2000 | 8.55 | 3.70 | 6.10 | -12.00 | 3.11 | 0.96 | 0.08 |
| gr2001 | 0.45 | 12.69 | 6.40 | 0.71 | 1.36 | -0.05 | -1.33 |
| gr2002 | -3.75 | -7.05 | -5.41 | 11.97 | 3.21 | NA | 8.22 |
| gr2003 | -10.20 | -13.60 | -11.90 | -27.20 | -11.60 | -11.50 | -4.17 |
| gr2004 | -17.20 | -15.90 | -16.50 | -10.20 | -14.90 | -15.10 | -9.83 |
| gr2005 | -1.89 | 0.18 | -0.86 | -12.20 | -2.34 | -0.24 | 1.22 |
| aagr89-96 | 0.60 | 0.95 | 0.78 | 3.73 | 3.21 | 3.14 | 4.53 |
| aagr96-98 | -3.22 | -4.16 | -3.69 | -2.35 | -2.65 | -1.70 | 3.16 |
| aagr98-05 | -9.96 | -10.00 | -10.00 | -16.90 | -9.79 | -9.17 | -4.37 |

Notes: grY stands for the growth rate of year Y-1 and Y. aagrKR stands for the average annual growth rate for periods K and R.

below "Fisher price Index" for all the sample periods of the study as expected because the indices are unweighted. Furthermore, "Fisher price index" and "Two-period dummy variable index" are chosen for the analysis for the following reasons: "Fisher price index" does not constrain the coefficients of the characteristics and it assumes that prices depend only on the characteristics and the body of the car. "Two-period dummy variable index" is based on the two-period minimum constraint on characteristics coefficient but it allows capturing omitted characteristics by using manufacturing dummy variables. Note that these results, regarding unweighted indices, are the only results I mention in the main body of the chapter. More results regarding unweighted indices can be found in the appendix.

Table 2.3 reports the sales weighted indices for new automobiles. It can be noticed that after the weighting with the sales, the car market openness led to 2.35 to 3.69 % decline (comparatively with 0.78 to 3.73% during 89-96) in AAGR for the 1993 policy change and about 10-17 % decline for the taxation policy change. Two-period index shows a strictly decline between 1996 and 1998.

As I already stated above, used car"s prices were collected from two individual dealers. Unfortunately, no characteristics for those vehicles were collected. It is assumed that a five year old vehicle, which was sold in 2003, had the same characteristics with

Table 2.4: Weighted Direct Used Cars effect

| Year | Laspeyres | Paasche | Fisher | Twoperiod | Pooled | Match | Mean |
|---|---|---|---|---|---|---|---|
| 1997 | -9.2 | -9.3 | -9.3 | -0.3 | -9.5 | 0.0 | -41.6 |
| 1998 | -7.6 | -11.9 | -9.8 | 0.3 | -13.9 | 2.9 | -43.9 |
| 1999 | 9.5 | -7.2 | 0.8 | -4.6 | -4.0 | 9.0 | -36.0 |
| 2000 | 15.2 | -3.0 | 5.7 | 3.1 | 4.1 | 14.6 | -24.3 |
| 2001 | -0.2 | -31.5 | -17.3 | -5.9 | 2.3 | 16.9 | -30.3 |
| 2002 | 8.5 | -28.6 | -12.0 | -5.6 | -2.4 | 16.8 | -38.5 |
| 2004 | 42.0 | -24.7 | 3.4 | -0.9 | 8.1 | 16.8 | -22.2 |
| 2005 | 34.1 | -28.5 | -2.0 | 7.3 | 6.5 | 18.0 | -24.0 |

Source: own calculations; number represents the direct effect as a percentage of the new automobile indices values.

a new vehicle that was sold in 1998. The same procedure is followed for the "whole automobile indices". The difference between "new automobile indices" and "whole automobile indices" is the direct used cars effect.

Tables A.3 and 2.4 present the direct effect as a percentage of the "new automobile indices" values. The mean direct effect percentage is negative with or without weighting. This is due to the fact that used cars have relatively lower prices than the new cars. The match direct effect percentage is positive in the case of weighting. This indicates that the match index for the whole industry is higher than the match index for new cars only. Consequently, used cars models that survived the matching method tend to make the index go up in all periods from 1998 to 2005. The Fisher direct effect percentage is negative without weighting but when weighting is used, it is negative for some years and positive for some others. As Weighted Direct Used Cars effects cannot give the same effect for all periods for Fisher and two period dummy variable indices, it is essential to examine the weighted indices for the whole market. These are given in Table 2.5.

According to Table 2.5, there is an AAGR of -6.72% and -13.3% for the Fisher index and the two-period index respectively for years 2002-2005. It was -10% and -16.9% for the Fisher index and the two-period index respectively for "sales-weighted new automobile indices". This indicates that the introduction of used cars diclined the price indices less and this effect is between 3.28% and 3.6% in terms of AAGR. As for the 1996-1998 period, there is an AAGR of -8.52% and -2.5% for the Fisher index and the two-period index respectively, whereas there is an AAGR of -3.69% and -2.35% for the Fisher index and the two-period index respectively for "sales-weighted new automobile indices". This shows a minimum decline in AAGR of 0.15% as a direct effect due to the introduction of used cars. That is, the introduction of used goods lead to a direct decrease in AAGR for the first policy change and a direct strong increase in AAGR for the second policy change.

For the indirect effect a comparison of the two periods 89-96 and 96-98 is essential.

Table 2.5: The sales weighted Indices for whole automobile market: Percentages change from previews years (gr) and averages annual growth rates (aagr)

| Rates-Year | Laspeyres | Paasche | Fisher | Twoperiod | Pooled | Match | Mean |
|---|---|---|---|---|---|---|---|
| gr1990 | -13.70 | -10.70 | -12.20 | -0.93 | -2.75 | -1.32 | -1.44 |
| gr1991 | 0.94 | 3.97 | 2.45 | 2.94 | 0.05 | -0.72 | 3.60 |
| gr1992 | 6.78 | 7.30 | 7.04 | 10.50 | 7.43 | 7.43 | 6.21 |
| gr1993 | 2.42 | 1.82 | 2.12 | -3.42 | 1.95 | 5.19 | -1.97 |
| gr1994 | 1.63 | 0.51 | 1.07 | 7.77 | 8.81 | 6.30 | 14.80 |
| gr1995 | 8.63 | 9.60 | 9.11 | 9.41 | 6.44 | 4.24 | 4.63 |
| gr1996 | -0.84 | -4.35 | -2.61 | 1.35 | -0.06 | 1.20 | 6.76 |
| gr1997 | -10.90 | -11.10 | -11.00 | -3.11 | -10.80 | -2.40 | -37.8 |
| gr1998 | -2.94 | -8.96 | -6.00 | -1.89 | -7.44 | 1.84 | -3.95 |
| gr1999 | 9.68 | 12.10 | 10.90 | 0.17 | 8.36 | 6.56 | 12.40 |
| gr2000 | 14.17 | 8.38 | 11.24 | -4.89 | 11.79 | 6.08 | 9.37 |
| gr2001 | -13.00 | -20.50 | -16.80 | -8.11 | -0.41 | 2.03 | -1.63 |
| gr2002 | 4.64 | -3.10 | 0.70 | 12.35 | -1.49 | -0.11 | -4.44 |
| gr2003 | 21.02 | -3.37 | 8.14 | -22.90 | -8.32 | -11.50 | 55.74 |
| gr2004 | -19.50 | -20.60 | -20.10 | -11.10 | -9.18 | -15.10 | -29.90 |
| gr2005 | -7.35 | -4.82 | -6.10 | -4.93 | -3.74 | 0.75 | -1.09 |
| aagr89-96 | 0.60 | 0.95 | 0.78 | 3.82 | 3.04 | 3.14 | 4.53 |
| aagr96-98 | -6.99 | -10.00 | -8.52 | -2.50 | -9.16 | -0.30 | -22.70 |
| aagr98-05 | -3.36 | -9.97 | -6.72 | -13.30 | -7.11 | -8.87 | 2.61 |

Notes: grY stands for the growth rate of year Y-1 and Y. aagrKR stands for the average annual growth rate for periods K and R.

Table 2.6: Results using engine capacity only as characteristics; Weighted Indices

| Index-Market | aagr89-96 | aagr89-98 | diff |
|---|---|---|---|
| Fisher-New Cars | 3.76 | 2.50 | -1.26 |
| Twoperiod-New Cars | 3.07 | 1.97 | -1.10 |
| Fisher-All Cars | 3.76 | -3.76 | -7.52 |
| Twoperiod-All Cars | 3.08 | 1.59 | -1.49 |

Notes: Average Annual Growth Rates and their difference are reported. "All cars" represents the joint market of new and used cars.

As the growth rates of 89-96 and 96-98 are computed for different length of periods -eight and three years respectively- a direct comparison cannot be done. Consequently, a comparison for AAGR of 89-96 and AAGR of 89-98 is made. In case that policy change of 1993 did not happen, an estimation of AAGR of 89-98 would be the AAGR of 89-96. In order to take a more efficient indirect effect, the assumption about the car "virtual characteristics" before 1996 can be relaxed by using only one car characteristic: engine capacity. The results of this exercise are given in table 2.6. The indirect effect is a decline of AAGR about 1.1% to 1.26%. The direct effect for the whole period 1989-1998 is -0.39 for the two-period index and -6,26 for the Fisher index. Both of them are bigger than the ones I found above due to the absence of virtual characteristics. The same procedure without relaxing the assumption is followed and a direct effect of -0.05 for the two-period index and -1,14 for the Fisher index, which are lower values as expected. The indirect effect without relaxing the assumption is found -1.39 for the two-period index and -1,01 for the Fisher index.

### 2.5.1 Cyprus Statistical Service Results

The Cyprus Statistical Service uses a sample from seven companies for calculating the automobile price index. Unfortunately, they do not announce the company names and they refer to them with capital letters A to G. I am using 27 companies for my indices such as Alfa Romeo, Audi, Bmw, Fiat, Ford, Honda, Mazda, Mercedes, Mitsubishi, Nissan, Opel, Peugeot, Renault, Seat, Subaru, Toyota, Volkswagen, Volvo etc. For their used car indices, they are using the used car selling prices of three of these companies called A to C. I am using used car selling prices from two individual dealers containing cars models from twenty companies including Honda, Mazda, Mitsubishi, Nissan and Toyota. The sales weighted price indices of the Cyprus Statistical Service from 1998-2005 (w/o 1999) for new cars, used cars and the whole car industry are reported in Table 2.7.

Although my sample is much different from their sample, my "new-cars sales weighted match index" is very close to their index for the period 1998-2005. This can be seen in Figure 5. However, this does not happen for the whole industry indices.

Table 2.7: Cyprus Statistical Service Price Index

| Index | 1998 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|---|---|---|
| New | 100 | 101.84 | 102.39 | 97.00 | 90.47 | 75.12 | 74.30 |
| Used | 100 | 102.97 | 103.34 | 98.28 | 87.71 | 79.26 | 76.01 |
| All | 100 | 102.32 | 102.80 | 97.55 | 89.29 | 76.88 | 75.03 |

Source: Cyprus Statistical Service.

The reason is of course their limited sample and the fact that many Cypriots prefer individual sellers for buying a used car instead of the manufacturing company. As one can see from Table 2.7 the whole industry index is higher than the new-cars index for all the period from 1998-2005 (except 2003). This is the same effect as in Tables A.3 and 2.4.

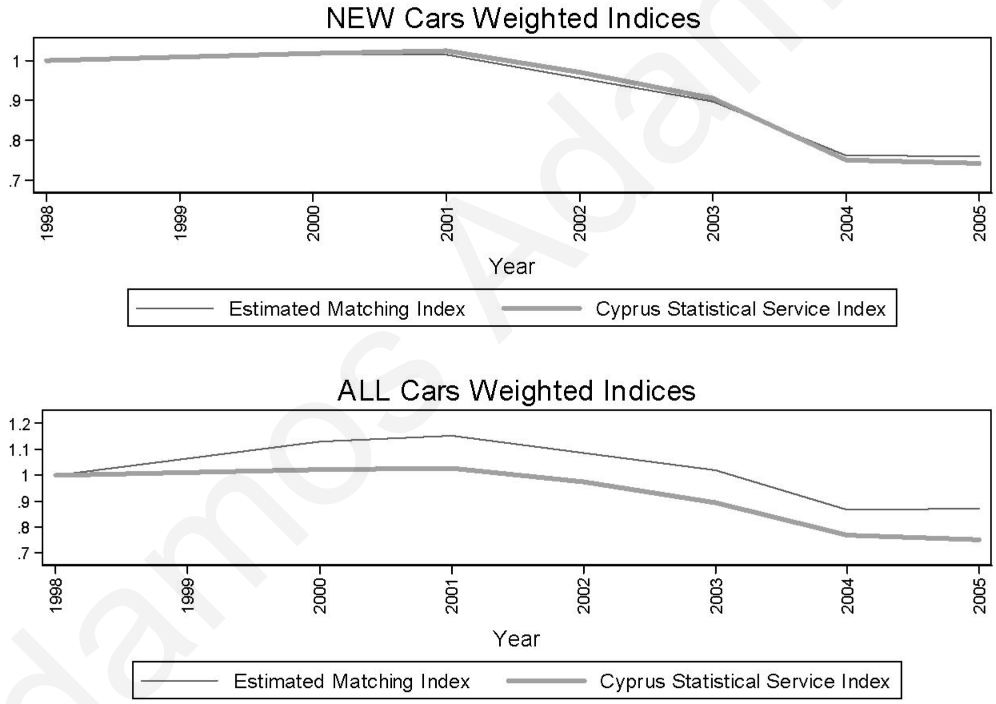



Figure 2.5: Comparison with Cyprus Statistical Service Indices

Additionally, for the period 2002-2005, they find an AAGR of -8,5% for new cars and an AAGR of -8,37% for the whole industry. My match index shows an AAGR of -9,17% for new cars and an AAGR of -8,87% for the whole industry. Both indices showed that the introduction of used cars yield to a direct effect of a less negative AAGR for the whole industry for the period 2002 to 2005. Although I find similar effect with the match indices, I find that the difference between the two indices is much higher. This is due to the fact that these kinds of indices suffer from selection problems and these results are inconclusive.

Finally, as expected, both the Fisher and the two period dummy variable indices are lower than the matching ones for both new and whole automobile weighted indices. The only exception is between 1989 and 1996. In this range of years my models are "matched", so match method works better. Cyprus statistical service still uses the match method to create those indices. Even if they find a way to include the effect of the replacement of an old model with an upgraded one, there is still the problem of the biasness due to their non-random sample. As a result, they may overestimate their index. This cannot happen here as I do not use the match index as the basic index for my results.

## 2.6 Conclusion

In this chapter the impact of used goods on CPI is investigated through a unique experiment; the beginning of imports of used cars in the Cyprus automobile market. As Cyprus is a relatively small economy, the policy change led to a comparatively high increase in competition. Several price indices are constructed for the investigation of two effects on CPI due to the policy change. Both effects are found to be negative. Over a ten year period the minimum decline in the prices of new cars reached an average annual growth rate of 1.1%. For a three year period the minimum decline in the prices of used cars reached an average annual growth rate of 0.15%. This means that the increased competition from the import of used cars led to a significant reduction of prices of both used and new cars. Before the entrance of Cyprus into the European Union, the commission demanded from candidate countries to have its inflation under 2.5%. Although I do not examine what the inflation would have been that period if the policy change never had happened, I can show that this policy change seems to help Cyprus keep its inflation in relatively lower levels.

Finally, Cyprus Statistical Service is still using the match method to construct the consumer price index. The match model index incurs a selection bias as the price changes of the goods that survive the comparison method are not a random sample of all price changes. When a new upgraded car model appears in the market, it is considered as a new model for comparison purposes. So the match index method does not allow for the comparison between the price of the new and the old model. Through the years, the quality of cars goes up. If the improved quality value of the good exceeds the increase of its price then the Cyprus Statistical Service tends to overestimate the real price index. I found that when a direct comparison cannot be done, then they indeed overestimate the CPI.

# Chapter 3

# Markup Estimates from Discrete Choice Models

## 3.1 Introduction

Discrete choice models (DCMs) have been widely used in recent years to estimate demand for differentiated products (Berry, 1994; Berry, Levinsohn, and Pakes, 1995). When coupled with an assumption on firm behavior (typically Bertrand-Nash pricing), DCMs can produce estimates of marginal cost and therefore estimates of markups. These estimates have been used to address several questions that interest industrial organization economists, such as the impact of mergers and the measurement of market power. Actual markups are rarely observed in practice because firm's cost is private information that firms are not generally willing to divulge. Moreover, firms' notion of a markup may not necessarily coincide with the corresponding notion in economics because firms do not typically think in terms of marginal cost. As a result, it is very rare for economists to be able to compare their estimates of marginal costs or markups with their "true" counterparts. Being able to do so would be a useful way of assessing the performance of DCMs.

In this chapter I am able to assess the performance of DCMs by exploiting some auxiliary information in the Cyprus automobile market in order to obtain estimates of markups that are completely independent of those obtained from the structural models. I refer to my markups as model-free or calculated markups, as they are computed from simple algebraic relationships and are not the outcome of econometric estimation. I caution that my alternative markup estimates are not hard data. I need to make assumptions in order to compute them, therefore my estimates are not assumption-free even if they are model-free. The usefulness of this approach lies in the fact that these assumptions are very different from those made in the standard differentiated product model, hence the calculated markups can be used as a useful benchmark for comparison.

The idiosyncracy of my data stems from the tax system. Automobiles in Cyprus are heavily taxed with a variety of different instruments. The most important ones are a consumption tax that is a percentage of the vehicle's import price and a flat per unit tax. Individuals that meet certain criteria can be exempt from paying taxes on automobile purchases. For a period of several years I am able to observe two prices for each model: a price with taxes and a price without them. Thus for each model I have two expressions linking marginal cost and prices but I have three unknowns: marginal cost, the markup for taxed vehicles and the markup for tax-free vehicles. By making an assumption on the relationship between the two markups I can obtain the desired estimates. A simple assumption one can make is that the two markups are the same. I explore this and several other possibilities. The fact that the consumption tax is imposed on the import price, which is essentially marginal cost, is the key feature of the data that I am able to leverage.

I note once more that my alternative markup estimates are not actual data but are based on specific assumptions. However these assumptions are plausible and are justified by previous empirical evidence. This allows me to make the following comparison exercise. I use two different sets of assumptions to generate two estimates of markups. If the two estimates are similar (as measured by some metric that remains to be determined), then this would be fairly strong evidence in favor of both sets of assumptions because it seems implausible that I would obtain similar estimates if one or both assumptions are incorrect. Conversely, if the two markups differ, this would indicate that at least one of the assumptions is wrong but it would not tell me which one.

I estimate demand using the simple logit, the nested logit and the random coefficients model. The full sample covers thirteen years (1989-2002) but I only have a limited number of characteristics for the whole period. Therefore, I also obtain separate estimates from a reduced sample (1995-2002) which allows me to include additional characteristics at the expense of having fewer observations. Using the full dataset, the markups obtained from DCMs are on average higher than the model-free markups. Using the reduced sample, the markups from the model are closer to the calculated ones. Overall, the comparison of the two sets of markups leads me to conclude that they are reasonably similar, which bodes well for DCMs.

## 3.2 Data

Information on car sales was obtained from the Cyprus Road Transport Department, which keeps track of vehicle registrations. Prices of new automobiles for the period 1989-2002 were obtained from a local car magazine. The magazine also reports various vehicle characteristics (such as length, width, cylinders, etc.) starting in 1995; only engine capacity was reported prior to that. I was unable to locate all past issues, so data are missing for some months, mostly in the earlier years. The number of models

Table 3.1: Price and tax information for selected car models

| Model (eng. size, liters) | Year | Price with tax (CP) | Price without tax (CP) | Ad valorem taxes (%) | Unit tax (CP) | VAT rate (%) |
|---|---|---|---|---|---|---|
| Toyota Corolla (1.299) | 1989 | 7150 | 3425 | 124.5 | 75 | 0 |
| | 1990 | 6800 | 3250 | 124.5 | 75 | 0 |
| | 1991 | 6700 | 3400 | 118.0 | 75 | 0 |
| | 1992 | 7625 | 3900 | 114.8 | 75 | 5 |
| | 1993 | 7850 | 4100 | 111.6 | 75 | 5 |
| | 1994 | 8350 | 4200 | 108.3 | 75 | 8 |
| | 1995 | 9300 | 5100 | 105.1 | 75 | 8 |
| Honda Civic (1.499) | 1989 | 8300 | 3950 | 129.5 | 75 | 0 |
| | 1990 | 8100 | 4275 | 129.5 | 75 | 0 |
| | 1991 | 8313 | 4350 | 123.0 | 75 | 0 |
| | 1992 | 9800 | 5450 | 119.8 | 75 | 5 |
| | 1993 | 10846 | 5825 | 116.6 | 75 | 5 |
| | 1994 | 12750 | 6200 | 113.3 | 75 | 8 |
| | 1995 | 12750 | 6200 | 110.1 | 75 | 8 |
| Peugeot 405 (1.899) | 1990 | 18500 | 9200 | 124.5 | 875 | 0 |
| | 1991 | 18600 | 9500 | 119.1 | 875 | 0 |
| | 1992 | 17500 | 9200 | 116.5 | 875 | 5 |
| | 1993 | 15500 | 8500 | 113.8 | 875 | 5 |
| | 1994 | 15800 | 7700 | 111.0 | 875 | 8 |
| | 1995 | 17200 | 8900 | 108.4 | 875 | 8 |

in the magazine listed per month ranges from 25 to 57. Estimating demand for the entire 1989-2002 period means that the only characteristic I can use is engine capacity (I also use dummies for countries of origin to control for quality). As a robustness check, I also estimate demand for the 1995-2002 period, which allows me to include more characteristics but at the expense of having fewer observations.

Several taxes and levies were imposed on automobiles during the period under examination. There were three different types of taxes on the vehicle's import cost-import-freight (cif) price. The total ad valorem tax rate depended on the size of the vehicle (in terms of engine capacity) and its country of origin. During the period covered by the study ad valorem tax rates ranged from 80%-130% for sedans and from 40%-60% for sport utility vehicles (SUVs). A unit (per vehicle) tax as a function of engine capacity was also levied. Finally, a value-added tax was introduced in 1995. All taxes were payable upon registration. In Table 3.1 I present prices and tax rates and levies for three selected automobile models. Prices are the nominal final prices in Cyprus Pounds (CP) for taxed and untaxed cars. The unit tax is also in Cyprus Pounds. The ratio of price with tax versus price without tax for these models varies from 1.80 to 2.10. The unit tax is greater for Peugeot-405 because it belongs to a higher engine capacity category. The ad valorem tax rate was more than 100% for

Table 3.2: Data summary

| Variable | # of obs | Mean | Std. dev. | Min | Median | Max |
|---|---|---|---|---|---|---|
| Engine Capacity (in liters) | 616 | 1.6 | 0.38 | 0.8 | 1.6 | 3.5 |
| Price with tax (CP) | 616 | 14091 | 7572 | 4700 | 11725 | 48000 |
| Price without tax (CP) | 456 | 7452 | 3515 | 2450 | 6300 | 17750 |
| Ad valorem taxes (%) | 616 | 105.2 | 13.1 | 58.6 | 103.6 | 163 |
| Unit Tax (CP) | 616 | 381.4 | 500.4 | 0 | 275 | 6575 |
| VAT rate (%) | 616 | 7.3 | 3.5 | 0 | 8 | 13 |
| Sales (units) | 616 | 158.8 | 247.5 | 1 | 61 | 1815 |
| Income (CP) | 8306 | 10680 | 8196 | 0 | 9133 | 132914 |

all the three models. Table 3.2 summarizes my main variables. Tax-free prices are available for about 74% of the sample.

## 3.3 Computation of markups from auxiliary data

There are no car manufacturers in Cyprus; all cars are sold by importers. The marginal cost of vehicle model $j$ for an importer is its import (cif) price, $P_j^I$. The vehicle is subject to an ad valorem tax at a rate $\tau_j$ and a unit tax $T_j$, bringing the total marginal cost to $(1+\tau_j)P_j^I + T_j$. Both $\tau$ and $T$ are indexed by $j$ as they are functions of model characteristics. The importer adds his profit margin $M_j^{WT}$ (the letters stand for 'margin with tax') and then value-added tax is applied to the total at a rate $v$. The relationship between the import price of a vehicle and the final price with all taxes applied is therefore given by:

$$P_j^{WT} = \left[(1+\tau_j)P_j^I + T_j + M_j^{WT}\right](1+v) \tag{3.1}$$

When the buyer is exempt from taxes, the expression linking the import price and final price is simply

$$P_j^{NT} = P_j^I + M_j^{NT} \tag{3.2}$$

The markup $M_j^{NT}$ imposed on a tax-free sale may differ from the markup $M_j^{WT}$ imposed on a tax-inclusive sale. Equations (3.1) and (3.2) have three unknowns: the two markups and the import prices. In order to proceed with the markups calculation, I need an assumption about the relationship between $M_j^{WT}$ and $M_j^{NT}$. Despite the need for an assumption, equations (3.1) and (3.2) do give me some leverage, which comes from the fact that the tax $\tau_j$ is levied on the import price, which is marginal cost, rather than on the seller's price, as is the case with VAT or sales taxes.

In order to illustrate exactly what it is I leverage, consider a seller selling a good whose marginal cost is $C$. The government can observe $C$. It wants to impose a tax $\tau$ which can be levied either on the marginal cost or on the seller's final price. If the tax is levied on the seller's price, the relationship between cost and final price is given by $P = (C + M)(1 + \tau)$. If the tax is levied on marginal cost, the corresponding relationship is $P = C(1 + \tau) + M$ ($M$ may be different in the two cases). Consider what happens in either case when the tax rate is changed from $\tau^0$ to $\tau^1$. In the case where the tax is levied on marginal cost, the difference between the new price and old price is $P^1 - P^0 = (\tau^1 - \tau^0)C + M^1 - M^0$. Thus I can identify marginal cost if I observe $P^1$ and $P^0$ and make an assumption on the *change* in markups. If the tax is levied on seller price, then the change in price is $P^1 - P^0 = (\tau^1 - \tau^0)C + M^1(1+\tau_1) - M^0(1+\tau_0)$. An assumption on the change in markups is not sufficient to identify marginal cost. For example, assuming $M^1 = M^0$ would leave us with $P^1 - P^0 = (\tau^1 - \tau^0)(C + M)$, which still has two unknowns.

### 3.3.1 The equal markups assumption

As illustrated by the example above, the information I have allows me to identify markups if I am willing to make an assumption on the relationship between markups for taxed versus tax-free cars. A first approximation is to assume that the importer charges equal markups: $M_j^{WT} = M_j^{NT} \equiv M_j^{EQ}$.[1] From equations (3.1) and (3.2) I obtain:

$$M_j^{EQ} = \frac{1}{\tau_j}\left[(1+\tau_j)P_j^{NT} - \frac{P_j^{WT}}{1+v} + T_j\right] \tag{3.3}$$

Equation (3.3) is the expression I use for the calculation of markups under the equal markups assumption. Note that, for the reasons explained above, the markup is unidentified in this case if $\tau_j = 0$.

Another way to see this is to consider the difference between the pre-VAT price with tax and price without tax:

$$\frac{P_j^{WT}}{1+v} - P_j^{NT} = \tau_j P_j^I + T_j + (M_j^{WT} - M_j^{NT}) \tag{3.4}$$

$$P_j^I = \frac{1}{\tau_j}\left[\frac{P_j^{WT}}{1+v} - P_j^{NT} - T_j - \left(M_j^{WT} - M_j^{NT}\right)\right] \tag{3.5}$$

Is this assumption reasonable? Automobile retailers operating in this regime face two segmented markets and they are in a position to price discriminate between them. They should therefore set prices optimally in each market. In that case, markups will only be the same if elasticities (evaluated at the market outcome) are the same. This is possible but by no means inevitable. The literature on tax incidence can provide some guidance on this issue. The theoretical literature tries to identify the impact of different types of taxes on the final price. If the after-tax price increases by exactly the amount of the tax, then the tax is said to be fully shifted (100% pass-through). This

[1] I discuss possible justifications for this assumption later on in this section.

would be equivalent to my equal markups assumption. If the price increases by more (less) than the amount of the tax, the tax is said to be overshifted (undershifted).

Delipalla and Keen (1992) and Anderson, de Palma, and Kreider (2001) analyzed the case of both ad valorem and unit excise taxes in the context of homogeneous oligopoly and differentiated oligopoly respectively. As Anderson, de Palma, and Kreider (2001) point out, the conclusions are surprisingly similar. Unit excise taxes generally lead to higher prices and there may be overshifting or undershifting depending on the curvature of demand. Making a prediction requires knowing (or estimating) the precise nature of demand, which is extremely difficult to do in practice. Hence the theoretical literature can not provide much guidance.

Empirical evidence on tax incidence is surprisingly sparse. Poterba (1996) examined price responses to changes in state and local sales taxes (unit taxes) by exploiting variation in tax policy across cities and across time. He used postwar (1947-1977) and prewar (1925-1939) price data on clothing and personal care items (homogeneous products). He found that consumer prices adjust one-for-one with tax changes for the postwar period. During the prewar period he finds undershifting for clothing only. He concludes that his paper "presents evidence that broadly supports the view that retail sales taxes are fully forward shifted, raising consumer prices by the amount of the tax increase" (p. 173). Besley and Rosen (1999) assembled a panel of quarterly data for 12 commodities and 155 cities over the period 1982-90 and employed a similar approach to Poterba (1996) to test the same hypothesis. For the period they examine they found that for the majority of commodities taxes are overshifted to consumers, while for the remaining commodities taxes are found to be fully shifted.

The literature on tax incidence does not provide firm predictions as to the degree of tax incidence. From a purely theoretical standpoint, the equal markups assumption seems untenable. Although it can not be ruled out, it would only occur under very particular circumstances. The evidence in the empirical literature paints a different picture. Full shifting of taxes onto prices is found to be quite common, even if it is not prevalent. I interpret the empirical literature as providing some support for the equal markups assumption.

I further argue that full shifting is more likely to be observed under the circumstances of my case study rather than most empirical studies of tax incidence. These studies obtain their estimates by comparing regimes with different tax levels, either over time or across geographical regions. In our case, the product is sold at two different prices *at the same time and place*. Prices both with and without taxes are posted, making it easy for consumers to figure out whether the difference in price is equal to the tax. I believe that these circumstances are likely to lead to full shifting as firms do not want to be accused of treating the two consumer groups unequally.

In order to obtain more concrete evidence, I have met with retailers in order to discuss their pricing policies regarding tax-free vehicle sales. I have talked to three retailers. Two of the retailers responded that higher markups for untaxed products cannot be set as customers may be informed about the precise amount of the tax and would complain if the difference from the full price is less than the amount of the tax. These responses are consistent with my claim that the concurrent sale of the same product at two different prices and the transparency of the circumstances makes it difficult for firms to charge substantially different markups. One retailer said that they set higher markups for tax-free automobiles.

Based on the discussion above – and while acknowledging that the evidence is by no means conclusive – I believe that the equal markups assumption is a reasonable approximation of actual pricing behavior and I make it the focus of the analysis in the rest of the chapter.

### 3.3.2 Equal percentage markups

A second possibility is to assume that the importer charges equal percentage markups: $\frac{M_j^{WT}}{(1+\tau_j)P_j^I+T_j} = \frac{M_j^{NT}}{P^I}$ Using this assumption and equations (3.1) and (3.2) I obtain:

$$\frac{P_j^{WT}}{(1+v)P_j^{NT}} = \frac{(1+\tau_j)P_j^I + T_j}{P_j^I} \tag{3.6}$$

This leads to the following expression for taxed-cars-markups:

$$M_j^{WT} = \frac{P_j^{WT}\left[\frac{P_j^{WT}}{(1+v)} - T_j\right] - (1+\tau_j)P_j^{WT}P_j^{NT}}{P_j^{WT} - (1+\tau_j)(1+v)P_j^{NT}} \tag{3.7}$$

Equation (3.7) is the expression I use for the calculation of markups under the equal percentage markup assumption. Note that if $P_j^{WT} - (1+\tau_j)(1+v)P_j^{NT} = 0$, I cannot solve for markups. This can only happen if $T_j = 0$ (see equation (3.6)).

Another way to see this is to consider the difference between the pre-VAT price with tax and price without tax given by equation (3.4). It is easy to solve for the markups differences using the equal percentage markup assumption. The term $M_j^{WT} - M_j^{NT}$ is equal to $\left[\tau_j + \frac{T_j}{P_j^I}\right] M_j^{NT}$. Consequently equation (3.4) becomes:

$$\frac{P_j^{WT}}{1+v} - P_j^{NT} = \tau_j P_j^I + T_j + \left[\tau_j + \frac{T_j}{P_j^I}\right] M_j^{NT} \tag{3.8}$$

If only a tax $\tau$ is imposed on the import price, the difference between the pre-VAT price with tax and price without tax is equal to $\tau(P^I + M^{NT}) = \tau P^{NT}$. However, if a unit tax is added to the import price this difference becomes $T(1+\frac{M^{NT}}{P^I}) = T\frac{P^{NT}}{P^I}$. From that I can infer $P^I$ and therefore $M^{WT}$.

## 3.4 Estimation of markups using DCMs

This section describes how estimates of markups can be obtained using the simple logit (SL), nested logit (NL) and random coefficients (RC) models. Actual estimates are reported along with calculated markups in section 3.5.

### 3.4.1 Markups from DCMs

Consider a market with $J$ differentiated products. Let $P_j$ denote the price of product $j$. Similarly, $x_j$ denotes a K-dimensional vector of observed product characteristics of $j$ and $\xi_j$ denotes an unobserved product characteristic of $j$. In every period, individual $i$ makes a choice among the $J$ products available and choice 0, the option of no purchase.

In the simple logit model the utility consumer $i$ obtains from buying brand $j$ (time subscripts are omitted for brevity) is given by the following equation:

$$u_{ij} = x_j\beta - \alpha P_j + \xi_j + \varepsilon_{ij}. \tag{3.9}$$

The term $\varepsilon_{ij}$ is an idiosyncratic shock with mean zero.

In the nested logit model the corresponding utility is:

$$u_{ij} = x_j\beta - \alpha P_j + \xi_j + \zeta_{ig}(\sigma) + (1-\sigma)\varepsilon_{ij}. \tag{3.10}$$

The term $\zeta_{ig}(\sigma)$ is a group-specific random coefficient that allows goods that belong to the same group g to contribute a common component of utility to the individual i. The parameter $\sigma$ measures the extent to which products within the same group are substitutes to each other.

In the random coefficients model utility is given by:

$$u_{ij} = x_j\beta_i - \alpha_i P_j + \xi_j + \varepsilon_{ij}. \tag{3.11}$$

The terms $\alpha_i$ can be modeled as $\alpha+\tilde{\alpha}H_i$ and the term $\beta_i$ can be formed as $\beta+\tilde{\beta}H_i$. The terms $\tilde{\alpha}$ and $\tilde{\beta}$ are the variant across consumers parameters and $H_i$ are the consumers' characteristics which can be consumers' demographics or random draws.

In a market that firms assumed to be price setters to maximize their profits and assuming the existence of pure-strategy interior equilibrium, then a vector of optimal prices can be obtained as follows:

$$\frac{1}{1+v}P = C + \frac{1}{1+v}\Delta(P,X,\xi;\theta)^{-1}S(P,X,\xi;\theta), \tag{3.12}$$

where $v$ is the VAT rate and $\theta$ the estimated parameters. I define the markup as

$$M \equiv \frac{1}{1+v}P - C = \frac{1}{1+v}\Delta(P,X,\xi;\theta)^{-1}S(P,X,\xi;\theta). \tag{3.13}$$

Where $\Delta$ is a J by J matrix whose (j, k) element is given by:

$$\Delta_{jk} = \begin{cases} -\frac{dS_k}{dP_j} & \text{if } k \text{ and } j \text{ are sold by the same retailer} \\ 0 & \text{otherwise} \end{cases} \tag{3.14}$$

For each of the three models the derivative $\frac{dS_k}{dP_j}$ is:
Simple logit:

$$\frac{dS_k}{dP_j} = \begin{cases} -\alpha S_j(1-S_j) & \text{if} \quad k=j \\ \alpha S_j S_k & \text{if} \quad k \neq j \end{cases} \tag{3.15}$$

Nested logit:

$$\frac{dS_k}{dP_j} = \begin{cases} -\frac{\alpha}{1-\sigma} S_j[1-\sigma S_{j|g} - (1-\sigma)S_j] & \text{if} \quad k=j \text{ and } \quad k,j \in g \\ \alpha S_j[S_k + \frac{\sigma}{1-\sigma} S_{k|g}] & \text{if} \quad k \neq j \text{ and } \quad k,j \in g \\ \alpha S_j S_k & \text{if} \quad k \neq j \text{ and } \quad k,j \notin g \end{cases} \tag{3.16}$$

Random coefficients:

$$\frac{dS_k}{dP_j} = \begin{cases} \int -\alpha_i S_{ij}(1-S_{ij}) dP_H^*(H) & \text{if} \quad k=j \\ \int \alpha_i S_{ij} S_{ik} dP_H^*(H) & \text{if} \quad k \neq j \end{cases} \tag{3.17}$$

where $P_H^*(H)$ denotes population distributions functions according to consumers' characteristics and $S_{ij}$ is the probability of consumer $i$ purchasing product $j$.

The goal of the rest of this subsection is to identify the relationship between the markups obtained from DCMs, for products sold by the same retailer.

If retailer r is selling $J_r$ products, then according to BLP (1995) the $J_r$ first order conditions are:

$$S_j + \sum_{r \in J_r} (P_r - mc_r) \frac{dS_r}{dP_j} = 0 \tag{3.18}$$

Let assume for simplicity that a retailer is selling only two products. In this case, product's markups, $\mu$, must satisfy the following two FOCs:

$$S_1 + \mu_1 \frac{dS_1}{dP_1} + \mu_2 \frac{dS_2}{dP_1} = 0 \tag{3.19}$$

$$S_2 + \mu_2 \frac{dS_2}{dP_2} + \mu_1 \frac{dS_1}{dP_2} = 0 \tag{3.20}$$

Equations (3.19) and (3.20) can be rewritten in matrix notation as:

$$S - \Delta\mu = 0$$

Where

$$\Delta = \begin{pmatrix} -\frac{dS_1}{dP_1} & -\frac{dS_2}{dP_1} \\ -\frac{dS_1}{dP_2} & -\frac{dS_2}{dP_2} \end{pmatrix}.$$

Markup terms are given by:

$$\mu = \Delta^{-1} S \tag{3.21}$$

The ratio of the markup terms $\mu_1$ and $\mu_2$ can be computed using the outcome of equation (3.21) as follows:

$$\frac{\mu_1}{\mu_2} = \frac{\frac{dS_2}{dP_2} S_1 - \frac{dS_2}{dP_1} S_2}{-\frac{dS_1}{dP_2} S_1 + \frac{dS_1}{dP_1} S_2} \tag{3.22}$$

Equation (3.22) can be used to identify if the markups estimated from a specific DCM are the same or not for two products sold by the same retailer. If $\frac{\mu_1}{\mu_2} = 1$ then $\mu_1 = \mu_2$. The markups are the same for the case of simple logit and the case of nested logit if both products belong to the same group. The proof can be found in the appendix.

### 3.4.2 Estimation details

The demand equation for the logit model that links market shares to prices and car characteristics is given below:

$$\ln(s_{jt}) - \ln(s_{0t}) = x_{jt}\beta - \alpha P_{jt} + \xi_{jt} \tag{3.23}$$

To estimate the demand function above, I must control for any correlation between prices and the error term. The error term represents product characteristics that are observed by consumers but not by the econometrician. Products with better characteristics should command higher prices, leading to a positive relationship between the error term and price. To control for the endogeneity of price, I need to find variables that are correlated with price but are independent of unobserved product characteristics. I follow the literature in this respect and consider the instruments proposed by Berry, Levinsohn, and Pakes (1995) as candidate instruments. In principle, variables that enter the supply side but not the demand side, such as taxes, are candidate instruments. Among these, I chose to use the sum of engine capacity of other products sold by the same firm squared as an instrument for prices. This can be considered as a candidate instrument. According to Berry, Levinsohn, and Pakes (1995) interactions and squares of candidate instruments can be candidate instruments. Taxes can also be used; the unit tax, unit tax squared and constant tax proved to be good instruments for prices. The choice of instruments was guided by the appropriate tests for instrument relevance and overidentification.

The demand equation for the nested logit model links market shares to prices, car characteristics and within-group share in the following way:

$$\ln(s_{jt}) - \ln(s_{0t}) = x_{jt}\beta - \alpha P_{jt} + \sigma \ln(s_{j/g}) + \xi_{jt} \tag{3.24}$$

For this model, per-unit tax and constant tax are used as instruments for prices. The log of within share is also endogenous in this model so I use as an instrument the sum of engine capacity of all the other products in the group. An important choice for the nested logit model is the categorization of products into groups. Common practice in models of automobile demand is to split the models on the basis of engine size. This nesting worked for me also. I created three size categories (small, midsize, large) and a fourth group for sport utility vehicles.[2]

The random coefficients model is estimated using Nevo's algorithm. I use the same set of instruments for prices as the one I use for the simple logit model. The appropriate tests show that all the instruments used for all three DCMs are correlated with prices (and within group shares for the case of nested logit) and the overidentification test shows that they are uncorrelated with the error term.

In the random coefficients model I had to choose what interactions of product and consumer characteristics to include. I chose to include an interaction of prices with the income and an interaction of engine capacity with draws obtained by a multivariate normal distribution. In addition, I tried an interaction of prices and engine capacity with random draws only, that is without using consumers' demographics. Income was demeaned across markets-years and across consumers. As Nevo (2000) points out, if consumer characteristics changed during the computation, the non-linear search is unlikely to converge. So I drew these characteristics once at the beginning.

### 3.4.3 Estimates

Table 3.3 reports demand parameter estimates for the full sample (1989-2002) for the three discrete-choice models: simple logit (SL), nested logit (NL) and random coefficients (RC-1 and RC-2). The simple logit model yields $\alpha = 0.246$ and the coefficient of the attribute engine capacity is positive. Both are statistically significant as expected. Country dummies and constant are also statistically significant. French, German and Swedish products seem to offer better quality compared to the omitted Japanese cars, whereas, Czech, English, Italian, Korean, Russian and Spanish products tends to decrease the consumers' mean utility. The grouping in nested logit is relevant with $\sigma = 0.33$. The signs of the remaining coefficients are the same as the simple logit model but their absolute values are reduced as expected due to the existence of within shares in this model. All coefficients are statistically significant.

For both random coefficient models all the coefficients, except the interaction of engine capacity with random draws, are statistically significant. The coefficients of the country dummies and constant are very near to those of simple logit. The same happens for the coefficient of engine capacity since the coefficient of its interaction with

[2] Clerides (2008) allows for different correlation parameter $\sigma$ for SUVs and non-SUVs. If I do the same, I find that $\sigma$ is 0.73 for non-SUVs and 0.42 for SUVs. In this case, the null hypothesis that the model is under-identified is rejected and the Hansen J statistic, which is a test of the null hypothesis that the instruments are valid, shows a p-value of 0.98 which means the null hypothesis cannot be rejected. However, the parameter $\sigma$ for SUVs is statistically insignificant as I only have 23 observations of SUVs. For this reason I constrained $\sigma$ to be the same for all the groups.

Table 3.3: Demand estimates from DCMs

| Variables | SL | NL | RC-1 | RC-2 |
|---|---|---|---|---|
| Price | -0.246$^{**}$ | -0.172$^{**}$ | -0.380$^{**}$ | -0.318$^{**}$ |
| | (0.020) | (0.027) | (0.121) | (0.051) |
| Within-share | | 0.330$^{**}$ | | |
| | | (0.090) | | |
| Czech Rep. | -3.956$^{**}$ | -2.577$^{**}$ | -3.995$^{**}$ | -4.030$^{**}$ |
| | (0.350) | (0.476) | (0.361) | (0.364) |
| England | -1.224$^{**}$ | -0.819$^{**}$ | -1.228$^{**}$ | -1.230$^{**}$ |
| | (0.233) | (0.193) | (0.238) | (0.238) |
| France | 0.532$^{**}$ | 0.405$^{**}$ | 0.587$^{**}$ | 0.565$^{**}$ |
| | (0.197) | (0.141) | (0.207) | (0.206) |
| Germany | 1.893$^{**}$ | 1.410$^{**}$ | 2.009$^{**}$ | 1.990$^{**}$ |
| | (0.191) | (0.201) | (0.198) | (0.188) |
| Italy | -0.663$^{**}$ | -0.349$^{*}$ | -0.672$^{**}$ | -0.672$^{**}$ |
| | (0.220) | (0.161) | (0.213) | (0.214) |
| Korea | -2.087$^{**}$ | -1.279$^{**}$ | -2.182$^{**}$ | -2.160$^{**}$ |
| | (0.270) | (0.301) | (0.274) | (0.277) |
| Russia | -2.504$^{**}$ | -1.721$^{**}$ | -2.776$^{**}$ | -2.688$^{**}$ |
| | (0.488) | (0.423) | (0.553) | (0.505) |
| Spain | -1.321$^{**}$ | -0.763$^{**}$ | -1.358$^{**}$ | -1.360$^{**}$ |
| | (0.350) | (0.298) | (0.339) | (0.353) |
| Sweden | 1.788$^{**}$ | 1.177$^{**}$ | 1.837$^{**}$ | 1.807$^{**}$ |
| | (0.401) | (0.358) | (0.571) | (0.423) |
| Engine capacity | 2.768$^{**}$ | 1.602$^{**}$ | 3.125$^{**}$ | 3.013$^{**}$ |
| (liters) | (0.256) | (0.397) | (0.375) | (0.845) |
| Constant | -7.254$^{**}$ | -5.869$^{**}$ | -6.613$^{**}$ | -6.898$^{**}$ |
| | (0.346) | (0.449) | (1.141) | (0.947) |
| Price*Income | | | 0.123$^{\dagger}$ | |
| | | | (0.066) | |
| Standard Deviation | | | | 0.056$^{\dagger}$ |
| of Price | | | | (0.032) |
| Standard Deviation | | | 0.004 | 0.131 |
| of Engine capacity | | | (8.602) | (1.760) |
| Sargan-Hansen | 3,23 chisq(3) | 1,24 chisq(1) | 2,01 chisq(3) | 2,09 chisq(3) |
| test | p-value:0,36 | p-value:0,27 | p-value:0,57 | p-value:0,55 |

Significance levels: $\dagger$ : 10%, $*$ : 5%, $**$ : 1%. Standard errors are reported in parentheses.

Table 3.4: First step results

| Dependent Var: | Price(1) | Price(2) | Within-share |
|---|---|---|---|
| Independent Vars | | | |
| Czech Rep. | -1.111 | -1.512$^{\dagger}$ | -3.887$^{**}$ |
| | (0.778) | (0.814) | (0.396) |
| England | -1.233$^{\dagger}$ | -0.946 | -0.952$^{**}$ |
| | (0.664) | (0.668) | (0.231) |
| France | -0.213 | -0.106 | 0.690$^{**}$ |
| | (0.296) | (0.274) | (0.211) |
| Germany | 4.588$^{**}$ | 4.865$^{**}$ | 0.750$^{**}$ |
| | (0.514) | (0.532) | (0.155) |
| Italy | 0.405 | 0.395 | -0.901$^{**}$ |
| | (0.311) | (0.265) | (0.251) |
| Korea | -0.997$^{*}$ | -1.521$^{**}$ | -1.880$^{**}$ |
| | (0.418) | (0.459) | (0.262) |
| Russia | -3.399$^{**}$ | -3.426$^{**}$ | -1.854$^{**}$ |
| | (0.283) | (0.253) | (0.459) |
| Spain | -4.247$^{**}$ | -4.037$^{**}$ | -0.354 |
| | (0.983) | (0.802) | (0.453) |
| Sweden | 7.672$^{**}$ | 9.836$^{**}$ | -0.306 |
| | (1.051) | (1.279) | (0.276) |
| Engine capacity | 8.079$^{**}$ | 10.281$^{**}$ | 0.845$^{**}$ |
| (liters) | (0.406) | (0.886) | (0.190) |
| Constant | 4.625$^{*}$ | -6.853$^{\dagger}$ | -2.201$^{*}$ |
| | (1.832) | (4.075) | (0.983) |
| Unit tax | 0.012$^{**}$ | 0.0063$^{**}$ | -0.00070$^{**}$ |
| | (0.0010) | (0.0019) | (0.00017) |
| Unit tax square | -0.000011$^{**}$ | | |
| | (0.000002) | | |
| Constant tax | -0.043$^{*}$ | 0.069$^{\dagger}$ | -0.0083$^{**}$ |
| | (0.018) | (0.039) | (0.00096) |
| Sum Engine cap. other pr.by same firm square | -0.0021$^{*}$ | | |
| | (0.0010) | | |
| Sum Engine cap. all other pr. in the group | | -0.00055$^{*}$ | -0.00065$^{**}$ |
| | | (0.00026) | (0.00012) |

Significance levels: $\dagger$ : 10%, $*$ : 5%, $**$ : 1%. Standard errors are reported in parentheses.

random draws is very low compared to the coefficient of engine capacity. The random coefficients model (1) predicts that above-average-income consumers tend to be less price-sensitive. The richer consumer has an alpha of 0.1195 and the poorer consumer an alpha of 1.2191. The variation of engine capacity coefficient is 3.109-3.141. The random coefficients model (2) predicts a lower alpha of 0.1046 and a higher alpha of 0.5346. The standard deviation for the engine capacity, the absolute value of the coefficient, is 0.131 (statistically insignificant) and is leading to a coefficient variation of 2.619-3.450. The implied mean own price elasticity is -3.89 for the simple logit model, -3.95 for nested logit model, -4.28 for random coefficients model (1) and -4.15 for random coefficients model (2). These elasticities are close to what is usually found in the literature. The overidentification test with the null hypothesis that the instrument are valid, cannot be rejected. Table 3.4 reports the first step estimation of prices on instruments and characteristic. It is observed that all the instruments are statistically significant which is a proof that they are correlated with prices. As the overidentification test cannot be rejected, this means that the instruments are uncorrelated with the demand error term. Similarly, for the nested logit the first step estimation of within shares on instruments and characteristics shows that within-share's instruments are statistically significant.

## 3.5 Markup comparison

Since the markups obtained by DCMs are the outcome of deflated prices, I also need to deflate the calculated markups. The deflator I used for both sets of markups is the same. Additionally, it is important to recall that only 456 retail prices for untaxed cars are observed. Consequently, a direct comparison can be done only for those observations.

Table 3.5: Markup statistics

| Stats | SL | NL | RC-1 | RC-2 | Equal markups | Equal % markups |
|---|---|---|---|---|---|---|
| Min | 3.599 | 3.440 | 2.732 | 2.973 | 0.246 | -2,081 |
| 5% | 3.615 | 3.536 | 2.855 | 3.072 | 0.848 | 6.956 |
| 25% | 3.766 | 3.619 | 3.018 | 3.208 | 1.475 | 9.469 |
| 50% | 3.776 | 3.756 | 3.229 | 3.362 | 2.320 | 13.563 |
| 75% | 3.885 | 3.965 | 3.553 | 3.579 | 3.287 | 23.786 |
| 95% | 4.096 | 4.460 | 4.119 | 4.075 | 4.977 | 44.966 |
| Max | 4.151 | 5.901 | 6.547 | 7.183 | 8.895 | 490.273 |
| Mean | 3.829 | 3.847 | 3.327 | 3.443 | 2.533 | 15.385 |
| Std dev. | 0.142 | 0.334 | 0.414 | 0.346 | 1.410 | 106.913 |

Table 3.5 provides some basic statistics regarding both set of markups. Calculated markups under the equal percentage markups assumption appear to be extremely high. In fact, the import prices under this assumption are estimated to be negative for 96%

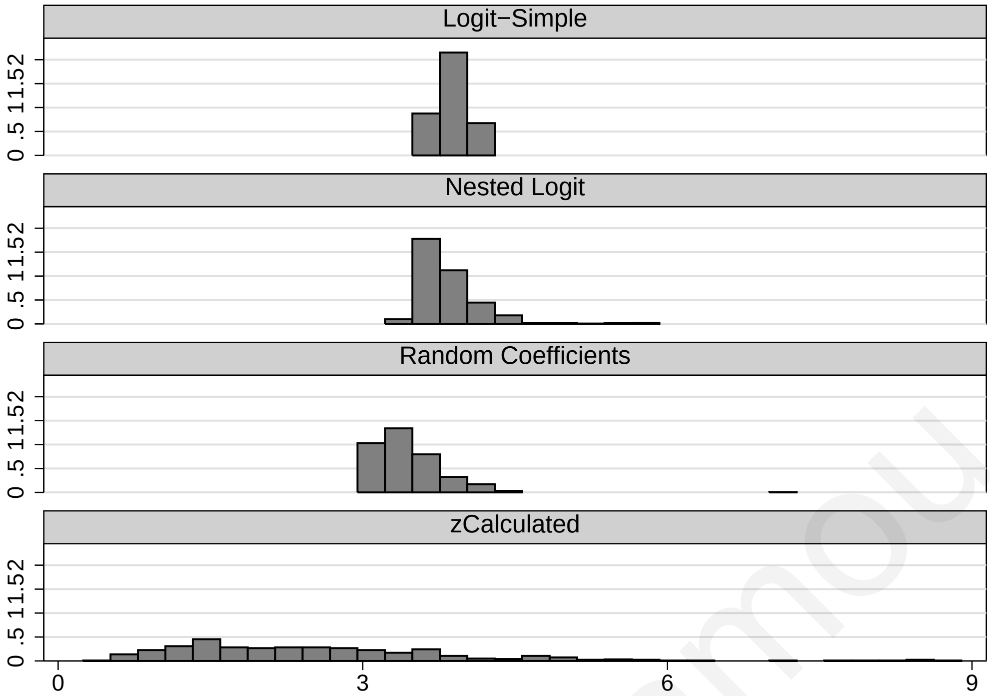



Figure 3.1: Distribution of markups

of the sample. By contrast, calculated markups under the equal markups assumption seems more plausible. Clearly the assumption of equal percentage markups is not appropriate and I do exclude it from further analysis.

Table 3.6: Median markup-to-marginal-cost ratio per class

| Class | SL | NL | RC-1 | RC-2 | Equal Markups |
|---|---|---|---|---|---|
| Small | 0,911 | 0,933 | 0,592 | 0,660 | 0,240 |
| Medium | 0,479 | 0,486 | 0,368 | 0,390 | 0,236 |
| Large | 0,205 | 0,202 | 0,206 | 0,200 | 0,169 |
| SUV | 0,226 | 0,307 | 0,224 | 0,216 | 0,371 |

The calculated markups obtained by the logit model have the lower standard deviation as expected. The minimum value is 3.599 and the maximum value is 4.151 (recall that the units are thousands of Cyprus pounds). The low dispersion is due to the fact that only the shares differentiate the markups among different products. Estimates get more dispersed as I allow for more heterogeneity among consumers. Calculated markups that probably account for more consumer heterogeneity are substantially more dispersed than those from DCMs. This can also be seen in Figure 3.1, which shows the distribution of the estimates scaled to density units. Markups obtained from the random coefficient are lower than those from the nested logit and simple logit. Calculated markups are substantially lower than on average than those obtained from all three DCMs.

Table 3.7: Median Markups per class

| Class | SL | NL | RC-1 | RC-2 | Equal Markups |
|---|---|---|---|---|---|
| Small | 3,776 | 3,778 | 2,931 | 3,162 | 1,488 |
| Medium | 3,781 | 3,790 | 3,185 | 3,310 | 2,348 |
| Large | 3,770 | 3,689 | 3,673 | 3,657 | 3,094 |
| SUV | 3,789 | 5,147 | 3,705 | 3,705 | 5,235 |

The median markups to marginal cost ratio by class are presented in Table 3.6. For DCMs, I observe that the ratio declines as moving from smaller to larger vehicles, as might be expected. Calculated markups shows a decline as the class is changed from small and medium to large. The low difference between small and medium class is due to the fact that accounting model predicts very low markups for very small automobiles compared to DCMs. If the 38 smaller automobiles are excluded from the sample, then the median markup for small cars is 0.275. The nested logit is closer to calculated markups for the SUV class (compared to the other DCMs) and the random coefficients model is closer to calculated markups for the size classes. The simple logit does not seem to perform as well as the other models because it does not allow for consumer heterogeneity.

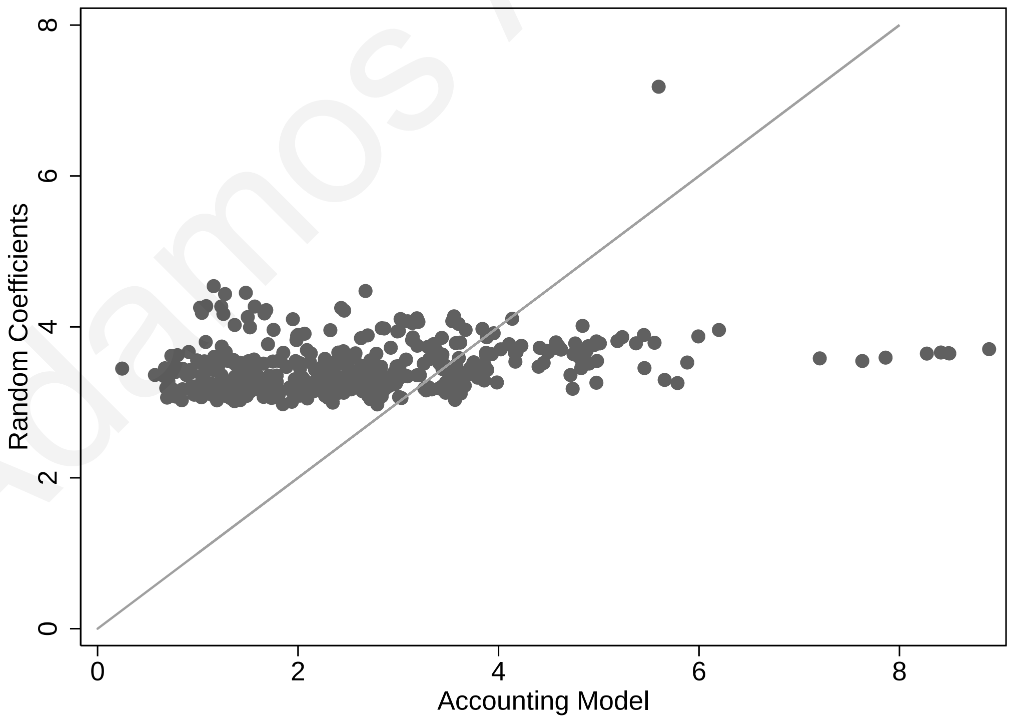



Figure 3.2: Scatter Plot of the two set of markups

The median absolute markups by class are presented in table 3.7. The markups obtained by random coefficients increase across size classes like calculated markups. Nested logit estimates, on the other hand, are closer to calculated markups for the case of SUVs.

Table 3.8: Correlations

| Model | SL | NL | RC-1 | RC-2 | Equal Markups |
|---|---|---|---|---|---|
| SL | 1,000 | | | | |
| NL | 0,577 | 1,000 | | | |
| RC-1 | 0,298 | 0,189 | 1,000 | | |
| RC-2 | 0,421 | 0,231 | 0,961 | 1,000 | |
| Equal Markups | -0,215 | 0,090 | 0,358 | 0,276 | 1,000 |

The correlations of markup estimates are provided in Table 3.8. I observe relatively higher correlation between the accounting model and the random coefficients model compared to the correlation between the accounting model and the nested logit. This is expected because nested logit predicts the same markups for products sold by the same retailer and belong to the same class (See section 3.4). Between the simple logit and the accounting model the correlation is negative, but recall that simple logit estimates are the least dispersed and that all the product sold by the same retailer have the same markups.

Figure 3.2 provides the scatter plots of markups obtained from random coefficient (RC-2) and markups obtained from accounting model. I observe the presence of outlying points across the 45 degree line. This happens for the majority of the observations.

## 3.6 Analysis with additional characteristics

As a test of possible biases, I also estimate demand for the 1995-2002 period, which allows me to include more characteristics but at the expense of having fewer observations. The set of instruments I use for logit and random coefficients models are per unit tax, constant tax, import duty and the sum of engine capacity of other products sold by the same firm. Import duty is proved to be a valid instrument for this subset based on the overidentification test and the first stage results. For nested logit, per unit tax, import duty and the sum of engine capacity of all the other products in the group are used as instruments. The results are presented in Table B.2 in the appendix.

For the random coefficients models both interactions of consumer and product characteristics are insignificant. This is likely due to the fact that I have a low number of observations. I increase the consumers draws from 2000 to 5000 but still the interactions are insignificant. However for model (2) $\alpha$ varies from 0.048 to 1.604, whereas for model (1) the coefficients of both price and its interaction with income are insignificant. This may be due to the fact that there is not a lot of variation for income for the years I examine. The parameter $\alpha$ varies from -0.081 to 3.799, which means that very rich

Table 3.9: Markup statistics (subsample)

| Stats | SL | NL | RC-1 | RC-2 | Equal markups |
|---|---|---|---|---|---|
| Minimum | 2,700 | 2,242 | 1,339 | 1,539 | 0,694 |
| Percentile 5% | 2,703 | 2,285 | 1,537 | 1,621 | 1,035 |
| Percentile 25% | 2,778 | 2,349 | 1,765 | 1,796 | 1,675 |
| Percentile 50% | 2,826 | 2,390 | 2,170 | 2,173 | 2,455 |
| Percentile 75% | 2,829 | 2,505 | 2,771 | 2,801 | 3,441 |
| Percentile 95% | 2,845 | 2,755 | 3,847 | 3,596 | 4,983 |
| Maximum | 2,849 | 3,268 | 5,544 | 5,053 | 8,497 |
| Mean | 2,804 | 2,451 | 2,345 | 2,356 | 2,689 |
| Std dev | 0,041 | 0,176 | 0,754 | 0,678 | 1,443 |

Table 3.10: Median markup-to-marginal-cost ratio per class

| Class | SL | NL | RC-1 | RC-2 | Equal Markups |
|---|---|---|---|---|---|
| Small | 0,551 | 0,446 | 0,277 | 0,279 | 0,314 |
| Medium | 0,311 | 0,273 | 0,216 | 0,217 | 0,233 |
| Large | 0,168 | 0,137 | 0,177 | 0,176 | 0,194 |
| SUV | 0,158 | 0,149 | 0,184 | 0,167 | 0,324 |

consumers have a negative $\alpha$ and this is inconsistent with demand theory. For this reason I exclude this model from the analysis later.

Table 3.11: Median Markups per class

| Class | SL | NL | RC-1 | RC-2 | Equal Markups |
|---|---|---|---|---|---|
| Small | 2,826 | 2,390 | 1,631 | 1,724 | 1,824 |
| Medium | 2,827 | 2,390 | 2,077 | 2,095 | 2,330 |
| Large | 2,825 | 2,376 | 2,953 | 2,918 | 3,216 |
| SUV | 2,778 | 2,713 | 3,158 | 2,944 | 4,983 |

The two additional attributes, frame and cylinders, have a positive and statistical significant coefficient. The implied mean own price elasticity is -5.14 for the simple logit model, -6.00 for nested logit model, -5.87 for random coefficients model (1) and -5.76 for random coefficients model (2). As the price elasticities (in absolute values) are higher than before, I expect lower markups for this subset.

In Table 3.9, as in the whole sample, estimates get more dispersed as I allow for more heterogeneity among consumers. The main differences between full sample and sub-sample is that random coefficients markups are much more dispersed compared to the other DCMs and closer to accounting model in this issue. This can be seen in Figure 3.3. In addition, the markups obtained by the accounting model are now much

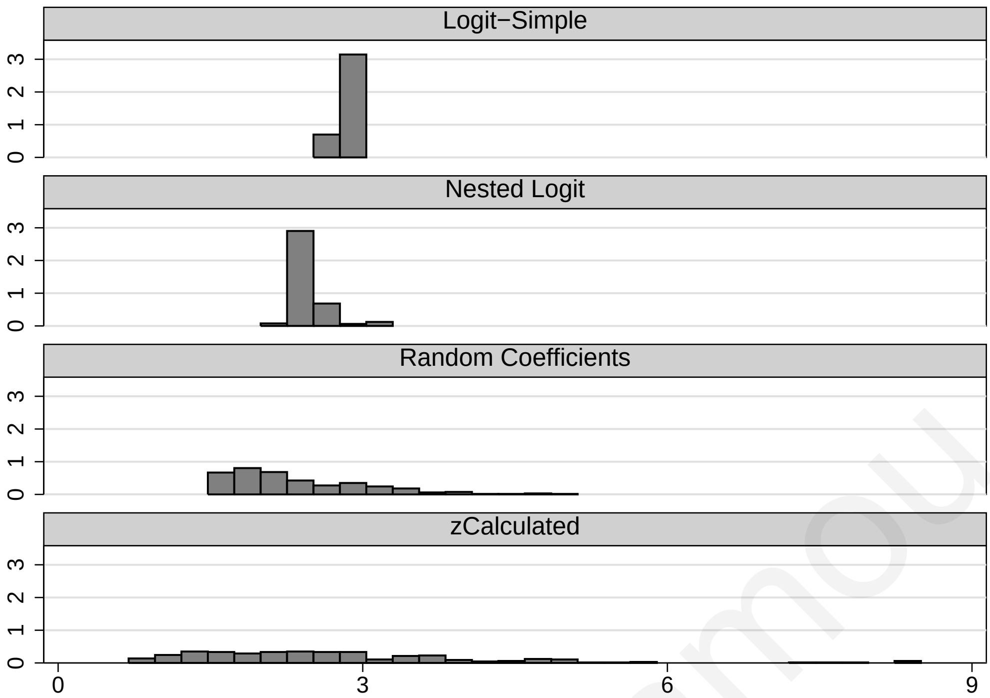



Figure 3.3: Distribution of markups for sub-sample

Table 3.12: Correlations

| Model | SL | NL | RC-2 | Equal Markups |
|---|---|---|---|---|
| SL | 1,000 | | | |
| NL | 0,234 | 1,000 | | |
| RC-2 | 0,125 | 0,063 | 1,000 | |
| Equal Markups | -0,106 | 0,041 | 0,452 | 1,000 |

closer to the values of the DCMs markups. This change can either be a result of the additional characteristics that I include in the demand estimation or of the change in my sample. To answer this question, the sub-sample is used without the inclusion of the additional characteristics. The related table B.1 can be found in the appendix. I find that the predicted DCM markups are as high as the markups in the whole sample. As a result, I conclude that the difference is due to the additional characteristics, and therefore these characteristics are essential for the estimation of markups.

The median markups to marginal cost ratio by class are presented in Table 3.10. For both DCMs and accounting model, I observe that the ratio declines as moving from smaller to larger vehicles. Random coefficients' estimates are closer to calculated markups for size classes. However, nested logit does not predict markups closer to the ones of the accounting model for SUV class as it did for the case of the whole sample. The median absolute markups by class are presented in Table 3.11. The

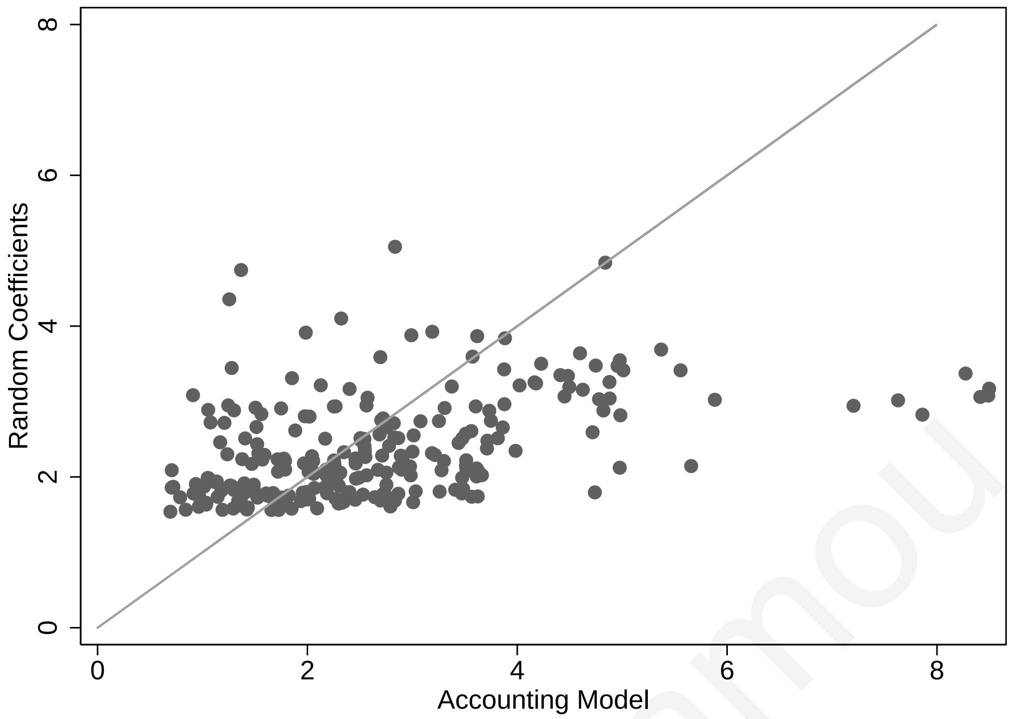



Figure 3.4: Scatter Plot of the two set of markups for subsample

markups obtained by random coefficients are closer to calculated markups for size classes. Nested logit does not perform well in this case.

The correlations of markup estimates are provided in Table 3.12. The correlation of markups obtained from random coefficients and accounting model is much higher than their correlation obtained from the whole sample. This can also be observed in Figure 3.4.

## 3.7 Conclusion

Discrete choice models (DCMs) have been widely used in recent years to estimate demand for differentiated products. These models yield estimates of marginal cost and markups that have been used to address several questions of interest, such as the impact of mergers and the measurement of market power. Due to lack of data, researchers are rarely able to evaluate the accuracy of their estimates by comparing them to actual data or alternative estimates. The aim of this chapter is to compare markups implied by DCMs to markups obtained by a different approach. The fact that I observe prices of the same car model that is sold with taxes and without taxes, allows me to use a simple accounting model that relates the import prices with the final prices for taxed and tax-free cars. This allows me to calculate markups under some simple non-equilibrium assumptions and compare them with markups obtained by discrete-choice models.

I estimate DCMs using the entire dataset as well as using a subset of the data that covers a shorter period, but includes additional demand attributes. When using the entire dataset, I found that the markups obtained from DCMs are generally higher than model-free markups, but when using the subset with the additional characteristics, the two sets of markups look reasonably close. This means that the use of additional demand attributes is essential for the estimation of markups even with the cost of a reduced dataset. Markups from the nested logit model are similar to those from the random coefficient model in terms of levels but they fail to generate enough dispersion in markups across different types of cars. I conclude that even simple DCMs like the nested logit can do quite well in approximating the overall level of markups but richer models are needed in order to capture more subtle differences across choices.

# Chapter 4

# Evaluation of the effectiveness of CO2-related taxation: The car market of Greece

## 4.1 Introduction

Transportation constitutes about one fifth of worldwide energy consumption and CO2 emissions. Its share is increasing in OECD countries, because of continuous growth in total vehicle kilometers traveled and slow improvements in automobile fuel economy, and is projected to remain stable in non-OECD countries only because electricity consumption is expected to grow more strongly (IEA (2006)). This comes in sharp contrast to greenhouse gas mitigation achievements in other sectors like power generation (in OECD countries) and industrial processes. It is therefore crucial to implement more aggressive policy measures if they are to ensure progress in limiting fuel consumption and CO2 emissions.

The most widely discussed policy instruments are fuel economy standards, which aim to induce technological progress in vehicle manufacturers, and fuel taxes, which intend to discourage people from purchasing and using cars that consume too much fuel. A third policy option, currently under serious consideration in Europe, is the change in the taxation system of motor vehicles, so that, among several available car models, consumers are encouraged to purchase those models with the lowest CO2 emissions. This may be a promising policy option since it involves a market-based instrument that can affect directly consumer behaviour, in contrast to command-and-control regulations that may be economically inefficient. Moreover, unlike fuel tax increases, which may be politically unattractive, particularly in European countries with already high fuel taxes, CO2-based taxation can be designed so as to be neutral for public revenues - a feature that can improve the political acceptance of such a policy.

Depending on vehicle tax systems in each country, revenue neutrality can be achieved in two ways: a) For countries which implement a registration tax in all new car purchases, this tax can be calculated on the basis of CO2 emissions only, in a way that total revenues of the new tax scheme are equal to those of the previous scheme - taking into account the estimated shifts in market shares of car models because of the response of consumers to tax incentives. b) Countries without a registration tax (mostly automobile producing countries in Europe) can implement a "feebate" system, in which consumers receive a rebate when purchasing low-CO2 cars or incur an additional fee when purchasing a high-CO2 car. If the system is properly designed, then total revenues from fees may be approximately equal to governmental payments for rebates.

Most European Union countries have currently put in place a CO2-based component in their calculation of vehicle taxes; either as a part of registration taxes, paid when a car is purchased, or of circulation taxes paid annually by each vehicle owner. ACEA (2009) and OECD (2009) provide an overview of the CO2-based taxation schemes implemented before the end of year 2009 by individual countries. However, little detailed research has been conducted at European level up to now. As a result, neither ex-ante nor ex-post evaluation of these schemes exists so far. Studies carried out on behalf of the European Commission have dealt with this issue in an aggregate manner and with simple statistical/econometric methods (COWI (2002); TIS, INFRAS, Erasmus, and DIW (2002)).

The "feebate" option has been discussed and analysed in North America for several years; see for example the simulations of Greene, Patterson, Singh, and Li (2005) and the references contained therein. Recently, Peters, Mueller, de Haan, and Scholz (2008) have discussed issues in the design of a "feebate" system in Europe and have supported their analysis with stated preference data from consumer surveys in Switzerland. Moreover, de Haan, Mueller, and Scholz (2009) have applied an agent-based microsimulation model of car purchasing consumer behaviour, which attempts to account for both direct monetary effects of such a system on consumer behaviour and indirect effects because of gradual changes in consumer preferences.

The aim of this chapter is to evaluate potential public policy interventions that could lead to the reduction of CO2 emissions of motor vehicles. In order to do this, I apply a discrete-choice model of consumer demand for automobiles, and I estimate the parameters of the model using a detailed dataset of aggregate car sales and car characteristics for two European countries.

I employ state of the art methods of estimating discrete-choice models of product differentiation. These techniques enable structural estimation of demand for differentiated products. In the demand side, consumers consider products as a set of product characteristics. Each consumer will choose the set of product characteristics that gives him/her the higher utility. Therefore, utility depends on product characteristics. According to how these characteristics can be treated in the estimation procedure, they can be broken into three different categories; price, observed characteristics (such as engine size) and unobserved characteristics (such as outside elegance). Under certain standard assumptions, one can derive the Simple Multinominal Logit model. It is well known that the distribution of this model yields unreasonable substitution patterns among products. In order to overcome these patterns, Berry (1994) proposed the nested multinominal logit model and Berry, Levinsohn, and Pakes (1995) developed their random coefficient model known as the BLP model. The last two models allow for heterogeneity among consumers and lead to more reasonable substitution patterns.

By estimating a discrete-choice model of product differentiation that allows for heterogeneity among consumers, it is possible to estimate consumer welfare, public revenues, firm markups and CO2 emissions. One can then proceed with a change in the tax regime, in order to find the simulated prices faced by the consumers and the simulated shares of each automobile. This can be done in two steps. In a first step, the taxation based on a car"s CO2 emission levels will affect the final prices faced by the consumers. If firms decide not to change their markups, the alternative tax will pass through by 100% to the final prices, or else, the pass-through will be different for each car model. I examine both cases. In a second step, prices under the alternative tax regimes will affect consumer choices and hence the shares of a given car model will change. Under the simulated prices and simulated shares, it is then possible to assess welfare, public revenues, firm mark-ups and emissions under the alternative CO2 tax scenario and compare them with the actual ones. Fershtman, Gandal, and Markovich (1999) use this procedure to examine a per-car tax and a tax based on engine size using data from the automobile market of Israel. I am following the same approach but for a different type of tax.

To my knowledge, this is the first study that explores the effect of CO2-based taxation in Europe by estimating a structural model for European countries which takes into account that prices come from the firms" profit maximization problem. Recently, Vance and Mehlin (2009) used similar data to estimate a discrete-choice model of demand for differentiated products in order to explore the effect of annual circulation taxes and fuel taxes on automobile demand in Germany. That analysis ignores the firm"s profit maximization problem, which means that if car prices are correlated with unobserved car characteristics the econometric estimates will be biased. In this chapter I report the results from the car market in Greece, whereas in the next chapter I examine the automobiles market in Germany.

## 4.2 The model

Berry (1994) notes that "the nested logit may be preferred when a heavy penalty is place on computational complexity or when a researcher wants to model substitution effects as depending only on predetermined class of products, whereas, the random coefficients model will be preferred when a premium is placed on estimating richer patterns of demand". In this project, I choose to use the nested logit as it allows for linear estimation techniques which can be employed for multiple policy simulations without a large computational burden [1]. In this way it might also be possible for governmental authorities to have several scenarios available in order to decide the desired CO2-based tax depending on actual national tax regimes.

The nested logit model assumes that products are grouped in different categories within one or more nests; in the case of automobiles, the nest comprises several categories of cars grouped according to body type and engine size (e.g. sedan cars with engine size ranging from 1.6 to 2.0 liters). Consumers are identical within each group but different from one group to another. Demand is modeled with the following equation (Berry (1994)):

$$\ln(S_j) - \ln(S_0) = x_j\beta - \alpha P_j + \sigma \ln(S_{j/g}) + \xi_j \tag{4.1}$$

where $P_j$ is the observed price of product j, $x_j$ is a k-dimensional vector of observed attributes of product j (such as horsepower, engine size, emission levels etc.), $\xi_j$ is a disturbance summarizing unobserved characteristics of product j, $\ln(S_{j/g})$ is the natural logarithm of within group shares, $S_j$ is the market share of product j (sales divided by M consumers) and $S_0$ is the outside's good share. $\beta$, $\alpha$, $\sigma$ are the demand parameters needed to be estimated.

On the supply side firms maximize profits. Solving the firm's profit maximization problem, as in Berry (1994), I derive the first order condition under the assumption of Bertrand-Nash equilibrium in prices.

$$\frac{P_j}{1+v} = mc_j + \frac{1-\sigma}{\alpha(1+v)(1-\sigma S_{j/g} - (1-\sigma)S_j)} \tag{4.2}$$

where $mc_j$ is the marginal cost of product j, and v is the value added tax rate. $\alpha$ and $\sigma$ are the parameters appearing in demand equation (4.1). The second term on the right hand side is the markup term, the difference between the seller's price and marginal cost. Marginal cost can be thought of as representing both production cost and various taxes and fees. For example one possibility would be $mc_j = C_j(1+t_j)+T_j$, where $C_j$ is the marginal production cost of product j, $t_j$ could be an ad valorem tax on the product's import price (e.g. an import duty where applicable), and $T_j$ is a product-specific tax (excise tax) imposed on individual product j. Thus the supply equation becomes:

$$\frac{P_j}{1+v} = C_j(1+t_j) + T_j + \frac{1-\sigma}{\alpha(1+v)(1-\sigma S_{j/g} - (1-\sigma)S_j)} \tag{4.3}$$

Marginal production cost is typically modelled as constant in output and linear in

[1] It is not very difficult to apply a random coefficient model similar to the one I presented in the previous chapter. However, policy makers prefer models that support linear estimation techniques and since this project is designed mostly for them, I focus on models supporting linear estimation techniques. In the next chapter, I give emphasis on a nested logit model that allows for more heterogeneity among consumers but still allows for linear estimation techniques.

product characteristics: $C_j = w_j\gamma + \omega_j$, where $w_j$ is a vector of product characteristics that affect production costs and $\omega_j$ is an error term that accounts for unobserved characteristics of product j. Thus the supply equation becomes:

$$\frac{P_j}{1+v} = (1+t_j)w_j\gamma + T_j + \frac{1-\sigma}{\alpha(1+v)(1-\sigma S_{j/g} - (1-\sigma)S_j)} + (1+t_j)\omega_j \qquad (4.4)$$

Parameters $\gamma$, $\beta$, $\alpha$ and $\sigma$ need to be estimated jointly through a joint estimation of demand and supply equations, (4.1) and (4.4) respectively). This is essential for our simulations. Alternatively one can estimate demand only (eq.(4.1)) and use the first order condition (eq.(4.3)) to conclude to a specific marginal cost without jointly estimating the demand and supply equations. Estimating the demand and supply jointly poses the advantage of increasing the efficiency of the estimates at the cost of requiring more structure.

To estimate the demand or to estimate the demand and supply jointly it is necessary to address the endogeneity of prices and "within" shares. The demand error term $\xi_j$ is correlated both with price and the within-group share. If firms observe unobserved quality $\xi_j$ they will take it into account when they set prices. This will induce a positive correlation between price and the error term, thus leading to an upward bias (lower $\alpha$ in absolute terms) in the estimated coefficient in an OLS regression. The other endogenous variable, the within-group share, is also positively correlated with unobserved quality and the coefficient $\sigma$ will also be biased upwards in the OLS case. For this reason, general method of moments (GMM) or instrumental variable (IV) methods should be used. In the case of joint estimation of demand and supply, it is necessary to solve the system of two equations using GMM because the equations are not linear in shares and "within" shares, and because $\xi_j$ and $\omega_j$ might be correlated. Nevo (2000) points out that adding a supply side in model structure for the case of random coefficients leads to a small increase in computational and programming complexity for standard static supply-side models.

Additionally, for the demand equation (4.1), it is possible to allow the parameter $\sigma$ to vary across groups. The $\sigma_g$ terms can be estimated by interacting $\ln(S_{j/g})$ with a set of group-specific dummy variables $G_jg$ that take the value of 1 if product j belongs to group g and 0 otherwise. Finally, the markup term in equation (4.3) is under the assumption that all the firms produce only one differentiated product. However, this is not the case and the markup term should take the form I explain in the previous chapter using equation 3.18. According to Fershtman, Gandal, and Markovich (1999) the markup term for the case of nested logit with one nest and under the assumption that firms produce more than one product becomes:

$$MU = \frac{1-\sigma}{\alpha(1+v)(1-\sigma S_{f/g} - (1-\sigma)S_{f,g})}$$

where $S_{f/g} = \sum_f S_{j/g}$ denotes the share of firm f's products within group g and $S_{f,g} = \sum_f S_j$ represents the firm's group g sales as a percentage of the potential market. According to this equation, the markup terms of two products which belong to the same group and sold by the same firm are exactly the same. The proof if the above statement is provided in the previous chapter.

### 4.2.1 Joint estimation of demand and supply equations

To estimate the two equations jointly using GMM, I need to stack the two vectors $\xi_j$ and $\omega_j$ in order to minimize the GMM objective function over the parameters.

We have N observations and $K_1$ instruments for the demand equation and $K_2$ instruments for the supply equation. So $\xi$ and $\omega$ are Nx1 vectors, $Z_1$ is an $NxK_1$ matrix, $Z_2$ is an $NxK_2$ matrix, $\Phi_1^{-1}$ is a $K_1xK_1$ matrix and $\Phi_2^{-1}$ is a $K_2xK_2$ matrix. With a separate optimization procedure, GMM objectives are $\xi' Z_1 \Phi_1^{-1} Z_1' \xi$ and $\omega' Z_2 \Phi_2^{-1} Z_2' \omega$ for demand and supply respectively.

$$\epsilon = \begin{bmatrix} \xi \\ \omega \end{bmatrix}, Z = \begin{bmatrix} Z_1 & 0 \\ 0 & Z_2 \end{bmatrix}, \Phi = Z'\Omega Z, \Omega = \begin{bmatrix} \epsilon_1^2 & 0 & 0 & 0 & 0 \\ 0 & \epsilon_2^2 & 0 & 0 & 0 \\ 0 & 0 & \ddots & 0 & 0 \\ 0 & 0 & 0 & \epsilon_{2N-1}^2 & 0 \\ 0 & 0 & 0 & 0 & \epsilon_{2N}^2 \end{bmatrix}.$$

By stacking together $\xi$ and $\omega$ a vector $\epsilon$ can be created, which is 2Nx1. A matrix Z is also created, which is $2Nx(K_1 + K_2)$, and $\Phi^{-1}$, which is $(K_1 + K_2)x(K_1 + K_2)$.

Using demand and supply equations one gets:

$$\epsilon = \begin{bmatrix} \xi \\ \omega \end{bmatrix} = \begin{bmatrix} \ln(S_j) - \ln(S_0) - x_j\beta + \alpha P_j - \sum_g \sigma_g G_{jg} \ln(S_{j/g}) \\ \frac{P_j}{(1+v)(1+t_j)} - w_j\gamma - \frac{T_j}{1+t_j} - \frac{1-\sigma}{\alpha(1+v)(1+t_j)(1-\sigma S_{f/g} - (1-\sigma) S_{f,g})} \end{bmatrix}.$$

The GMM objective function is $\epsilon' Z \Phi^{-1} Z' \epsilon$. $Z_1$ are the demand instruments and $Z_2$ are the supply instruments. Extensive discussion of candidate instruments of the endogenous variables that enter the demand equation ($Z_1$) can be found in Berry, Levinsohn, and Pakes (1995) and Bresnahan, Stern, and Trajtenberg (1997). According to Fershtman and Gandal (1998), "the firm's share in a particular group is increasing in the number of other products it sells in the group and decreasing in the number of products sold by competitors. Further, a firm's share in the group is increasing in the sum of the value of characteristics of the other products it sells in the group and decreasing in the sum of value of the characteristics of products sold by competitors in the group". So they suggest that the number of products that the firm sells in the group and the sum of characteristics of the other products that the firm sells in the group can be used as instruments for the 'within' firm's shares. Additionally, the number of products sold by competitors and the sum of characteristics of products sold by competitors can be used as instruments ($Z_2$) of the "within" firm's shares, which is the only endogenous variable that enters the supply equation.

The estimator that is used is the efficient GMM estimator. The estimation requires 2 steps. In the first step, $\epsilon' Z \Phi^{-1} Z' \epsilon$ is minimized using the relationship $\Omega = I_{2N}$ so $\Phi^{-1} = (Z'Z)^{-1}$ . This is done because under conditional homoskedasticity the efficient GMM estimator becomes 2SLS. Then in the second step one may use the residuals to form the appropriate $\tilde{\Omega}$ to estimate the GMM estimator with a weight $\Phi^{-1} = (Z'\tilde{\Omega}Z)^{-1}$. For calculating the standard errors, I compute the asymptotic variance of the efficient GMM estimator, Avar=$(X'Z\Phi^{-1}Z'X)^{-1}$.

### 4.2.2 Public Revenues, Environmental Effects, Firm Profits and Consumer Welfare

Using the estimates $\tilde{\gamma}$,$\tilde{\beta}$ ,$\tilde{\alpha}$ and $\tilde{\sigma}$ , it is possible to compute welfare (W), firm profits (from the markup term) and public revenues. Public revenues for product j are $\frac{vP_j}{1+v} + t\tilde{C}_j + T_j$, and firm profits for product j are $\frac{1-\tilde{\sigma_g}}{\tilde{\alpha}(1+v)(1-\tilde{\sigma_g}S_{f/g}-(1-\tilde{\sigma_g})S_{f,g})}$. Hence, one can multiply both of them with the sales volume (shares*M) and then obtain the sum per market and year. The environmental effect is the sum of CO2 emissions; one can multiply CO2 emissions with sales volume and then sum them up for each market and year.

If one defines $D_g = \sum_{j \in J_g} e^{\frac{\delta_j}{1-\sigma_g}}$, where $\delta_j = x_j\beta - \alpha P_j + \xi_j$, then consumers welfare - according to Trajtenberg (1989) - is:

$$W = \frac{1}{\alpha} \ln(\sum_g D_g^{1-\sigma_g}) + C$$

where C is the constant of integration and can be ignored because only the change in consumer welfare ($W_{simul} - W_{actual}$) is of interest.

### 4.2.3 Simulations

The objective is to use an alternative tax regime based on each car's CO2 emission levels in order to compute simulated shares, prices, public revenues, firm profits, CO2 emissions and consumers welfare. Then it is possible to compare simulated variables with the actual ones. To do that exercise we firstly need to compute the simulated prices and shares.

Assume that a "feebate" tax can be introduced, in which consumers receive a rebate when purchasing low-CO2 cars or incur an additional fee when purchasing a high-CO2 car. Then a tax $A_j$ enters linearly in the FOC (eq.(4.3)), where $A_j$ is positive for high-CO2 car and negative for low-CO2 cars. This tax will affect prices faced by the consumers and the change in prices will affect consumer choice. Consequently, the market shares of a given car model will change. The change in prices depends on each firm's decision to change its mark-ups or not. If a firm decides not to change its markups, the new tax will pass through by 100% on the final prices, or else, the pass-through will be different for each car model. In this chapter I examine both cases.

Suppose that firms do not change their markups. Then the simulated prices are simply the actual prices plus $A_j$, and the shares can be computed analytically by using these simulated prices and the following formula (Berry (1994)):

$$S_j(\delta, \sigma_g) = \frac{e^{\frac{\delta_j}{1-\sigma_g}}}{D_g^{\sigma_g}(\sum_g D_g^{1-\sigma_g})} \tag{4.5}$$

where $\delta_j = x_j\beta - \alpha P_j + \xi_j$ and $D_g = \sum_{j \in J_g} e^{\frac{\delta_j}{1-\sigma_g}}$

If firms decide to change their markups, then the system of equations must be solved simultaneously to find the simulated prices and then, using equation (4.5), we obtain the simulated shares.

In the case of joint estimation of demand and supply, the estimated parameters $\tilde{\gamma}$,$\tilde{\beta}$ ,$\tilde{\alpha}$, $\tilde{\sigma_g}$ and the residuals $\tilde{\xi_j}$ and $\tilde{\omega_j}$ are available. Then $\delta_j$ is a function of $P_j^{sim}$ and therefore $S_j$ is a function of $P_j^{sim}$, using equation (4.5). As a result, $S_{f/g}$ and $S_{f,g}$ will also be functions of $P_j^{sim}$. The supply equation has simulated prices on the left-hand side and the markup term (MU) on the right-hand side, which is a function of simulated prices:

$$\frac{P_j^{sim}}{1+v} = (1+t_j)w_j\tilde{\gamma} + T_j + MU(P_j^{sim}) + A_j + (1+t_j)\tilde{\omega_j}$$

Thus it is possible to solve N non-linear equations to find the simulated prices by adding an error term $\psi_j$ and find the simulated prices that minimize $\psi_j'\psi_j$ . Alternatively one can use contraction mapping, which converges to a solution in our case. Berry, Levinsohn, and Pakes (1995) prove that the following contraction mapping works for the case of random coefficients:

$$F(\delta) = \delta + \ln(S_j) - \ln(S_j(\delta))$$

In that model $S_j$ are the observed shares and $S_j(\delta)$ are the estimated shares. BLP find a $\delta$ such that their estimated shares are equal with the observed shares. In my case, the following contraction mapping can be used:

$$F(\delta) = \delta$$

This actually leads to a $\delta$ such that both sales shares and prices will converge, and with this $\delta$ simulated prices and shares can be obtained. Both procedures above lead to the same solution.

## 4.3 Data

Data regarding Greece were obtained from JATO Dynamics. I started with 50,701 observations for market years 1998-2008 which contain data about sales, prices and characteristics. The database provided records of two car models with the same engine size, fuel and transmission type but with a difference in a minor characteristic (e.g. the availability or not of climate control) as different observations. I merged such models in one, by summing up their sales and calculating a sales-weighted average price. I then removed from the dataset a few outliers such as models with a sales volume less than 10, models with a sales price of over 100,000 Euros and models with engine capacity more than 5 liters; these can be considered to belong to a very special market, oriented only to very high income consumers. This process of model aggregation and removal led to a dataset of 3,909 observations in total. Out of these, 546 observations involve Sport Utility Vehicles, 442 Multi-Purpose Vehicles, 171 luxury cars and 318 sports cars; the rest, or 62% of the sample, comprise "regular" cars. Some basic variables are described in Table 4.1.

Table 4.1: Descriptive statistics of the Greek dataset (obs: 3909)

| Stats | Eng. Size | CO2 emis. | HP | Torque | Sales | Prices |
|---|---|---|---|---|---|---|
| Min | 0.599 | 103 | 39 | 53 | 11 | 6.735 |
| 5% | 1.108 | 139 | 61 | 93 | 15 | 10.155 |
| 25% | 1.390 | 161 | 90 | 126 | 52 | 14.766 |
| 50% | 1.598 | 184 | 113 | 150 | 198 | 21.289 |
| 75% | 1.995 | 212 | 150 | 203 | 811 | 32.757 |
| 95% | 3.192 | 286 | 240 | 320 | 3272 | 61.815 |
| Max | 4.966 | 405 | 420 | 483 | 12844 | 120.866 |
| Mean | 1.801 | 192 | 127 | 175 | 726 | 26.697 |
| Std dev. | 0.638 | 45 | 54 | 71 | 1312 | 17.077 |

Source: Data provided by "JATO Dynamics".

Table 4.2 shows the average prices, sales, engine capacity and CO2 emissions by vehicle class. The "small" class contains automobiles with engine capacity between 0.6 and 1.4 liters, the 'medium' class contains cars with engine capacity from 1.4 to 1.8 liters and the rest are considered as large automobiles. As expected, larger cars have higher CO2 emissions and prices but lower sales. This classification is the one I use in the demand estimation below.

One of the most interesting features of these data is the variability of CO2 emissions of relatively similar cars. If one observes the CO2 performance of vehicles within the same segment, it becomes evident that, other vehicle attributes being equal, CO2 emissions vary by up to a factor of two. This indicates that appropriate incentives, e.g. through vehicle taxation, can encourage consumers to buy low-CO2 cars even without changing radically their preferences. In the United Kingdom it has been assessed that

Table 4.2: Descriptive statistics of the Greek dataset by vehicle class

| Class | observ. | Eng. Size | CO2 emis. | Sales | Prices |
|---|---|---|---|---|---|
| Small | 1196 | 1.164 | 153.69 | 1470 | 13.349 |
| Medium | 1437 | 1.652 | 183.77 | 591 | 22.368 |
| Large | 1276 | 2.472 | 237.92 | 181 | 44.084 |

Source: Data provided by "JATO Dynamics".

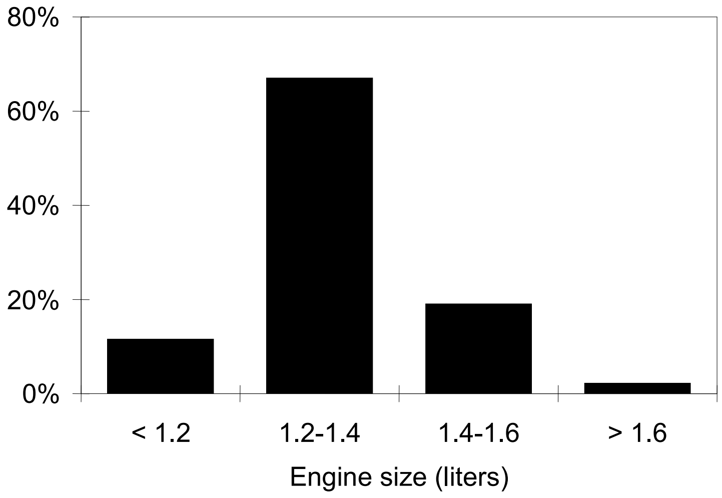
choosing the lowest CO2 emitters in any car market segment can make a difference of about 25% to fuel efficiency and CO2 emissions (King (2007)).

Figures 4.1 and 4.2 illustrate this aspect by showing the distribution of engine size and CO2 emissions of cars in two of the most popular market segments for automobiles sold in Greece in the year 2008. It is evident that, while most car models fall within a relatively narrow range of engine size (as well as engine power, not shown here), their CO2 emission levels are more dispersed. This is also demonstrated in Table 4.3, which shows a further analysis of the data shown in Figure 2. Out of the models with the smallest engine size in that specific segment (between 1.8 and 2.0 liters), 83% emit more than 160 g/km CO2 and 25% emit even more than 180 g/km; at the same time cars with somewhat larger engine size (over than 2.0 liters) have a high share (41%) of models emitting less than 160 g/km.

This means that even if consumers do not shift away from their preferred market segment, it is still possible to reduce new car CO2 emissions by a considerable amount through e.g. a higher tax on high-CO2 cars of that segment. To what extent, however, such a shift is possible depends on all other vehicle attributes that affect consumer decisions, and hence only the detailed empirical analysis according to the model described in the previous section might provide robust evidence for or against such policies.

Table 4.3: Distribution of CO2 emissions of car models that belong to two sub-segments of market segment "D1+D2 Upper medium-sized cars" sold in Greece in the year 2008

| CO2 emissions | Eng. Size 1.8-2.0 liters | Eng. Size $\geq$ 2.01 liters |
|---|---|---|
| $\leq$ 160 | 17% | 41% |
| 161-180 | 58% | 24% |
| $\geq$ 180 | 25% | 36% |
| Total | 100% | 100% |
| Average CO2 emissions: | 172 | 173 |



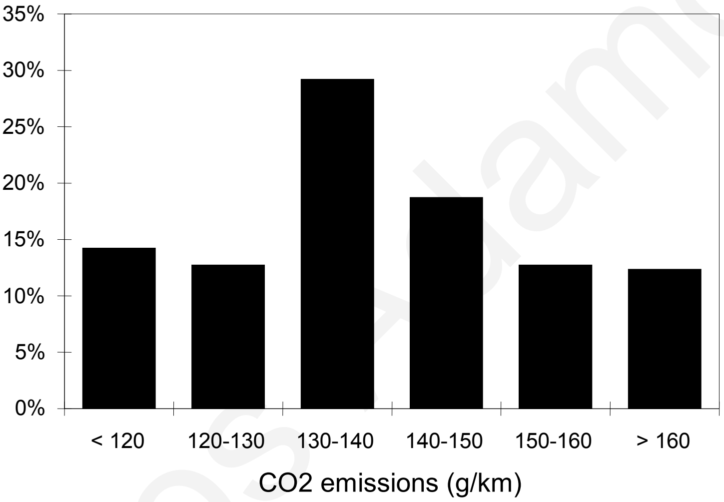




Figure 4.1: Distribution of engine size (top) and $CO_2$ emissions (bottom) for cars of market segment 'B small cars' sold in Greece in the year 2008
Notes: $CO_2$ emission levels are those of the composite (urban and extra-urban) legislated driving cycle used in Europe. Classification of cars into specific segments follows the categorization of the automotive data provider.



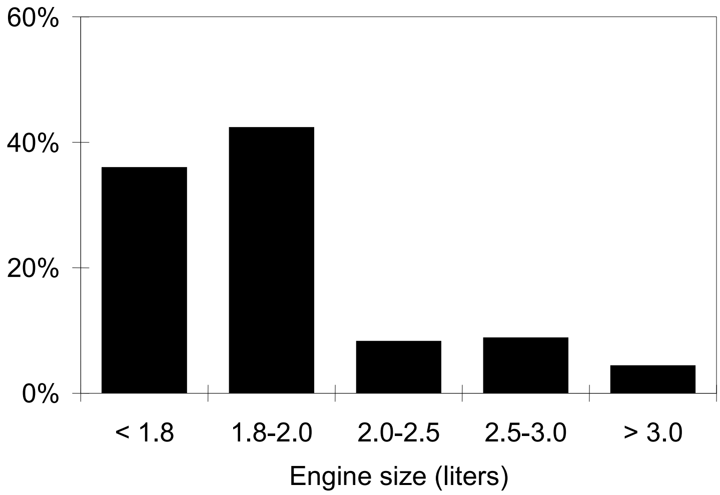
## 4.4 Estimation

### 4.4.1 The supply equation in the case of Greece

The taxation system in Greece for years 1998-2008 involves an ad valorem tax that is added to import prices. VAT applies not to final prices but to markups and import prices (and not to the ad valorem tax). This makes it necessary to change the FOC and, instead of equation (4.2), to use the following expression:

$$P_j = (1 + v + t_j)C_j + \frac{1 - \sigma_g}{\alpha(1 - \sigma_g S_{f/g} - (1 - \sigma_g S_{f,g}))} \tag{4.6}$$

After a personal communication with several representatives of major car retailers



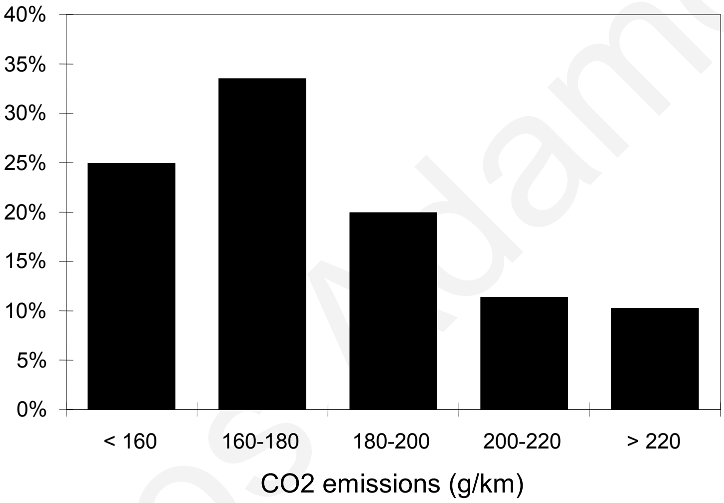




Figure 4.2: Distribution of engine size (top) and $CO_2$ emissions (bottom) for cars of market segments 'D1+D2 Upper medium-sized cars' sold in Greece in the year 2008
Notes: See explanatory notes in Figure 1.

in Greece, I concluded that auto manufacturing firms - and not retailers on their own - determine their markups. I therefore model the decisions of the car manufacturer on the supply side.

### 4.4.2 Results

Table 4.4 presents the estimation results. The choice of instruments in this model specification (number of models in the group, $CO_2$ emission of own models and $CO_2$ emission of own models squared) was guided by the appropriate tests for instrument relevance and overidentification. The Anderson canonical correlation LM statistic - a test of the null hypothesis that the model is under-identified - was rejected. The Sargan statistic - a test of the null hypothesis that the instruments are valid - could not be rejected. It is worth noting that tax rates did not prove to be useful instruments. In addition, I provide the result of the estimation of the demand only and not demand

and supply jointly [2]. Therefore, the marginal cost is obtained by equation (4.6) given that the markups are obtained using the demand estimates.

Engine capacity, horsepower, torque, climate control and airbags are important car attributes for the demand side. CO2 emissions turned out to be statistically insignificant. SUVs, sports and luxury cars have a positive and significant coefficient but MPVs have a negative and significant coefficient. The average own price elasticities are -6.08 (-1.66 for small, -3.78 for medium and -12.84 for large cars). The average markups are 5.881 (8.171 for small, 6.050 for medium and 3.545 for large cars). On the cost side, car characteristics are all statistically significant and positive.

Public revenues for all years of our sample are found to be 6 002 million Euros (at 2005 prices) or 2 115 Euros per car; these represent only the revenues from the ad valorem tax t. Average CO2 emissions are 167.5 grams per kilometer per car. Retailer profits are found to be 20 490 million Euros'2005 or 7 219 Euros per car. Finally, welfare (without C) is about 720 Euros per car for 1998, increases to 1060 Euros for 1999 and 1200 Euros for 2000, and then gradually declines up to 880 Euros for year 2008.

## 4.5 Policy simulations

Having estimated the parameters of the model as described above, I have then simulated the effects of two different vehicle taxation policies on automobile sales, prices, public revenues, firm profits, welfare and sales-weighted CO2 emissions. Results for each one of the two policies are reported below. I first compute (but do not report here for the sake of brevity) the effects assuming that changes in taxation are fully passed through by firms to consumers, and then calculate the effects of a (probably more realistic) scenario which assumes that, after changes in the tax system, retailers maximize their profit and set different markups for different models. All results that will be presented in this Section show the effect of taxation on the most recent car models, i.e. those available in year 2008; this provides a better indication about the eventual changes in car sales in the near future (e.g. in years 2010 or 2011), which is the reason why these policy simulations are carried out in the first place.

### 4.5.1 Simulation of the effect of a CO2 "feebate" on the Greek car market

The first policy exercise assumes that a "feebate" $A_j$ is introduced. All other taxes remain the same as before. As sales-weighted average CO2 emissions of cars sold in Greece in the year 2008 are found to be 159.5 grams per kilometer (g/km) per automobile, a linear tax is introduced in such a way that it is positive for cars with

[2] I estimated the demand and supply jointly with the same $\sigma$ for each group. The demand coefficients are very close to the coefficients of the estimation of the demand only.

Table 4.4: Demand and Supply estimates

| Variables | Demand side parameters | Cost side parameters |
|---|---|---|
| Price('000,2005) | -0.077** | |
| | (0.0062) | |
| $\ln(S_{j/g}) * G_{j,small}$ | 0.383** | |
| | (0.065) | |
| $\ln(S_{j/g}) * G_{j,medium}$ | 0.544** | |
| | (0.066) | |
| $\ln(S_{j/g}) * G_{j,large}$ | 0.736** | |
| | (0.070) | |
| Engine capacity | 0.561** | 3.52** |
| | (0.104) | (0.24) |
| CO2 Emissions | 0.0013 | 0.034** |
| | (0.00096) | (0.0030) |
| Horsepower | 0.0061** | 0.064** |
| | (0.0011) | (0.0036) |
| Torque | 0.0025** | 0.011** |
| | (0.00087) | (0.0031) |
| Climate Control | 0.280** | 1.340** |
| | (0.038) | (0.123) |
| Airbags | 0.167** | 1.320** |
| | (0.057) | (0.173) |
| SUV | 0.547** | 1.676** |
| | (0.092) | (0.217) |
| MPV | -0.439** | 0.806** |
| | (0.080) | (0.162) |
| LUXURY | 0.822** | 7.168** |
| | (0.110) | (0.258) |
| SPORT | 0.151† | 3.973** |
| | (0.081) | (0.195) |
| Constant | -7.109** | -9.956** |
| | (0.275) | (0.386) |
| F-test | 189.69** | 1206.3** |
| Underidentification test | 79.42, p-val:0.000 | |
| Overidentification test | 1.81, p-val:0.178 | |

Significance levels: † : 10%, ∗ : 5%, ∗∗ : 1%. Standard errors are reported in parentheses. Time dummies are included but not reported for brevity. Country dummies are reported in a special table in the appendix.

CO2 emissions over 159.5 g/km and negative for cars with emissions lower than this threshold: $A_j = \mu(CO2 - 159.5)$, where CO2 is the CO2 emissions level of model j.

In this exercise, coefficient $\mu$ is equal to 31 Euros, which implies that retail prices may decline by up to 20% for individual low-CO2 car models, while they can rise by more than 10% for big models with very high CO2 emissions. The value of $\mu$ has been set at such a level that the government cannot subsidize any car model with a rebate higher than the average tax imposed on all models; this ensures that the government does not risk losing too many public revenues due to the new taxation system.

I first assumed that the "feebate" passes fully through to retail prices. As a next step, I relaxed the assumption of 100% pass-through of taxes to prices; by doing so, I allow retailers to maximize their profit and set different markups for each car. Demand and supply equations are solved simultaneously to find the simulated prices and simulated shares. As the results of the two cases are very similar, I report here only the outcome of the (more realistic) simulation that allows for different markups per car.

Table 4.5: Effect of a "feebate" on prices and sales volumes of cars by CO2 emissions class

| CO2 emissions class (g/km) | Prices without "feebate" | Simulated Prices with "feebate" | Difference | Sales without "feebate" | Simulated Sales with "feebate" | Difference |
|---|---|---|---|---|---|---|
| $\leq$ 130 | 10609 | 9362 | -11.8% | 29283 | 33553 | 14.6% |
| 130-160 | 13849 | 13646 | -1.5% | 123059 | 127858 | 3.9% |
| 160-180 | 18640 | 19063 | 2.3% | 53499 | 52286 | -2.3% |
| 180-200 | 25052 | 26376 | 5.3% | 22643 | 20839 | -8.0% |
| $\geq$ 200 | 40969 | 43427 | 6.0% | 20522 | 15376 | -25.1% |
| All | 17751 | 17098 | -3.7% | 249006 | 249912 | 0.4% |

Tables 4.5 and 4.6 report the changes in prices and market shares as a result of the introduction of this "feebate". Total automobile sales remain essentially unchanged; they increase by only 0.4% in the "feebate" scenario. Low-CO2 cars experience a decline in their prices and a consequent increase in their sales, which is stronger for the group of cars with emission levels below 130 g/km. Under the simulated market, sales-weighted CO2 emissions are reduced to 156.3 g/km per automobile, or -2% compared to observed emission levels in year 2008. Public revenues decrease by 100 Euros per car or 23 million Euros in total, which represent a decrease of the actual ad valorem tax revenues in year 2008 by 5% because of the significant decline in sales of large cars, which will generally experience an increase in their taxation under the "feebate" system because most large car models emit more than 159.5 g/km. Retailer profits are found to be 7170 Euros per car, which corresponds to an increase in retailer markups by 84 Euros per car or 1.2%; this is due to the shift of sales towards smaller cars which, as shown in section IV.1, have higher markup levels. Finally, consumer welfare rises from 882.1 Euros per car in the actual sales of year 2008 to 885.4 Euros per car in the

"feebate" scenario because of the slightly increased car sales in the "feebate" case.

Table 4.6: Effect of a "feebate" on average prices and average sales volumes of cars by engine size class

| Engine Size class | Prices without "feebate" | Simulated Prices with "feebate" | Difference | Sales without "feebate" | Simulated Sales with "feebate" | Difference |
|---|---|---|---|---|---|---|
| Small | 12655 | 12050 | -4.8% | 148987 | 154820 | 3.9% |
| Medium | 19959 | 20161 | 1.0% | 72720 | 70944 | -2.4% |
| Large | 39682 | 40467 | 2.0% | 27299 | 24148 | -11.5% |
| All | 17751 | 17098 | -3.7% | 249006 | 249912 | 0.4% |

Table 4.7 presents the effect of the "feebate" within engine size classes. It is evident that the CO2-based tax not only shifts sales towards smaller cars, but also provides an incentive for consumers, out of the models within their preferred vehicle class, to purchase those with lower CO2 emission levels. The shift is particularly pronounced in the cases of cars with very high and very low CO2 emissions; especially in medium and large cars the "feebate" affects very high-CO2 vehicles substantially, reducing their sales by more than 20%, so that even models with relatively high emissions (of the group 180-200 g/km) gain sales shares despite the increase in their retail prices.

Table 4.7: Effect of a "feebate" on prices and sales volumes of cars by engine size and CO2 emissions class - percentage differences from the current taxation regime

| CO2 emissions | Change in prices | | | Change in sales volume | | |
|---|---|---|---|---|---|---|
| class (g/km) | Small | Medium | Large | Small | Medium | Large |
| $\leq$ 130 | -11.8% | | | 14.6% | | |
| 130-160 | -3.2% | -0.8% | -0.6% | 2.8% | 5.7% | 49.9% |
| 160-180 | 1.5% | 1.8% | 1.4% | -4.8% | -2.1% | 26.7% |
| 180-200 | 4.7% | 3.9% | 3.3% | -15.4% | -12.3% | 3.5% |
| $\geq$ 200 | | 6.3% | 6.3% | | -21.5% | -25.7% |
| All | -4.8% | 1.0% | 2.0% | 3.9% | -2.4% | -11.5% |

Table 4.8 shows the resulting pass-through of taxes to retail prices by engine size and CO2 emissions class. The pass-through varies from 99.95% to 100.39% for individual models, and declines gradually for higher CO2 classes. This means that firms absorb some of the tax increase for high-CO2 cars in an attempt to mitigate some of the decrease in their sales. In any case, all pass-through values are very close to unity (or 100%), which explains why the results differ very little in comparison to those of the 100% pass-through case.

Table 4.8: Average pass-through of taxes to prices by car engine size and CO2 emissions class in the 'feebate' case (in %)

| CO2 emissions class (g/km) | Small | Medium | Large |
|---|---|---|---|
| $\leq$ 130 | 100.05 | | |
| 130-160 | 99.99 | 100.02 | 100.39 |
| 160-180 | 99.97 | 99.99 | 100.10 |
| 180-200 | 99.95 | 99.99 | 100.04 |
| $\geq$ 200 | | 99.97 | 100.01 |

### 4.5.2 Partial abolition of existing automobile taxes and introduction of a CO2-based tax in the Greek car market

The second policy exercise assumes that a part of the existing ad valorem tax on cars is abolished and replaced by a tax based on a car's CO2 emission levels. This is in line with policies currently implemented in many EU countries, where a part of a car's registration tax is calculated on the basis of emissions and another part on another vehicle attribute such as engine size. I chose to impose a tax equal to 15 Euros (at 2008 prices) for each gram of CO2 emitted per kilometer above a threshold of 100 g/km; it is straightforward to show that such a tax, for a lifetime of 150 000 kilometers, corresponds to a carbon price of 20-30 Euros per tonne of CO2. At the same time I reduced the ad-valorem tax rates by 43% so that, if sales volumes did not change in comparison to actual sales of year 2008, government revenues would remain equal to the actual 2008 revenues. Although it is obvious that such a taxation change will shift sales among different engine size classes, this assumption intends to ensure that public revenues do not deviate too much from those observed in year 2008.

Like in the previous section, I only report results of the case where the assumption of 100% pass-through of taxes to prices has been relaxed because, as in the case of the "feebate" presented above, pass-through rates are very close to unity - ranging from 99.99% to 100.87%. Tables 4.9 and 4.10 report (by engine size and emissions class respectively) the changes in prices and market shares as a result of the introduction of this tax. Since the CO2-related portion of the new tax is a linear function of emission levels above 100 g/km, whereas the current taxes are strongly non-linear as they grow rapidly with increasing engine size, the change in taxation system is beneficial for large cars: their engine size-related tax decreases by a large amount, so that their retail prices decline substantially (by 5.8%). As a result, their sales shares increase by more than 19% compared to actual shares observed in the Greek market in 2008. Conversely, small cars experience an increase in their prices and a subsequent fall in their sales volume.

Table 4.11 displays the effect of this tax within a combination of engine size and emissions classes. Although the existence of a CO2-based tax mitigates a little the

Table 4.9: Effect of a CO2-based registration tax on prices and sales volumes of cars by CO2 emissions class

| CO2 emissions class (g/km) | Prices without CO2 tax | Simulated Prices with CO2 tax | Difference | Sales without CO2 tax | Simulated Sales with CO2 tax | Difference |
|---|---|---|---|---|---|---|
| $\leq$ 130 | 10609 | 10781 | 1.6% | 29283 | 29207 | -0.3% |
| 130-160 | 13849 | 14328 | 3.5% | 123059 | 120370 | -2.2% |
| 160-180 | 18640 | 18864 | 1.2% | 53499 | 53054 | -0.8% |
| 180-200 | 25052 | 24503 | -2.2% | 22643 | 23073 | 1.9% |
| $\geq$ 200 | 40969 | 38917 | -5.0% | 20522 | 24530 | 19.5% |
| All | 17751 | 18224 | 2.7% | 249006 | 250234 | 0.5% |

Table 4.10: Effect of a CO2-based registration tax on average prices and average sales volumes of cars by engine size class

| Engine Size class | Prices without CO2 tax | Simulated Prices with CO2 tax | Difference | Sales without CO2 tax | Simulated Sales with CO2 tax | Difference |
|---|---|---|---|---|---|---|
| Small | 12655 | 13053 | 3.1% | 148987 | 144221 | -3.2% |
| Medium | 19959 | 19902 | -0.3% | 72720 | 73497 | 1.1% |
| Large | 39682 | 37366 | -5.8% | 27299 | 32516 | 19.1% |
| All | 17751 | 18224 | 2.7% | 249006 | 250234 | 0.5% |

increase in sales of high-CO2 cars, still the overall decline in the tax burden of large automobiles dominates and leads to significantly higher sales of large cars, even of those emitting more than 200 grams CO2 per kilometer. As a result, average emission levels rise by 2 g/km per car, a 1.3% increase compared to actual emission levels in year 2008; combined with a slight increase in total car sales, total CO2 emissions rise by 1.8%. Public revenues rise considerably, by 285 Euros per car or by 15.8% in total, because of the increased sales of bigger cars as well as the increased taxes imposed on smaller cars. As a result of the slight increase in total automobile sales, welfare also rises by 1% in total. Finally, firm markups decline by -0.7% in total, because consumers increasingly purchase larger cars, whose markups are lower as their demand is more elastic.

Overall, results of this policy simulation show that it is environmentally ineffective because of the current taxation system, which puts a heavy tax burden on large cars irrespective of their emission levels; a partial abolition of this system may have negative environmental repercussions, although it could be beneficial for public revenues.

To summarize the above results in a different way, Figure 4.3 illustrates simulated sales shares by emissions class and engine size respectively according to the two scenarios described in this Section, and compare them with the actual sales shares observed in the Greek market in year 2008.

Table 4.11: Effect of a $CO_2$ tax on prices and sales volumes of cars by engine size and $CO_2$ emissions class - percentage differences from the current taxation regime

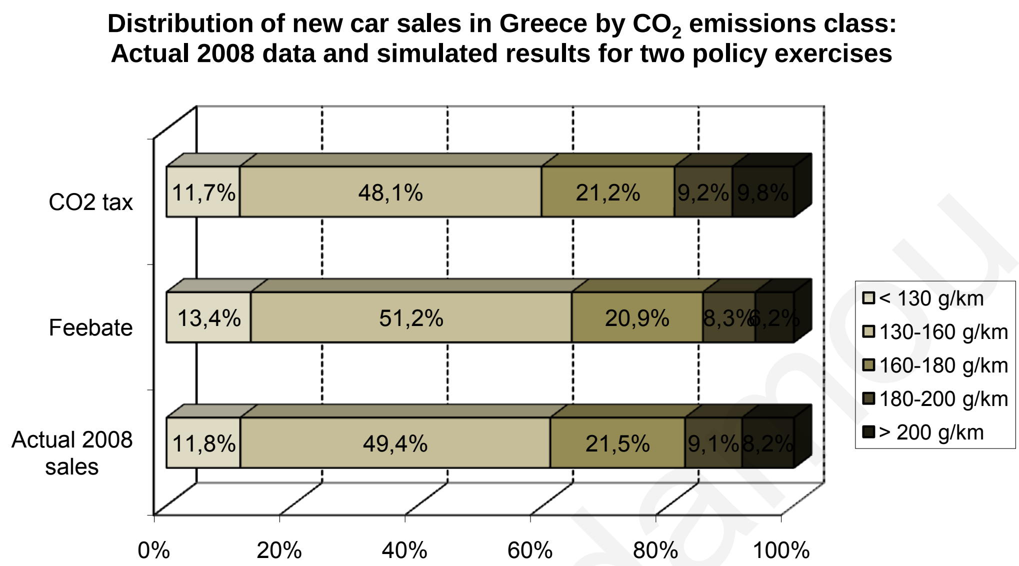
| $CO_2$ emissions | Change in prices | | | Change in sales volume | | |
|---|---|---|---|---|---|---|
| class (g/km) | Small | Medium | Large | Small | Medium | Large |
| $\leq$ 130 | 1.6% | | | -0.3% | | |
| 130-160 | 3.6% | -0.4% | -7.1% | -3.6% | 1.6% | 37.8% |
| 160-180 | 4.3% | -0.2% | -6.6% | -5.6% | 0.1% | 32.3% |
| 180-200 | 3.4% | -0.3% | -6.1% | -6.3% | 5.5% | 0.2% |
| $\geq$ 200 | | -0.3% | -6.8% | | -7.5% | 24.0% |
| All | 3.1% | -0.3% | -5.8% | -3.2% | 1.1% | 19.1% |

## 4.6 Concluding remarks and outlook

This chapter has described a model of oligopolistic competition in markets with differentiated products, simulating demand and supply under alternative tax regimes in the car market. It is applied using a detailed set of the car market of Greece. The objective is to determine consumer willingness to pay for environmentally friendly vehicles and to perform simulations in order to evaluate policies that could shift consumer purchases towards low-$CO_2$ cars and thus lead to the reduction of fuel use and $CO_2$ emissions.

There are obvious policy implications of this analysis. At a time when European countries increasingly adopt a $CO_2$-based element in the calculation of their vehicle taxes, the model described in this chapter constitutes a tool for the evaluation of real-world policy options. It is particularly important that the model can simulate shifts in market shares as a result of different taxation regimes, as car taxation policies seem to have been designed in many cases without a sound analysis of consumer response to these policies. As a result, the effect on public revenues is often assessed by governments in a very rough manner, which may lead to significant errors. If consumer response is overestimated then a specific policy does not have the effect it was initially assumed to have; on the other hand, if consumer response is underestimated then the policy may prove to be more successful than initially thought, which in turn may lead to a significant loss of public revenues - this was indeed the case of a $CO_2$ rebate system in the Netherlands in the year 2002.

The results of this study will also have important implications for EU-wide policies towards vehicle taxation. Although taxation generally remains under the competence of national authorities, attempts to harmonize vehicle taxes at EU level are under way. Some years ago, the European Commission issued a proposal for a law (Directive) that would, inter alia, oblige EU Member States to change their taxation schemes so that at least half of the total revenues from vehicle taxation came from $CO_2$-based taxes (EC (2005)). Virtually no progress has been made on this proposal, primarily because of issues of national sovereignty in taxation matters. However, in an ever more carbon-constrained world, these topics are always open for discussion. A modelling framework based on a state-of-the-art demand and supply model and robust econometric methods, as the one described in this chapter, can be a useful tool for analyzing such policy options in depth and contributing towards a more effective and efficient low-carbon transportation policy in Europe.



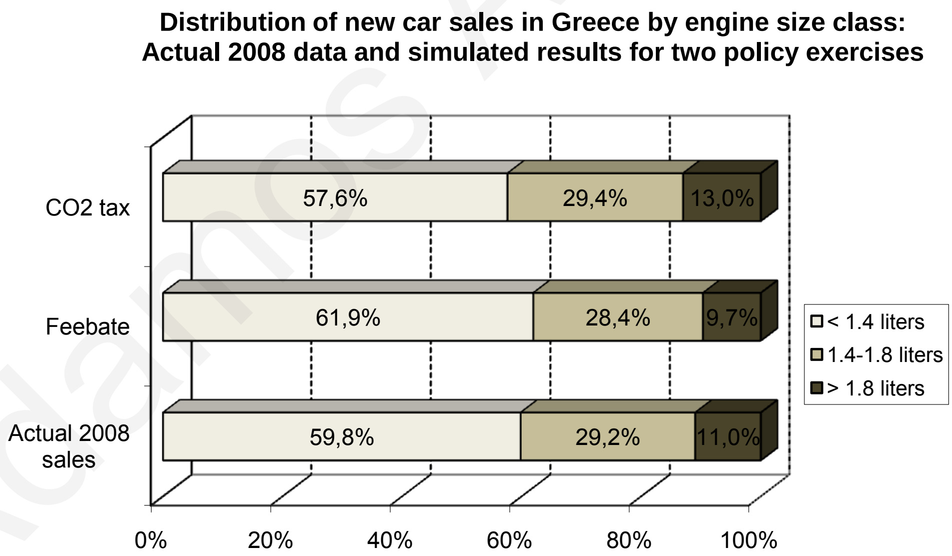




Figure 4.3: Comparison of actual and simulated automobile sales shares in Greece by emissions and engine size class

Note that sales-weighted average CO2 emissions are 159.5 g/km for actual sales of year 2008, 156.3 g/km in the "feebate" case and 161.5 g/km in the 'CO2 tax' case.

# Chapter 5

# Environmental and Economic Effects of CO2-based Automobile Taxes in Germany

## 5.1 Introduction

This chapter is an extension of the previous chapter. It presents the results from numerous simulations that have been carried out for the automobile market of Germany instead of Greece. The main difference of the two markets is that diesel private cars are not allowed in Greece (because Greek government argues that diesel destroy the ancient monuments). On the other hand diesel cars are allowed in Germany. As diesel fuel is more energy dense per unit volume and consumers may prefer automobiles with different fuel efficiencies (according to their needs). An additional classification according to fuel type is quite reasonable for the purposes of this project.

To evaluate fuel classification (nest classification), I checked whether fuel type may be interpreted as a discrete variable capturing the cars continuous physical characteristics. I compared the cars physical characteristics horsepower, torque, frame, engine capacity and CO2 emissions across diesel and gasoline cars. It turned out that the range of characteristics of diesel cars did not generally overlap with that of gasoline cars. However, that might be obvious for horsepower and torque as diesel engines produce in general more torque and they have always less horsepower. These evidence support fuel type as nest classification.

That is; in this chapter I extended nested logit basic version in order to include two nests instead of one, thus allowing for more heterogeneity among consumers. I am not aware of another study that uses the nested logit with two nests and proceeds with environmental policy simulations; Verboven (1996), while using a two-nest specification, does not carry out simulations, whereas Fershtman, Gandal, and Markovich (1999), who do perform tax policy simulations, use the one-nest model.

Furthermore, the taxation system in Germany does not involve an ad valorem tax on import prices but only a VAT on final prices. This implies a different pricing equation for the case of Germany compared to the Greek case. It also implies that only a "feebate" policy exercise can be introduced. However, this is just a minor issue. The main reason I differentiated this chapter from the previous one is the change in methodology.

## 5.2 The model

For this chapter, I choose to use two nests to allow for more heterogeneity among consumers; in this way there are different consumers for each one of three car size classes group (small, medium and large) and two fuels sub-group (gasoline or diesel) for each size class group. Alternatively, a different ordering of the nesting structure can be used, in which groups can be defined according to fuel type and subgroups according to car size [1].

As explained in the previous chapter, the demand equation for the case of the nested logit with one nest can be modeled as follows (Berry (1994)):

$$\ln(S_j) - \ln(S_0) = x_j\beta - \alpha P_j + \sigma \ln(S_{j/g}) + \xi_j \tag{5.1}$$

where $P_j$ is the observed price of product j, $x_j$ is a k-dimensional vector of observed attributes of product j (such as horsepower, engine size, emission levels etc.), $\xi_j$ is a disturbance summarizing unobserved characteristics of product j, $\ln(S_{j/g})$ is the natural logarithm of within group shares, $S_j$ is the market share of product j (sales divided by M consumers) and $S_0$ is the outside's good share. $\beta$, $\alpha$, $\sigma$ are demand parameters that need to be estimated.

In the case of the nested logit with two nests the demand equation becomes:

$$\ln(S_j) - \ln(S_0) = x_j\beta - \alpha P_j + \sigma_1 \ln(S_{j/h}) + \sigma_2 \ln(S_{h/g}) + \xi_j \tag{5.2}$$

where $\ln(S_{j/h})$ is the share of product j in the sub-group h and $\ln(S_{h/g})$ is the share of all subgroup-h products in group g. The proof can be found in the appendix. In this model, if both $\sigma_1$ and $\sigma_2$ are zero, an individual's preferences are uncorrelated across all cars sold in market m, resulting in the simple logit model. If only $\sigma_1$ is positive and $\sigma_2$ is zero, individual preferences are only correlated across cars from the same subgroup, resulting in localized competition between cars from the same subgroup. If in addition $\sigma_2$ is positive, individual preferences are also correlated across cars from a different subgroup within the same group. If $\sigma_2$ approaches $\sigma_1$, preferences are equally correlated across all cars belonging to the same group. If $\sigma_1$ approaches one, cars in the same subgroup become perfect substitutes. If in addition $\sigma_2$ approaches one, cars in the same group become perfect substitutes. Furthermore, as shown by McFadden

[1] I will address this issue later, in the empirical part of this chapter.

(1978) and mentioned by Verboven (1996), the nested logit model with two nests is consistent with random-utility maximization for $0 \leq \sigma_2 \leq \sigma_1 \leq 1$.

On the supply side the basic equation is derived by the firm's profit maximization problem. As in Verboven (1996), the first order condition under the assumption of Bertrand-Nash equilibrium in prices is given by the following relationship:

$$\frac{P_j}{1+v} = mc_j + \frac{1}{\alpha(1+v)[\frac{1}{1-\sigma_1} - (\frac{1}{1-\sigma_1} - \frac{1}{1-\sigma_2})S_{f/h} - \frac{\sigma_2}{1-\sigma_2}S_{f/g} - S_f]} \tag{5.3}$$

where $mc_j$ is the marginal cost of product j, and v is the value added tax rate. $\alpha$, $\sigma_1$ and $\sigma_2$ are the parameters appearing in demand equation (5.2). $S_{f/h} = \sum_f S_{j/h}$ denotes the share of firm f's products within subgroup h, $S_{f/g} = \sum_f S_{j/g}$ denotes the share of firm f's products within group g and $S_f = \sum_f S_j$ represents the firm's products shares in the potential market.

The second term on the right hand side is the markup term, the difference between the seller's price and marginal cost. Marginal production cost is typically modelled as constant in output and linear in product characteristics: $mc_j = w_j\gamma + \omega_j$, where $w_j$ is a vector of product characteristics that affect production costs and $\omega_j$ is an error term that accounts for unobserved characteristics of product j. Thus the supply equation becomes:

$$\frac{P_j}{1+v} = w_j\gamma + \frac{1}{\alpha(1+v)[\frac{1}{1-\sigma_1} - (\frac{1}{1-\sigma_1} - \frac{1}{1-\sigma_2})S_{f/h} - \frac{\sigma_2}{1-\sigma_2}S_{f/g} - S_f]} + \omega_j \tag{5.4}$$

Parameters $\gamma$, $\beta$, $\alpha$ and $\sigma$ need to be estimated jointly through a joint estimation of demand and supply equations, (5.2) and (5.4) respectively). This is essential for simulation purposes. Alternatively, demand equation can be estimated separately (eq.(5.2)) and marginal cost can be found using the first order condition (eq.(5.3)). Estimating the demand and supply jointly poses the advantage of increasing the efficiency of the estimates at the cost of requiring more structure.

To estimate the model it is necessary to address the endogeneity of prices and "within" shares. The demand error term $\xi_j$ is correlated both with price, the within-subgroup share and the share of all subgroup-h products in group g. If firms observe unobserved quality $\xi_j$ they will take it into account when they set prices. This will induce a positive correlation between the price and the error term, thus leading to an upward bias (lower $\alpha$ in absolute terms) in the estimated coefficient in an OLS regression. The other endogenous variables are also positively correlated with unobserved quality and the coefficients $\sigma_1$ and $\sigma_2$ will also be biased upwards in the OLS case. For this reason, general method of moments (GMM) or instrumental variable (IV) methods should be used. In the case of joint estimation of demand and supply, it is necessary to solve the system of two equations using GMM because the equations are not linear in shares and "within" subgroup/group shares, and because $\xi_j$ and $\omega_j$

might be correlated.

### 5.2.1 Joint estimation of demand and supply equations

To estimate the two equations jointly using GMM, the two vectors $\xi_j$ and $\omega_j$ have to be stacked together in order to minimize the GMM objective function over the parameters at the same time.

There are N observations and $K_1$ instruments for the demand equation and $K_2$ instruments for the supply equation. So $\xi$ and $\omega$ are Nx1 vectors, $Z_1$ is an $NxK_1$ matrix, $Z_2$ is an $NxK_2$ matrix, $\Phi_1^{-1}$ is a $K_1xK_1$ matrix and $\Phi_2^{-1}$ is a $K_2xK_2$ matrix. With a separate optimization procedure , GMM objective functions are given by $\xi' Z_1 \Phi_1^{-1} Z_1' \xi$ and $\omega' Z_2 \Phi_2^{-1} Z_2' \omega$ for demand and supply respectively.

$$\epsilon = \begin{bmatrix} \xi \\ \omega \end{bmatrix}, Z = \begin{bmatrix} Z_1 & 0 \\ 0 & Z_2 \end{bmatrix}, \Phi = Z'\Omega Z, \Omega = \begin{bmatrix} \epsilon_1^2 & 0 & 0 & 0 & 0 \\ 0 & \epsilon_2^2 & 0 & 0 & 0 \\ 0 & 0 & \ddots & 0 & 0 \\ 0 & 0 & 0 & \epsilon_{2N-1}^2 & 0 \\ 0 & 0 & 0 & 0 & \epsilon_{2N}^2 \end{bmatrix}.$$

Combining these two by stacking $\xi$ and $\omega$, a vector $\epsilon$ can be created, which is 2Nx1. A matrix Z is also created, which is $2Nx(K_1 + K_2)$, and a $\Phi^{-1}$, which is $(K_1 + K_2)x(K_1 + K_2)$.

Using demand and supply equations one gets:

$$\epsilon = \begin{bmatrix} \xi \\ \omega \end{bmatrix} = \begin{bmatrix} \ln(S_j) - \ln(S_0) - x_j\beta + \alpha P_j - \sigma_1 \ln(S_{j/h}) - \sigma_2 \ln(S_{h/g}) \\ \frac{P_j}{(1+v)} - w_j\gamma - \frac{1}{\alpha(1+v)[\frac{1}{1-\sigma_1} - (\frac{1}{1-\sigma_1} - \frac{1}{1-\sigma_2})S_{f/h} - \frac{\sigma_2}{1-\sigma_2} S_{f/g} - S_f]} \end{bmatrix}.$$

The GMM objective is $\epsilon' Z \Phi^{-1} Z' \epsilon$. $Z_1$ are the demand instruments and $Z_2$ are the supply instruments. Extensive discussion of candidate instruments of the endogenous variables that enter the demand equation ($Z_1$) can be found in Berry, Levinsohn, and Pakes (1995), Bresnahan, Stern, and Trajtenberg (1997) and Fershtman and Gandal (1998).

The estimator that can be used is the efficient GMM estimator. The estimation requires 2 steps. In the first step, $\epsilon' Z \Phi^{-1} Z' \epsilon$ is minimized using the identity matrix as the weight matrix, that is $\Omega = I_{2N}$ so $\Phi^{-1} = (Z'Z)^{-1}$ . This is done because under conditional homoskedasticity the efficient GMM estimator becomes 2SLS. Then in the second step one may use the residuals from the first step estimation to form the appropriate $\tilde{\Omega}$ and get a new set of estimates with a weight $\Phi^{-1} = (Z'\tilde{\Omega}Z)^{-1}$. I compute standard errors from the asymptotic variance of the efficient GMM estimator: Avar=$(X'Z\Phi^{-1}Z'X)^{-1}$.

### 5.2.2 Public Revenues, Environmental Effects, Firm Profits and Consumer Welfare

Using the estimates $\tilde{\gamma}$,$\tilde{\beta}$ ,$\tilde{\alpha}$, $\tilde{\sigma_1}$ and $\tilde{\sigma_2}$ , it is possible to compute consumer welfare, firm profits (from the markup term) and public revenues. Public revenues for product j are $\frac{vP_j}{1+v}$, and firm profits for product j are:

$$MU_j = \frac{1}{\alpha(1+v)[\frac{1}{1-\tilde{\sigma_1}} - (\frac{1}{1-\tilde{\sigma_1}} - \frac{1}{1-\tilde{\sigma_2}})S_{f/h} - \frac{\tilde{\sigma_2}}{1-\tilde{\sigma_2}}S_{f/g} - S_f]}$$

Hence, one can multiply both of them with the sales volume (shares*M) and then obtain the sum per market and year. The environmental effect is the sum of CO2 emissions; one can multiply CO2 emissions with sales volume and then sum them up for each market and year.

Consumer welfare can be estimated using the following equation:

$$W = \frac{1}{\alpha}\ln(\sum_{g\in G}[\sum_{h\in g}[\sum_{j\in h}\exp(\frac{\delta_j}{1-\sigma_1})]^{\frac{1-\sigma_1}{1-\sigma_2}}]^{1-\sigma_2}) + C$$

where C is the constant of integration and can be ignored because only the change in consumer welfare ($W_{simul} - W_{actual}$) is of interest.

### 5.2.3 Simulations

The objective is to use an alternative tax regime based on each car's CO2 emission levels in order to compute simulated shares, prices, public revenues, firm profits, CO2 emissions and outside good share. Then it is possible to compare simulated variables with the actual ones. To do this exercise, I first need to compute the simulated prices and shares.

Assume that a "feebate" tax can be introduced, in which consumers receive a rebate when purchasing low-CO2 cars or incur an additional fee when purchasing a high-CO2 car. Then, a tax $A_j$ enters linearly in the FOC (eq.(5.3)), where $A_j$ is positive for high-CO2 car and negative for low-CO2 cars. This tax will affect the prices faced by consumers which in turn will affect consumer choice. Consequently, the market shares of a given car model will change. The change in prices depends on each firm's decision to change its markups or not. If a firm decides not to change its markups, the new tax will pass through by 100% on the final prices, or else, the pass-through will be different for each car model. In this chapter I examine only the case that the new tax will pass through by 100% on the final prices. This is not an unreasonable assumption since the derivative of price with respect to marginal cost to be near 1 [2].

[2] With the assumption that all the firms produce one product it is easy for someone to show that for the case of simple logit this derivative is $1 - S_j$ whereas for the case of simple logit that firms produce more than one product the derivative is $1 - \frac{S_j(1-S_j)}{S_j(1-S_j)+(1-\sum S_j)^2}$. Something similar can be proved using the implicit function theorem and nested logit. For the case of Greece, it has been shown

Suppose that firms do not change their markups. Then the simulated prices are simply the actual prices plus $A_j$, and the shares can be computed analytically by using these simulated prices and the following formula (Verboven (1996)):

$$S_j = \frac{\exp(\frac{\delta_j}{1-\sigma_1})}{\sum_{j\in h}\exp(\frac{\delta_j}{1-\sigma_1})} \frac{[\sum_{j\in h}\exp(\frac{\delta_j}{1-\sigma_1})]^{\frac{1-\sigma_1}{1-\sigma_2}}}{\sum_{h\in g}[\sum_{j\in h}\exp(\frac{\delta_j}{1-\sigma_1})]^{\frac{1-\sigma_1}{1-\sigma_2}}} \frac{[\sum_{h\in g}[\sum_{j\in h}\exp(\frac{\delta_j}{1-\sigma_1})]^{\frac{1-\sigma_1}{1-\sigma_2}}]^{1-\sigma_2}}{\sum_{g\in G}[\sum_{h\in g}[\sum_{j\in h}\exp(\frac{\delta_j}{1-\sigma_1})]^{\frac{1-\sigma_1}{1-\sigma_2}}]^{1-\sigma_2}} \tag{5.5}$$

where $\delta_j = x_j\beta - \alpha P_j + \xi_j$.

## 5.3 Data

Data regarding Germany were obtained from a private vendor, JATO Dynamics. The initial sample included 157,047 observations for the years 2002-2008. The dataset contains information about sales, prices and characteristics. The database provided records of two car models with the same engine size, fuel and transmission type but with a difference in a minor characteristic (e.g. the availability or not of climate control) as different observations. I merged such models in one, by summing up their sales and calculating a sales-weighted average price. Then I removed from the dataset a few outliers such as models with a sales volume less than 50, models with a sales price of over 100,000 Euros and models with engine capacity more than 5 liters; these can be considered to belong to a very special market, oriented only to very high income consumers. This process of model aggregation and removal led to a sample of 5,980 observations in total. Some basic variables are described in Table 5.1.

Table 5.1: Descriptive statistics of the German dataset (obs: 5980)

| Stats | Eng. Size | CO2 emis. | HP | Torque | Sales | Prices ('000,2005 euros) |
|---|---|---|---|---|---|---|
| Min | 0.6 | 81 | 41 | 69 | 51 | 6.968 |
| 5% | 1.2 | 127 | 68 | 110 | 83 | 12.198 |
| 25% | 1.6 | 160 | 103 | 160 | 321 | 18.012 |
| 50% | 2.0 | 189 | 136 | 226 | 1030 | 24.994 |
| 75% | 2.4 | 230 | 177 | 310 | 3381 | 34.794 |
| 95% | 4.0 | 293 | 286 | 450 | 16753 | 65.493 |
| Max | 5.0 | 442 | 524 | 870 | 115451 | 100.924 |
| Mean | 2.144 | 198 | 150 | 244 | 3668 | 29.152 |
| Std dev. | 0.810 | 53 | 68 | 109 | 7617 | 16.031 |

Source: Data provided by "JATO Dynamics".

Table 5.2 shows average prices, sales, engine capacity and CO2 emissions by vehicle class. The 'small' class contains automobiles with engine capacity less than 1.4 liters,

empirically that pass through were near 1.

the 'medium' class contains cars with engine capacity from 1.4 to 1.8 liters and the rest are considered as large automobiles. As expected, larger cars have higher CO2 emissions on average. In general, diesel cars are more expensive than similarly sized gasoline cars, and have lower CO2 emissions compared to their gasoline counterparts due to the higher fuel economy of diesel engines. This automobile classification (two fuel types and three engine size classes for each fuel type) is the one I use in the demand estimation below.

Table 5.2: Descriptive statistics of the German dataset by vehicle class

| Class | observ. | Eng. Size | CO2 emis. | Sales | Prices |
|---|---|---|---|---|---|
| Small-gasoline | 868 | 1.275 | 152.34 | 6348 | 13.901 |
| Medium-gasoline | 1684 | 1.812 | 193.83 | 3502 | 23.068 |
| Large-gasoline | 1393 | 3.136 | 263.11 | 946 | 45.404 |
| Small-diesel | 314 | 1.326 | 123.81 | 2033 | 15.830 |
| Medium-diesel | 960 | 1.884 | 159.47 | 6130 | 24.255 |
| Large-diesel | 761 | 2.718 | 220.86 | 3529 | 41.937 |

Source: Data provided by "JATO Dynamics".

One of the most interesting features of these data is the variability of CO2 emissions of relatively similar cars. If one observes the CO2 performance of vehicles within the same segment, it becomes evident that, other observed vehicle attributes being equal, CO2 emissions vary by up to a factor of two. This indicates that appropriate incentives, e.g. through vehicle taxation, can encourage consumers to buy low-CO2 cars even without changing radically their preferences. In the United Kingdom it has been assessed that choosing the lowest CO2 emitters in any car market segment can make a difference of about 25% to fuel efficiency and CO2 emissions (King (2007)).

## 5.4 Estimation

Table 5.3 presents the estimation results for the case in which groups are defined according to car size and subgroups according to fuel type. The choice of instruments in this model specification was guided by the appropriate tests for instrument relevance and overidentification. The Anderson canonical correlation LM statistic - a test of the null hypothesis that the model is under-identified - was rejected. The Sargan statistic - a test of the null hypothesis that the instruments are valid - cannot be rejected. In addition, I need to mention that I estimated demand only and not demand and supply jointly. Therefore, the marginal cost is obtained by equation (5.3) given that the markups are obtained using the demand estimates.

Engine capacity, horsepower, torque and frame are important car attributes for the demand side. Controlling for all other variables, CO2 emissions turned out to be statistically insignificant, implying that consumers do not seem to take a car's CO2

Table 5.3: Demand and Supply estimates

| Variables | Demand side parameters | Cost side parameters |
|---|---|---|
| Price('000,2005) | -0.195** | |
| | (0.025 ) | |
| $\ln(S_{j/h})$ | 0.508** | |
| | (0.081) | |
| $\ln(S_{h/g})$ | 0.713** | |
| | (0.098) | |
| Engine capacity | 0.510** | 3.135** |
| | (0.106) | (0.250) |
| CO2 Emissions | -0.00066 | 0.021** |
| | (0.0015) | (0.0026) |
| Horsepower | 0.015** | 0.069** |
| | (0.0023) | (0.0025) |
| Torque | 0.0078** | 0.030** |
| | (0.00088) | (0.0012) |
| Frame | 0.295** | 1.079** |
| | (0.047) | (0.091) |
| Manual gearbox | -0.398** | -2.878** |
| | (0.088) | (0.194) |
| Constant | -8.004** | -11.35** |
| | (0.293) | (0.660) |
| F-test | 106.77** | 1956.62** |
| Underidentification test | 56.52, p-val:0.000 | |
| Overidentification test | 1.96, Chi-sq(2) p-val:0.376 | |

Significance levels: † : 10%, ∗ : 5%, ∗∗ : 1%. Standard errors are reported in parentheses. Time dummies are included but not reported for brevity. Country dummies are reported in a special table in the appendix.

emissions explicitly into consideration when deciding to purchase a car. The median own price elasticity is 9.89 (5.44 for small gasoline cars, 8.94 for medium gasoline cars, 16.02 for large gasoline cars, 6.24 for small diesel cars, 9.60 for medium diesel cars and 15.16 for large-diesel cars). These elasticities are similar to those reported in earlier work (e.g. Verboven (1996)). On the cost side, results are as expected: most car characteristics are statistically significant and positive. However, the coefficient of CO2 emissions was expected to be negative because higher CO2 emissions capture an older technology which is expected to be cheaper. By using the reverse nesting structure this coefficient is negative and statistically significant. As $\sigma_1 \leq \sigma_2$, the nested logit with two nests is not consistent with random-utility maximization. Consequently, a nested logit model with the reverse nesting structure should be applied for estimation purposes.

Table 5.4 presents the estimation results for the case in which groups are defined according to fuel type and subgroups according to car size. The choice of instruments was guided by the appropriate tests for instrument relevance and overidentification. The Anderson canonical correlation LM statistic was rejected. The Sargan statistic cannot be rejected. As $\sigma_2 \leq \sigma_1$, the nested logit with two nests is consistent with random-utility maximization. Engine capacity, horsepower and frame are important car attributes for the demand side. Luxury and sport automobiles are highly considered compared to regular cars. SUV and MPV are also considered compared to regular cars but not as highly as luxury and sport cars. Automatic gearbox cars and cars with climate control are preferred. The signs on country dummies are also what might be expected: German cars are highly regarded while Chinese cars are not. CO2 emissions turned out to be statistically insignificant, implying that consumers do not seem to take a car's CO2 emissions explicitly into consideration when deciding to purchase a car. The median own price elasticity is 18. On the cost side, results are as expected: all car characteristics are statistically significant with the expected signs, with the exception of some country dummies. The coefficient of CO2 emissions is negative and statistically significant. Chinese cars are cheaper to produce and German cars are the most expensive production cars.

Public revenues for year 2008, due to Value Added Tax receipts from all automobile sales, are found to be 11,383 million Euros (at 2005 prices) or 3,890 Euros per car. Average CO2 emissions are 164 grams per kilometer per car. Retailer profits are found to be 4,391 million Euros and welfare (without C) is 2,994 million Euros.

## 5.5 Policy simulations

Using the estimated model parameters, I can simulate the implementation of a feebate in the German car market and assess the effects on automobile sales, prices, public revenues, firm profits, consumer welfare and sales-weighted CO2 emissions. All the

Table 5.4: Demand and Supply estimates with the reverse nesting structure

| Variables | Demand side parameters | Cost side parameters |
|---|---|---|
| Price('000,2005) | -0.074** | |
| | (0.0049) | |
| $\ln(S_{j/h})$ | 0.899** | |
| | (0.040) | |
| $\ln(S_{h/g})$ | 0.716** | |
| | (0.032) | |
| Engine capacity | 0.280** | 5.984** |
| | (0.036) | (0.220) |
| CO2 Emissions | 0.00025 | -0.012** |
| | (0.00068) | (0.0026) |
| Horsepower | 0.0067** | 0.071** |
| | (0.00047) | (0.0026) |
| Frame | 0.145** | 1.717** |
| | (0.0147) | (0.0954) |
| Manual gearbox | -0.123** | -2.114** |
| | (0.022) | (0.197) |
| Climate Control | 0.086** | 1.062** |
| | (0.018) | (0.157) |
| Luxury | 0.445** | 5.657** |
| | (0.043) | (0.245) |
| SUV | 0.245** | 3.572** |
| | (0.035) | (0.239) |
| Sport | 0.450** | 5.938** |
| | (0.047) | (0.246) |
| MPV | 0.043* | 0.961** |
| | (0.018) | (0.166) |
| Constant | -4.721** | -11.115** |
| | (0.182) | (0.699) |
| F-test | 754.18** | 1771.55** |
| Underidentification test | 64.00, p-val:0.000 | |
| Overidentification test | 5.79, Chi-sq(3) p-val:0.122 | |

Significance levels: † : 10%, ∗ : 5%, ∗∗ : 1%. Standard errors are reported in parentheses. Time dummies are included but not reported for brevity. Country dummies are reported in a special table in the appendix.

results presented in this section show the effect of taxation on the most recent car models of the dataset, i.e. those available in year 2008. This provides a better indication about the eventual changes in car sales in the near future (e.g. in years 2010 or 2011), which is the reason why these policy simulations are carried out in the first place.

More specifically, I assume that a "feebate" $A_j$ is introduced. The Value Added Tax applied in Germany remains the same as before. A linear tax is introduced in such a way that it is positive for cars with CO2 emissions over a given emission level (the so called pivot point) and negative for cars with emissions lower than this threshold:

$$A_j = \alpha(CO2 - PP)$$

where CO2 is the CO2 emissions level of model j and PP is the pivot point. Both CO2 and PP are expressed in grams of CO2 per kilometer (g/km), $\alpha$ in Euros per g/km and $A_j$ in Euros per car of model j.

I have carried out multiple simulations using different values of $\alpha$ and PP so as to simulate feebates of varying stringency, keeping in mind that public revenues should not decrease to an unrealistically low level due to very generous rebates offered to low-carbon cars.

Figures 5.1 illustrates the trade-off between environmental effectiveness and three economic variables - public revenues, firm markups and consumer welfare respectively. They display the results of simulations carried out with three different pivot points (160, 140 and 120 g/km) and four different feebate levels ($\alpha$ taking values of 15, 30, 45 and 60).

The higher the value of $\alpha$ the more stringent the system for high-carbon cars and the more generous to low-carbon ones. Therefore, with higher values of $\alpha$ it is possible to attain higher reductions of new car CO2 emissions through strong shifts in sales from high-carbon to low-carbon cars. On the other hand, such a system substantially increases the price of most large and medium-sized cars, thereby reducing automobile sales in general and leading to a drop in both firm markups (since fewer cars are sold) and consumer welfare (since some consumers avoid purchasing a new car at these prices). Public revenues also tend to decrease with increasing stringency of the feebate as more rebates have to be paid to buyers of low-carbon cars whose sales increase greatly.

If the pivot point is set at relatively high levels (e.g. 160 g/km) then the system is more lenient towards high-carbon cars (their prices do not rise very much), and at the same time it is more generous in rebates to low-carbon vehicles (as their emissions are much lower than the pivot point). This combination keeps firm markups and consumer welfare unchanged or even slightly higher than the "no feebate" case, but leads to a significant decline in public revenues: high-carbon cars do not pay a high fee while low-carbon cars receive substantial amounts in rebates and therefore increase their sales. The environmental effectiveness of such a system is limited due to the effects mentioned above. Using lower pivot points may keep public revenues under control - and may even slightly increase them in the case of a low pivot point such as 120 g/km - at the detriment of firms' and consumers' surplus, which drop because of a decline in car sales. These simulations illustrate that it is possible to design a feebate system (for example something close to 140 g/km) that can be reasonably effective in terms of reducing CO2 emissions of new cars without being particularly detrimental to other economic variables.

It is important to keep in mind the correspondence between such a "feebate" system and an equivalent carbon tax. Assuming that a car travels 200,000 kilometers throughout its lifetime, $\alpha = 15$ corresponds to a tax of 75 Euros per tonne of CO2, while a feebate with $\alpha = 60$ corresponds to a tax of 300 Euros per tonne of CO2. Although such values are higher than the usual value used to assess marginal CO2 damage costs (approximately 20-30 Euros per tonne CO2), it is still quite lower than the implied marginal carbon tax rates of some CO2-based vehicle tax systems currently implemented in European countries (Braathen (2011)).

Next, I present some figures that show in more detail the effects of different feebates by fuel, engine size and CO2 emissions class, focusing on the case in which the pivot point is 140 g/km. Remember that, as shown in Figure 5.1, this can lead to significant environmental gains without strongly compromising other economic variables.

Figure 5.2 shows the change in automobile prices caused on different fuel and engine size classes from the implementation of a lenient feebate ($\alpha = 15$) and a stringent feebate ($\alpha = 60$) respectively. In the lenient feebate case, prices change to a limited extent, from -3% for low-carbon diesel cars up to 4% for high-carbon gasoline cars. Note that these values are sales-weighted averages across specific emissions classes, which means that individual models may experience higher or lower price changes depending on each model's CO2 emission levels. In the stringent feebate case, the corresponding average price changes range from -10% to 15%. Overall, the feebate is more favorable to small cars and medium diesel cars as will be shown in Figure 5.5 below.

Changes in total automobile sales - compared to actual sales in Germany in year 2008 - are displayed in Figure 5.3 for the two 'extreme' feebate cases mentioned above. In each subgroup that belongs to a specific class, cars which belong to the lower CO2 emission class gain significantly in sales. Also, in each subgroup that belongs to a specific class, cars belonging to the second lower CO2 emission class may gain in sales. However, in the stringent feebate case, cars that belong to the second lower CO2 emission class that gain in sales in the lenient feebate case, may have a decrease in sales (e.g. small gasoline cars). Total sales of new cars (not shown on the graph), which amounted to 2.926 million cars in year 2008, decrease by about 2% in the lenient feebate case (2.863 millions) and by about 7% in the stringent feebate case (2.763 millions). This is the primary reason for reduced firm markups and consumer welfare as demonstrated in Figure 5.1.

In order to provide more insight into shifts in the automobile market induced by the feebate system, Figure 5.4 illustrates the simulated sales shares by emissions class, according to the four different feebate levels described above, and compares them with the actual sales shares observed in the German market in year 2008. Obviously, the more stringent the feebate the higher the fraction of low- and medium-CO2 cars sold in the market. From 53% of actual total sales, automobiles with emission levels up to 160 g/km dominate the market in the strong feebate case, reaching 75.3% of total sales. Higher emitting vehicles are faced with a drop in their sales; in the strong feebate case, the share of cars emitting over 200 g/km drops to one-sixth, from 9.9% to 1.7%; and the share of cars emitting between 160 and 180 g/km falls by 60%, from 12.5% to 5%.

The feebate leads to a shift towards sales of lower-carbon cars, and smaller size cars. As Figure 5.5 demonstrates, the sales fraction of cars with engine size less than 1.4 liters rises by 32%, from 31.7% (actual sales in 2008) to 41.8% (simulated sales with a strong feebate). Although the share of medium-sized cars drops from 53.3% to 49.8%, the corresponding fraction of medium-sized diesel cars rises considerably. The share of large cars diminishes by 44%, from 15% to 8.4%, but large gasoline cars share fall by 63%. Also, small gasoline cars share increase by 28% which is lower than the total increase of small cars. This reflects the fact that average emission levels are lower for diesel than for gasoline cars. These effects should be attributed to a shift from larger to smaller cars of the same fuel (from large to medium and small diesel cars and from large and medium to small gasoline cars).

## 5.6 Comparison of the funding: Greece VS Germany

According to the funding of chapters 4 and 5 comparisons on automobiles markets between Greece and Germany can been drawn. The main difference between the two markets is the fact that Greece diesel cars is not allowed in the two big cities of Athens and Thessaloniki in order for Greece government to provide a protection of the Greek ancient monuments, in contrast to Germany where diesel cars are not prohibited. Thus, to evaluate fuel classification I use the model of nested logit with two nests for Germany and for Greece a nested logit with one nest is used. The findings for Greece are based on two simulations, the feebate-rebate and the partial abolition of existing automobile taxes (and introduction of a CO2-based tax) to assess the effects on automobiles: sales, prices, firm profits, CO2 emission, government revenues and consumer welfare. Consequently, a comparison for partial abolition between Greece and Germany is not available as in Germany regulation taxes do not exist. The only comparison that can be drawn between the automobile markets of the two countries is concerned with feebate-rebate system. A simulation with a tax 31 euros per CO2 and a pivot point to 159,5 is introduced for Greece in contrast to Germany where multiple simulations were carried out for three different values of pivot point (high, medium, low) and four different tax values per C02 are introduced. According to the above, a comparison for the two countries" can be drawn only for high pivot point simulations. The related table for the case of Greece is the table 4.7 whereas for Germany it is presented in this section (table 5.5).

Table 5.5: Effect of a "feebate" on prices and sales volumes of cars by engine size and CO2 emissions class - percentage differences from the current taxation regime: The case of Germany, PP=160, $\alpha$=30

| CO2 emissions | Change in prices | | | Change in sales volume | | |
|---|---|---|---|---|---|---|
| class (g/km) | Small | Medium | Large | Small | Medium | Large |
| $\leq$ 130 | -10.8% | | | 100.0% | | |
| 130-160 | -1.9% | -0.4% | | 6.1% | 35.6% | |
| 160-180 | 2.7% | 1.6% | | -33.4% | -2.8% | |
| 180-200 | 4.5% | 2.9% | 2.7% | -62.2% | -35.9% | 28.3% |
| $\geq$ 200 | | 6.3% | 6.8% | | -61.5% | -47.6% |
| All | -2.3% | 2.2% | 6.4% | 14.9% | -11.2% | -40.3% |

Both tables present the effect of the "feebate" within engine size classes. It is evident from both markets that the CO2-based tax not only shifts sales towards smaller cars, but also provides an incentive for consumers, out of the models within their preferred vehicle class, to purchase those with lower CO2 emission levels. The shift is particularly pronounced in the cases of cars with very high and very low CO2 emissions. Although the change in prices for both markets is closed enough, this does not happen for the change in sales. Of course, this happens because the estimated own price elasticities for the German market is much higher compared to the Greek ones. For the case of Germany, according to figure 5.1, a simulation with a high pivot point leads to a neutral or slightly positive change in welfare and markups. With a relatively low tax of 30 euros per CO2, markups remain unchanged and welfare increase by 0.66%. In addition, a high pivot point decrease CO2 emissions but not effectively compare to lower pivot points. In contrast a high pivot point affects significantly public revenues which drop a lot. With the tax of 30 euros per CO2, public revenues decrease by 15.2%, whereas, CO2 emissions decrease by 6.1%. For the case of Greece the same picture is observed. Public revenues decrease by 5%, CO2 emissions decrease by 2%, Welfare increase by 0.4% and markups increase by 1.2%. In this market this simulation lead to low changes in welfare and firms markups and higher changes for CO2 emissions and public revenues. Indeed public revenues decrease with a relatively high percentage and this is consistent with the findings for the case of Germany. In overall, the changes for Greece are minor compare to the changes for Germany and this is due to the differences in price elasticities between the two markets. The change in markups for the case of Greece seems to be higher than expected but note that the Greek results were obtained after relaxing the assumption of 100% pass through. This change is slightly lower under the assumption of 100% pass through. I conclude that both markets are affected by the same way i described above and the results depends a lot on the price elasticities as expected.

## 5.7 Concluding remarks

The objective of this chapter is to evaluate policies that could shift consumer purchases towards low-CO2 cars and thus lead to the reduction of fuel use and CO2 emissions. Using a detailed dataset for the period 2002-2008, the chapter shows results for the car market of Germany by estimating a variation of nested logit model that includes two nests instead of one, thus allowing for more heterogeneity among consumers. My main simulation results come from a nested logit model that groups are defined according to fuel type and subgroups according to car size. The reverse nesting structure is not found consistent with random-utility maximization (McFadden (1978); Verboven (1996)).

For simulation purposes, a linear tax is introduced in such a way that it is positive for cars with CO2 emissions over a given emission level (the so called pivot point) and negative for cars with emissions lower than this threshold. If the pivot point is very high (approaching the average CO2 emissions per car), then it is much more difficult for the policy maker to reduce CO2 emissions even if the linear tax is very high. A high pivot point may increase firm markups and consumer welfare but leads to a significant decline in public revenues. On the other hand, a very low pivot point may increase public revenues and reduce CO2 emissions effectively at the expense of a huge decline in car total sales, leading to a high drop of markups and consumer welfare. It is essential for policy makers to choose wisely the pivot point and the linear tax in a way that they weigh precisely both costs and benefits.

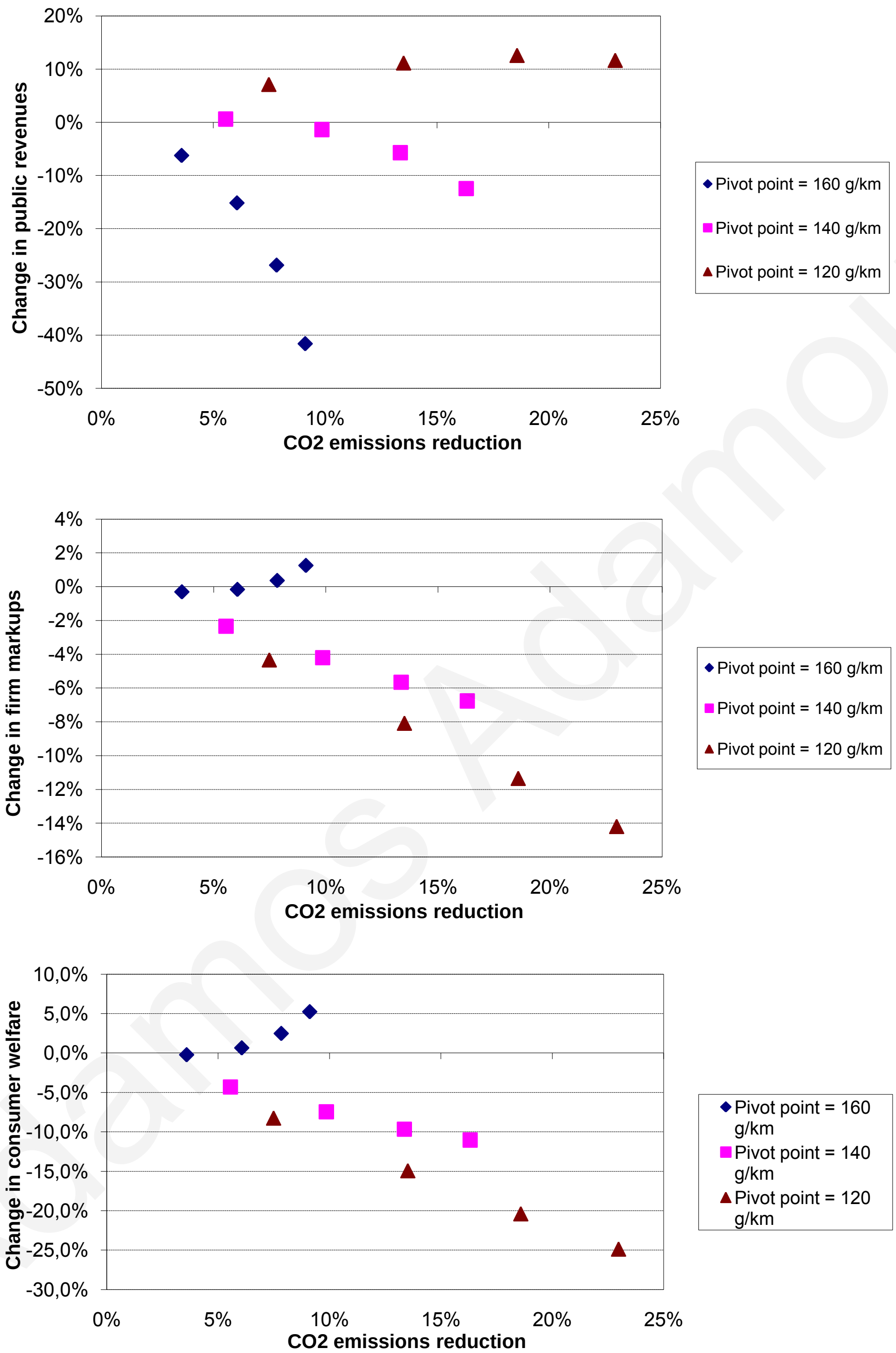
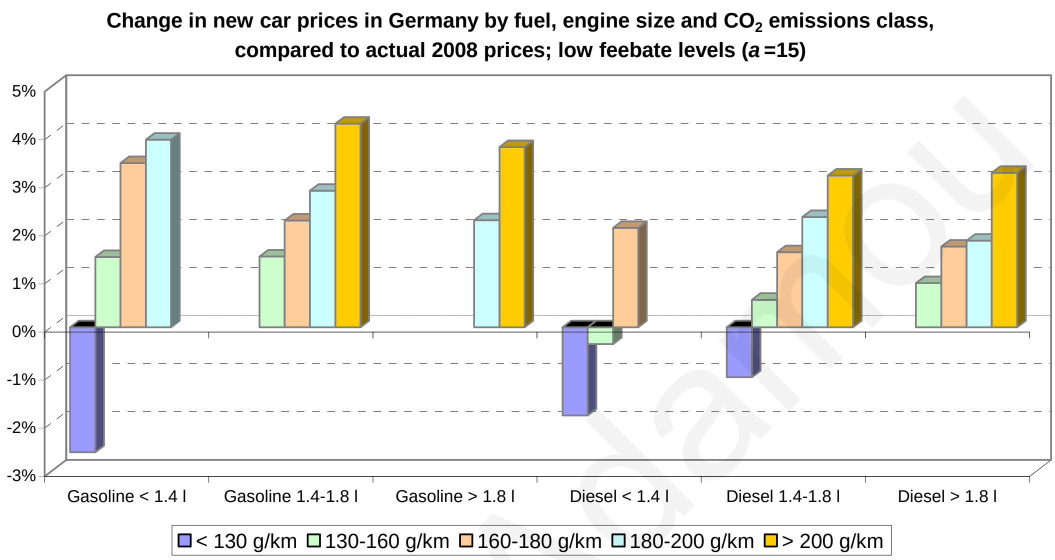



Figure 5.1: Effect a feebate on public revenues, firm markups and consumer welfare for different stringency levels and different pivot points. Changes are expressed in percentage terms compared to the values of the corresponding variables according to actual sales in the German car market in year 2008.



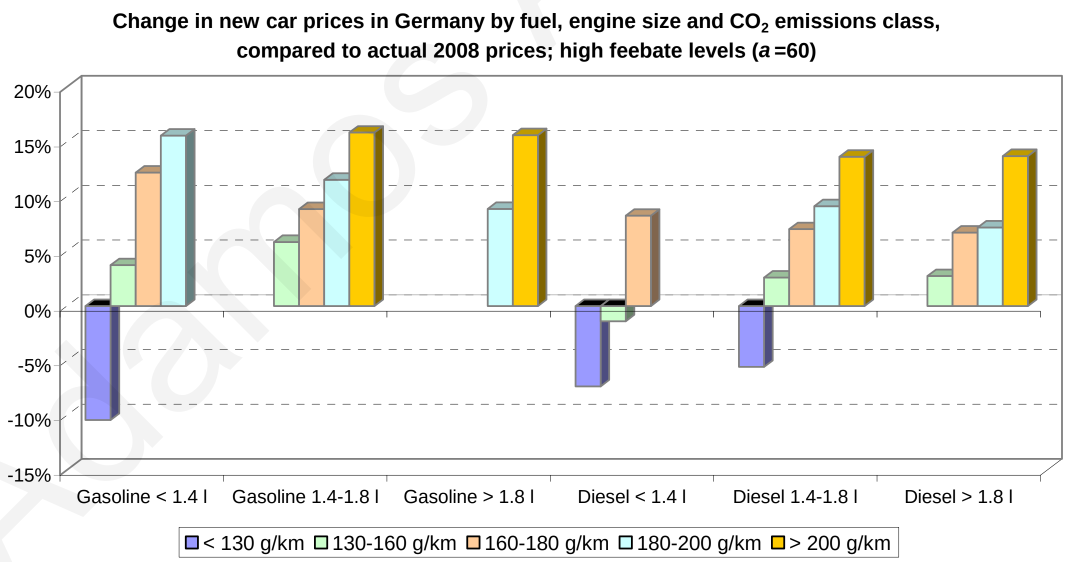




Figure 5.2: Simulated changes in prices in the German automobile market.

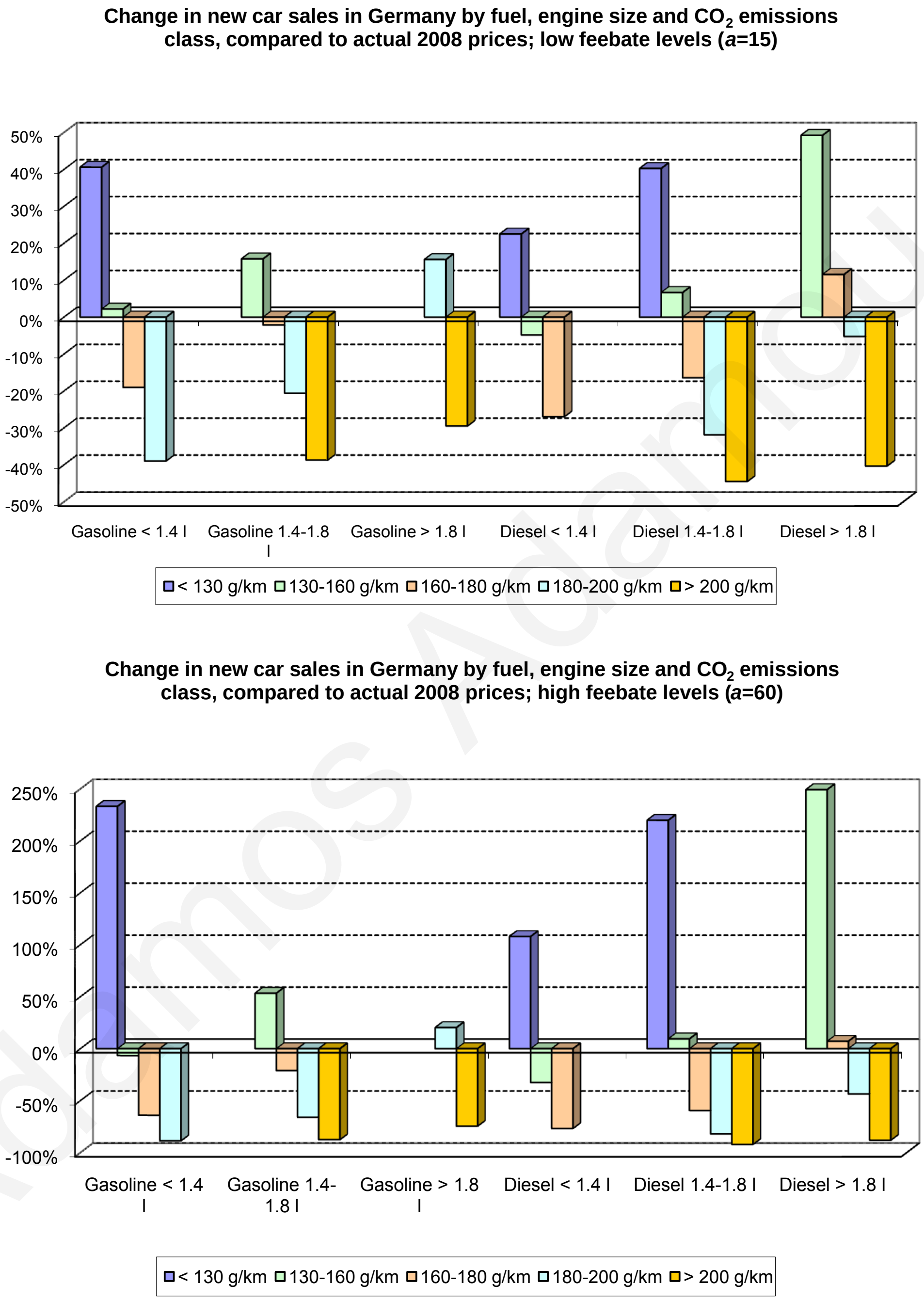



Figure 5.3: Simulated changes in sales volumes in the German automobile market.

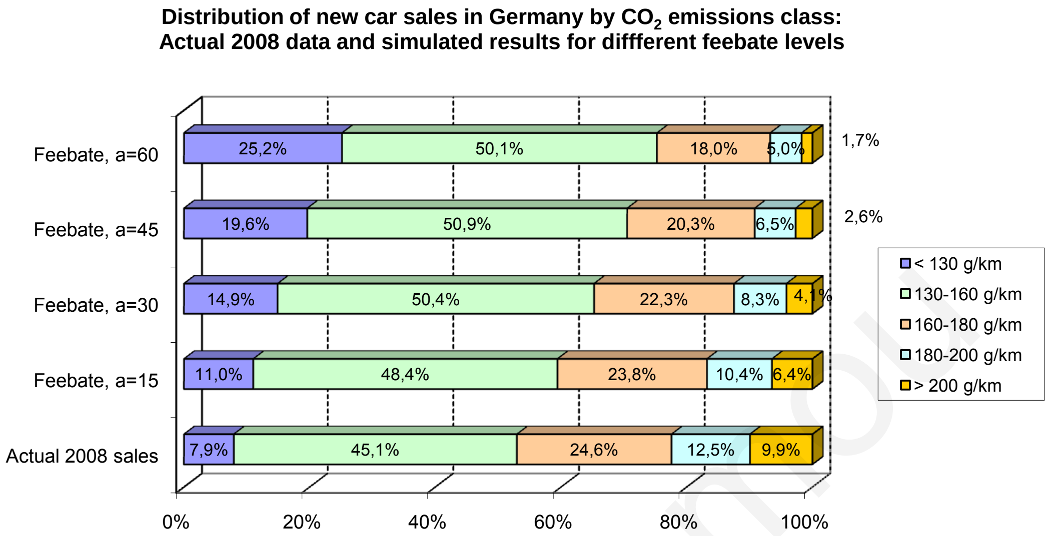



Figure 5.4: Actual and simulated sales shares in Germany by emissions category.

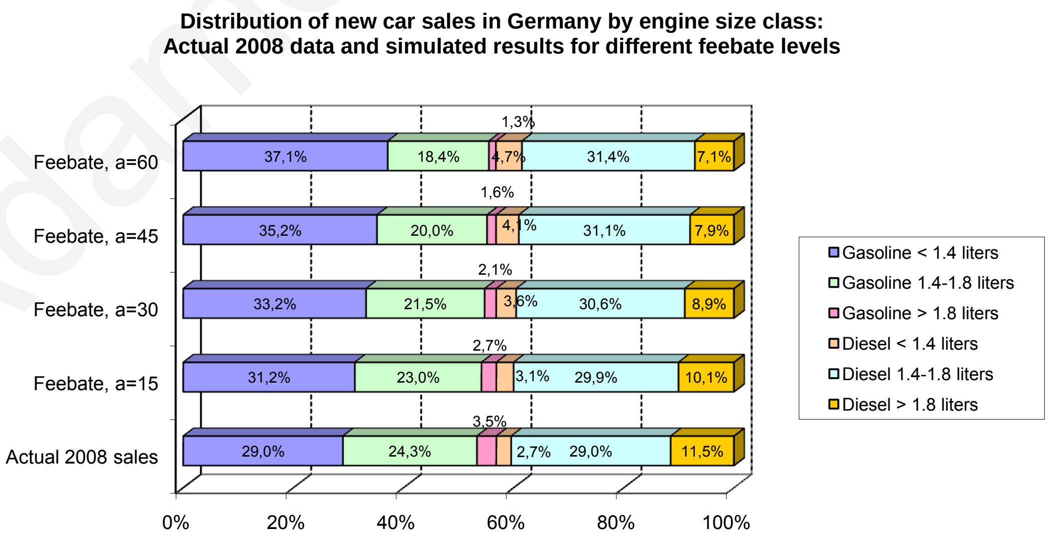



Figure 5.5: Actual and simulated sales shares in Germany by fuel and engine size.

# Chapter 6

# Conclusions

This dissertation focuses on an empirical analysis within the framework of an oligopoly market in which firms sell differentiated products. Automobiles markets are chosen for this investigation since they are well suited to the assumptions employed in the literature. My goal is to answer the following questions: 1) what is the impact of an introduction of used differentiated products on CPI in small economies which have no local industry and can only import these products 2) which model of the basic discrete-choice models of product differentiation can be used better for the estimation of firms markups and 3) what are the effects of alternative environmental taxation policies on the economy and the environment under the framework of oligopolistic markets with differentiated products. In chapter 2, I address the first question, in chapter 3 the second and in the remain two chapters the third.

In the second chapter, I exploit a unique natural experiment in order to investigate the impact of used imports on the price level in small economies. In 1993 Cyprus relaxed restrictions on the importation of used automobiles into the country. This led to a dramatic increase in imports of used cars; at their 1998 peak, used vehicles accounted for 72% of all car imports. This should have reduced the overall price level of automobiles for two reasons. First, increased competition from used cars must have caused a reduction of prices of new cars. Second, prices of used imports were lower than those of locally traded used vehicles. My objective is to test the validity of these theoretical predictions and to quantify the impact of used good imports on the price level.

The 1993 policy change increased the maximum allowable age of an imported vehicle from two years to five, making possible the importation of used cars from Japan into Cyprus. I use data on the prices of different automobile models to construct price indices for the 1989-2005 period. The hedonic indices I use, take into consideration the improvement of automobile quality, the introduction of new models in the car market, the withdrawal of older models from the market and the sales of different models. With price indices in hand I then proceed to investigate the impact of used imports on the price level. I find that increased competition from the import of used automobiles led to a significant reduction of automobile prices. This happens because of the reduction of prices of new cars due to competition (indirect effect) and because of the relatively lower prices of the used cars that enter the automobile market compared to the new cars prices (direct effect).

For the indirect effect, I construct price indices for new cars only. The indices show a significant increase in prices for period 89-96. The indices are significantly lower for the period 96-98. This captures the consumer hesitation as they were uncertain about the quality of the new product that enters the market. It seems that the uncertainty with regard to the quality of used imports had been disappeared three years after the policy change. To measure the indirect effect I compare the average annual growth rates (AAGR) in period 89-96 with the AAGR of period 96-98 because a good prediction for the AAGR for the period 96-98 is the AAGR of 89-96 if the policy change did not happen. For the direct effect, I construct price indices for new cars and indices for the whole market: new and used cars. I am doing that because i do not have as many observation for used cars as I have for new cars. The direct effect is measure as the difference of the indirect effect between the new car market and the whole car market. I found that the minimum decline in the prices of new cars reached the average annual growth rate of 1.1%. Regarding to the direct effect, I found a decline in the prices of the average annual growth rate of 0.15%. In economies with a relatively high share of this good in CPI basket (perhaps due to high taxation, as in Cyprus), a price reduction actually means a strong negative impact on CPI. The magnitude of the results of this chapter is significant. Many populous and relatively poor countries like India and Mexico are currently almost completely closed to used vehicle imports. If and when they open up, they are likely to start importing used vehicles in the millions from the United States or Japan and this will help them to reduce their inflation.

The aim of the third chapter is to empirically test which model of the basic discrete-choice models of product differentiation can be used better for the estimation of firms markups. I used an alternative way to calculate markups using a simple accounting model and then I compare those markups with the ones estimated using discrete-choice models. My alternative markups can be calculated due to the availability of some auxiliary information in the Cyprus automobile market. They are computed from simple algebraic relationships and are not the outcome of econometric estimation so they are completely independent of those obtained from discrete-choice models. I caution that my alternative markup estimates are not hard data. I need to make assumptions in order to compute them, therefore my estimates are not assumption-free even if they are model-free. The usefulness of this approach lies in the fact that these assumptions are very different from those made in the standard differentiated product model, hence the calculated markups can be used as a useful benchmark for comparison.

The idiosyncracy of my data stems from the tax system. Automobiles in Cyprus are heavily taxed with a variety of different instruments. The most important ones are a consumption tax that is a percentage of the vehicle's import price and a per unit tax. Some groups and individuals that meet certain criteria can be exempt from paying taxes on automobile purchases. For a period of several years I am able to observe two prices for each model: a price with taxes and a price without them. Thus for each model I have two expressions linking marginal cost and prices but I have three unknowns: marginal cost, the markup for taxed vehicles and the markup for tax-free vehicles. By making an assumption on the relationship between the two markups I can obtain the desired estimates.

I estimate discrete choice models using my entire dataset as well as with a subset of the data that covers a shorter period. The subset has the disadvantage of reducing my markups sample by about 43%, but it enriches the demand analysis since additional demand attributes can be included. When using the entire dataset, I found that the markups obtained from discrete choice models are generally higher than model-free markups but when using the subset the two sets of markups look reasonably similar. This means that the use of additional demand attributes is essential for the estimation of markups even with the cost of a reduced dataset. Markups from the nested model are similar to those from the random coefficient model in terms of levels but they fail to generate enough dispersion in markups across different types of cars. I conclude that even simple discrete choice models like the nested logit can do quite well in approximating the overall level of markups but richer models are needed in order to capture more subtle differences across choices.

The aim of chapters 4 and 5 is to evaluate potential public policy interventions that could lead to the reduction of CO2 emissions of motor vehicles. By estimating a discrete-choice model of product differentiation that allows for heterogeneity among consumers (I am using the nested logit in these chapters), I carried out numerous simulations for the automobile market of Greece and Germany and I assess changes in consumer welfare, public revenues, firm mark-ups and CO2 emissions according to different policy scenarios compared to the current vehicle taxation regime. The main difference in the two chapters is that I extended nested logit basic version in order to include two nests instead of one for the case of the German automobile markets. This is done because diesel cars are allowed in Germany but are not allowed in Greece and for the purpose of those two chapters an additional classification according to fuel type is quite reasonable.

Depending on vehicle tax systems in each of the two countries I carry out my simulations based on the existence or not of a registration tax in the current vehicle taxation regime. For Germany –which is a country without a registration tax– I implement a "feebate" system, in which consumers receive a rebate when purchasing low-CO2 cars or incur an additional fee when purchasing a high-CO2 car. The tax is positive for cars with CO2 emissions over a given emission level (the so called pivot point) and negative for cars with emissions lower than this threshold. For Greece, as there is a registration tax, beyond the "feebate" system, I also try an exercise which assumes that a part of the existing ad valorem tax on cars is abolished and replaced by a tax based on a car's CO2 emission levels. The latter exercise show that a partial abolition of existing automobile taxes and an introduction of a CO2-based tax may prove to be environmentally ineffective because the current taxation system may put a heavy tax burden on large cars irrespective of their emission levels, so a partial abolition of this system may have negative environmental repercussions, although it could be beneficial for public revenues.

For the case of Germany that I perform a lot of simulations, the pivot point is proved to be very essential for the decision of policy makers. If the pivot point is very high (approaching the current average CO2 emissions per car), then it is much more difficult for policy makers to reduce CO2 emissions even if the linear tax is very high. A high pivot point may increase firm markups and consumer welfare but leads to a significant decline in public revenues. On the other hand, a very low pivot point may increase public revenues and reduce CO2 emissions effectively at the cost of a huge decline in car total sales, leading to a high drop of markups and welfare. It is very important for policy makers to choose wisely the pivot point and the linear tax in a way that they weigh precisely both costs and benefits.

# Appendix A

# The Impact of Used Goods on CPI

## A.1 Hedonic Price Indices methods

### A.1.1 The time dummy variable index

$$\ln(P) = \alpha_0 + \sum_{j=1}^{k} \alpha_j X_j + \sum_{i=2}^{t} \beta_i D_i + \epsilon$$

Where P denotes prices of a product for all the periods, $\alpha_j$ measures the logarithms of "implicit price" for characteristic j, $X_j$ denotes the quantities of characteristic j. $D_i$ is the time dummy variable, and takes on value of 1 if the transaction occurs at the certain period i, and 0 otherwise. The coefficient $\beta_i$ measures the logarithm of price ratio between the current period and the base period.This equation is used for all the periods of the sample.

For example, the coefficient of $D_{1997}$ is the effect of the time change between 1989 (omitted year) and 1997. That coefficient estimates the natural logarithm of $\frac{P_{1997}}{P_{1989}}$ after taking into account the quality improvement of characteristics.

### A.1.2 The price-of-characteristics index

$$P_t = \gamma_{t0} + \sum_{j=1}^{k} \gamma_{tj} X_{tj} + \epsilon_t$$

$\gamma_{tj}$ represents the implicit price of characteristics j for period t. The intercept term $\gamma_{t0}$ can be interpreted as a group of characteristics not included in the regression or the price of the car's body. After someone takes the estimated coefficients, he can use the fitted values to find the two years price ratio. If he uses the mean of characteristics of the first year, then his index is a Laspeyres price index. If he uses the mean of characteristics of the following year, then his index is a Paasche price index. Their geometric mean is the fisher price index and it is calculated by taking the square root of the multiplication of Laspeyres and Paasche price indices.

$$I_{Laspeyres} = \frac{\gamma_{t0} + \sum_{j=1}^{k} \gamma_{tj} X_{(t-1)j}}{\gamma_{(t-1)0} + \sum_{j=1}^{k} \gamma_{(t-1)j} X_{(t-1)j}}$$

$$I_{Paasche} = \frac{\gamma_{t0} + \sum_{j=1}^{k} \gamma_{tj} X_{tj}}{\gamma_{(t-1)0} + \sum_{j=1}^{k} \gamma_{(t-1)j} X_{tj}}$$

$$I_{Fisher} = \sqrt{I_{Laspeyres} I_{Paasche}}$$

### A.1.3 The improving matched index

Suppose that a car model named f which was sold in year 1 is upgraded in year 2 and now is called g.

Way No1:

$$P = \gamma_0 + \sum_{j=1}^{k} \gamma_j X_j + \epsilon$$

for year 1 and all car models (including model f). Estimated $\gamma_j$ represent the "implicit characteristic prices" for year 1. I use $\gamma_j$ to estimate the price of model g in the period prior to its upgrading by valuing its characteristics. This can be done as follows:

$$estP_g = \gamma_0 + \sum_{j=1}^{k} \gamma_j (X_j)_g$$

Where $(X_j)_g$ are the characteristic quantities of model g. Match index $I_match$ can be estimated as actual price of g in year 2 divided by estimated price of g in year 1. That"s it, $I_match = \frac{P_g}{estP_g}$.

Way No2:

$$\ln(P) = \gamma_0 + \sum_{j=1}^{k} \gamma_j X_j + \epsilon$$

for all years and all car models. The hedonic coefficients $\gamma_j$ can be used for estimation of a hedonic quality adjustment term, $Q_{adj}$, as follows:

$$Q_{adj} = \exp(\gamma_0 + \sum_{j=1}^{k} \gamma_j / frac(X_j)_g (X_j)_f)$$

The estimated price for model g in the period 1 is $estP_g = Q_{adj} P_f$ and it"s again the estimated price of model g in the period prior to its upgrading ( e.g. year 1 for our example). So the match index can be computed with the same way as before ($I_match = \frac{P_g}{estP_g}$).

## A.2 MacKinnon, White and Davidson test

This test is useful for choosing between linear (l) and log-linear (logl) functional forms.

$$P = f(X, \gamma) + \epsilon$$

Where f is the hedonic functional form, X denotes the characteristics and $\gamma$ their coefficients.

The test"s six steps:

Step 1: Estimate the linear model and obtain the estimated P fitted values, $\widehat{P}_l$.

Step 2: Estimate the log-linear model and obtain the estimated $\ln(\widehat{P_{logl}})$ fitted values.

Step 3: Obtain $Z_1$ as $\ln(\widehat{P}_l) - \ln(\widehat{P_{logl}})$.

Step 4: Regress P on X's and $Z_1$. Reject $H_0$ if the coefficient of $Z_1$ is statistically significant.

Step 5: Obtain $Z_2$= $\exp(\ln(\widehat{P_{logl}})) - \widehat{P}_l$.

Step 6: Regress $\ln(P)$ on the logs of X's and $Z_2$. Reject $H_1$ if the coefficient of $Z_2$ is statistically significant.

This procedure must be repeated for the other two combinations of the three dominant functional forms. However, there is a possibility of rejecting all three functional forms (as in case of the box-cox test).

## A.3 Unweighted indices results

After 2002, all indices show a significant decline and between 1996 and 1998 a constant or a decline path is noticed. These can be shown better in table A.1. Only the "two period dummy variable index" shows a slight rise between 1996 and 1998 (excluding the mean index). This rise is due to the fact that I ignore the sales weighting. In table A.2, growth rates and sub-periods average annual growth rates are presented. For the "two period dummy variable index" there is an increase of 1.65 % for 1997 and a decline of 1.29 % for 1998. However, as the index goes up from 1.18 to 1.184 between 1996 and 1998 there is a positive average annual growth rate (AAGR) of 0.17 %. This is the indirect effect of the introduction of used Japanese vehicles in Cypriot market. The competition forced the new car"s prices to go down. Instead of an AAGR of 2.39% that is noticed between 1989 and 1996, there is an AAGR of 0.17% between 1996 and 1998. After 2002 a higher (lower in absolute values) AAGR of -8.54 % for the match index is recorded.

However, the Fisher and two period dummy variable indices provide better results for reasons that I explained in a previous section. Consequently, the car market openness led to an AAGR of -0.67 to 0.17 % (comparatively with 2.39 to 2,63% during 89-96) for the 1993 policy change and about 11 to 17 % decline for the taxation policy

Table A.1: The unweighted Indices for new automobile market: The Indices

| Year | Laspeyres | Paasche | Fisher | Twoperiod | Pooled | Match | Mean |
|---|---|---|---|---|---|---|---|
| 1989 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| 1990 | 0.993 | 0.997 | 0.995 | 0.955 | 1.022 | 1.011 | 1.012 |
| 1991 | 1.020 | 0.985 | 1.002 | 0.985 | 1.033 | 1.025 | 1.046 |
| 1992 | 1.080 | 1.022 | 1.050 | 0.997 | 1.045 | 1.051 | 1.073 |
| 1993 | 1.129 | 1.066 | 1.097 | 1.030 | 1.106 | 1.087 | 1.101 |
| 1994 | 1.169 | 1.099 | 1.133 | 1.081 | 1.166 | 1.134 | 1.213 |
| 1995 | 1.221 | 1.147 | 1.183 | 1.138 | 1.214 | 1.162 | 1.197 |
| 1996 | 1.236 | 1.164 | 1.199 | 1.180 | 1.238 | 1.210 | 1.267 |
| 1997 | 1.250 | 1.158 | 1.203 | 1.199 | 1.242 | 1.185 | 1.289 |
| 1998 | 1.225 | 1.143 | 1.183 | 1.184 | 1.224 | 1.181 | 1.303 |
| 1999 | 1.188 | 1.111 | 1.149 | 1.265 | 1.226 | 1.193 | 1.311 |
| 2000 | 1.174 | 1.020 | 1.094 | 1.210 | 1.272 | 1.199 | 1.302 |
| 2001 | 1.191 | 1.036 | 1.111 | 1.213 | 1.285 | 1.214 | 1.375 |
| 2002 | 1.237 | 1.095 | 1.164 | 1.389 | 1.389 | 1.214 | 1.463 |
| 2003 | 1.089 | 0.969 | 1.027 | 0.976 | 1.206 | 1.117 | 1.399 |
| 2004 | 0.877 | 0.778 | 0.826 | 0.854 | 1.058 | 0.936 | 1.124 |
| 2005 | 0.862 | 0.764 | 0.811 | 0.780 | 1.031 | 0.929 | 1.110 |

Table A.2: The unweighted Indices for new automobile market: Percentages change from previews years (gr) and averages annual growth rates (aagr)

| Rates-Year | Laspeyres | Paasche | Fisher | Twoperiod | Pooled | Match | Mean |
|---|---|---|---|---|---|---|---|
| gr1990 | -0.73 | -0.31 | -0.52 | -4.53 | 2.17 | 1.07 | 1.23 |
| gr1991 | 2.74 | -1.16 | 0.77 | 3.20 | 1.13 | 1.40 | 3.30 |
| gr1992 | 5.87 | 3.71 | 4.78 | 1.22 | 1.13 | 2.59 | 2.62 |
| gr1993 | 4.54 | 4.28 | 4.41 | 3.27 | 5.82 | 3.43 | 2.57 |
| gr1994 | 3.55 | 3.14 | 3.34 | 5.00 | 5.46 | 4.25 | 10.20 |
| gr1995 | 4.46 | 4.32 | 4.39 | 5.25 | 4.15 | 2.50 | -1.28 |
| gr1996 | 1.22 | 1.54 | 1.38 | 3.64 | 1.93 | 4.09 | 5.82 |
| gr1997 | 1.13 | -0.58 | 0.27 | 1.65 | 0.35 | -2.00 | 1.77 |
| gr1998 | -1.96 | -1.26 | -1.61 | -1.29 | -1.46 | -0.39 | 1.09 |
| gr1999 | -3.04 | -2.80 | -2.92 | 6.88 | 0.13 | 1.02 | 0.63 |
| gr2000 | -1.20 | -8.15 | -4.74 | -4.38 | 3.81 | 0.49 | -0.73 |
| gr2001 | 1.49 | 1.54 | 1.52 | 0.31 | 0.96 | 1.31 | 5.60 |
| gr2002 | 3.81 | 5.67 | 4.73 | 14.44 | 8.10 | 0.00 | 6.44 |
| gr2003 | -11.90 | -11.50 | -11.70 | -29.70 | -13.10 | -7.99 | -4.38 |
| gr2004 | -19.50 | -19.60 | -19.60 | -12.6 | -12.30 | -16.20 | -19.60 |
| gr2005 | -1.73 | -1.83 | -1.78 | -8.61 | -2.51 | -0.71 | -1.25 |
| aagr89-96 | 3.07 | 2.20 | 2.63 | 2.39 | 3.09 | 2.75 | 3.44 |
| aagr96-98 | -0.43 | -0.92 | -0.67 | 0.17 | -0.56 | -1.20 | 1.43 |
| aagr98-05 | -11.30 | -11.30 | -11.30 | -17.50 | -9.45 | -8.54 | -8.80 |

Notes: grY stands for the growth rate of year Y-1 and Y. aagrKR stands for the average annual growth rate for periods K and R.

Table A.3: Unweighted Direct Used Cars effect

| Year | Laspeyres | Paasche | Fisher | Twoperiod | Pooled | Match | Mean |
|---|---|---|---|---|---|---|---|
| 1997 | -4.6 | -4.0 | -4.3 | -0.3 | -5.3 | 0.0 | -17.3 |
| 1998 | -7.7 | -7.9 | -7.8 | 0.9 | -4.7 | -0.2 | -24.4 |
| 1999 | -8.4 | -11.2 | -9.8 | -0.1 | -2.4 | 0.7 | -18.4 |
| 2000 | -3.7 | -21.7 | -13.1 | -1.1 | -0.1 | 3.8 | -18.5 |
| 2001 | -5.2 | -22.0 | -14.0 | 1.5 | -0.6 | 3.4 | -17.7 |
| 2002 | 1.1 | -16.3 | -8.0 | -1.7 | -1.9 | 7.8 | -16.1 |
| 2004 | 4.5 | -14.9 | -5.7 | -1.3 | 3.7 | 7.8 | -12.9 |
| 2005 | 6.8 | -13.4 | -3.8 | 3.0 | 2.8 | 8.3 | -12.6 |

Source: own calculations; number represents the direct effect as a percentage of the new automobile indices values.

change. These results are based on the assumption that all vehicles models have the same sales.

# Appendix B

# Markup Estimates from Discrete Choice Models

## B.1 Description of DCMs

### B.1.1 The simple logit

The utility of consumer $i$ from buying product $j$ in year/market $t$ is given by the following equation:

$$u_{ijt} = x_{jt}\beta - \alpha P_{jt} + \xi_{jt} + \varepsilon_{ijt}$$

where $P_{jt}$ is the observed price of product $j$ in year $t$, $x_{jt}$ is a $k$-dimensional vector of observed characteristics of product $j$ in year $t$, $\xi_{jt}$ is an unobserved characteristic of product $j$ in year $t$ and $\varepsilon_{ijt}$ is an idiosyncratic shock with mean zero. The SL model leads to the following demand equation:

$$\ln(s_{jt}) - \ln(s_{0t}) = x_{jt}\beta - \alpha P_{jt} + \xi_{jt}$$

where $s_{jt}$ is the market share of product $j$ in period $t$ and $s_{0t}$ is the share of the outside good.

### B.1.2 The nested logit

The utility of consumer $i$ from buying product $j$ in year/market $t$ is given by the following equation:

$$u_{ijt} = x_{jt}\beta - \alpha P_{jt} + \xi_{jt} + \zeta_{igt}(\sigma) + (1 - \sigma)\varepsilon_{ijt}$$

where $\zeta_{igt}(\sigma)$ is a group-specific random coefficient that allows goods that belong to the same group $g$ in year $t$ to contribute a common component of utility to the individual $i$. The parameter $\sigma$ measures the extent to which products within the same group are substitutes to each other. The NL model leads to the following demand equation:

$$\ln(s_{jt}) - \ln(s_{0t}) = x_{jt}\beta - \alpha P_{jt} + \sigma \ln(s_{j/g}) + \xi_{jt}$$

where $s_{j/g}$ is the market share of product $j$ within its group $g$ in period $t$.

### B.1.3 The random coefficients model

The utility of consumer $i$ from buying product $j$ in year/market $t$ is given by the following equation:

$$u_{ijt} = x_{jt}\beta_i - \alpha_i P_{jt} + \xi_{jt} + \varepsilon_{ijt}$$

where $\alpha_i$ is modeled as $\alpha + \Pi_\alpha D_i + \Sigma_\alpha V_{i\alpha}$ and the term $\beta_i$ is formed as $\beta + \Pi_\beta D_i + \Sigma_\beta V_{i\beta}$. $D_i$ is a dX1 vector of demographic variables and $V_i$ is the additional unobserved characteristics that might affect the choice of the product. $\Pi$ is a (K+1)Xd matrix of coefficients and $\Sigma$ is a (K+1)X(K+1) matrix of parameters. V's are random draws from a multivariate normal distribution, while D's are drawn from nonparametric distributions known from data sources. The RC model does not lead to an analytic solution for the demand equation, therefore I use numerical methods. Define the mean utility level as $\delta_{jt} = x_{jt}\beta - \alpha P_{jt} + \xi_{jt}$. Following Berry, Levinsohn, and Pakes (1995), the following equation is a contraction mapping:

$$F(\delta_{jt}) = \delta_{jt} + \ln(s_{jt}) - \ln(s_{jt}(\delta_{jt})) \tag{B.1}$$

where $s_{jt}(\delta_{jt}) = \int s_{ijt} dP^*_D(D) dP^*_V(V)$ and $s_{ijt}$ is given by

$$\frac{\exp(\delta_{jt} + x_{jt}(\Pi_\beta D_i + \Sigma_\beta V_{i\beta}) - (\Pi_\alpha D_i + \Sigma_\alpha V_{i\alpha})P_{jt})}{1 + \sum_{k=1}^{J} \exp(\delta_{kt} + x_{kt}(\Pi_\beta D_i + \Sigma_\beta V_{i\beta}) - (\Pi_\alpha D_i + \Sigma_\alpha V_{i\alpha})P_{kt})}$$

.

### B.1.4 Markups for two products sold by the same retailer

In order to compute markups for each of the three DCMs used for this chapter, I need to compute the derivatives of the shares with respect to price. These derivatives are provided in section 3.4. Using the derivatives, the markups for two products sold by the same retailer are given by:

Simple Logit:

$$\frac{\mu_1}{\mu_2} = \frac{-\alpha S_1 S_2 (1 - S_2) - \alpha S_1 S_2^2}{-\alpha S_1^2 S_2 - \alpha S_1 S_2 (1 - S_1)} = \frac{(1 - S_2) + S_2}{S_1 + (1 - S_1)} = 1$$

Nested Logit (both products belong to the same group):

$$\frac{\mu_1}{\mu_2} = \frac{-\frac{\alpha}{(1-\sigma)} S_1 S_2 [1 - \sigma S_{2/g} - (1-\sigma) S_2] - \alpha S_1 S_2 (S_2 + \frac{\sigma}{(1-\sigma)} S_{2/g})}{-\alpha S_1 S_2 (S_1 + \frac{\sigma}{(1-\sigma)} S_{1/g}) - \frac{\alpha}{(1-\sigma)} S_1 S_2 [1 - \sigma S_{1/g} - (1-\sigma) S_1]}$$

$$\frac{\mu_1}{\mu_2} = \frac{[1-\sigma S_{2/g} - (1-\sigma)S_2] + (1-\sigma)S_2 + \sigma S_{2/g}}{(1-\sigma)S_1 + \sigma S_{1/g} + [1-\sigma S_{1/g} - (1-\sigma)S_1]} = 1$$

Nested Logit (both products belong to a different group):

$$\frac{\mu_1}{\mu_2} = \frac{-\frac{\alpha}{(1-\sigma)}S_1S_2[1-\sigma S_{2/g} - (1-\sigma)S_2] - \alpha S_1 S_2^2}{-\alpha S_1^2 S_2 - \frac{\alpha}{(1-\sigma)}S_1S_2[1-\sigma S_{1/g} - (1-\sigma)S_1]}$$

$$\frac{\mu_1}{\mu_2} = \frac{[1-\sigma S_{2/g} - (1-\sigma)S_2] + (1-\sigma)S_2}{(1-\sigma)S_1 + [1-\sigma S_{1/g} - (1-\sigma)S_1]} = \frac{1-\sigma S_{2/g}}{1-\sigma S_{1/g}} \neq 1$$

Random Coefficients:

$$\frac{\mu_1}{\mu_2} = \frac{-S_1 \int \alpha_i S_{i2}(1-S_{i2})dP_H^*(H) - S_2 \int \alpha_i S_{i1} S_{i2} dP_H^*(H)}{-S_1 \int \alpha_i S_{i1} S_{i2} dP_H^*(H) - S_2 \int \alpha_i S_{i1}(1-S_{i1})dP_H^*(H)} \neq 1$$

## B.2 Income Distribution

Data for household income is difficult to found in Cyprus for all the years of the sample. However, I manage to get information on the income distribution from surveys conducted by the Cyprus Statistical Service for years 1991, 1996 and 2003. There are 2,703 households for year 1991, 2,636 households for year 1996 and 2,967 households for year 2003. All the households between the years of the survey are different. In order to get incomes for all the years, I test whether incomes for each of the three years follow a specific two-parameter distribution. I found that gamma distribution fits the data and I estimate its shape parameter ($\alpha$) and its scale parameter ($\beta$) for the 3 years of the survey using maximum likelihood. Remember that income is used as a consumer demographic for the random coefficients model.

The probability density function of the gamma distribution can be expressed in terms of the gamma function parameterized in terms of a shape parameter $\alpha$ and scale parameter $\beta$. Both $\alpha$ and $\beta$ are positive values. The equation defining the probability density function of a gamma-distributed random variable $x$ is:

$f(x;\alpha,\beta) = \frac{x^{\alpha-1}e^{-x/\beta}}{\beta^{\alpha}\Gamma(\alpha)}$ for $x > 0$ and $\alpha, \beta > 0$

The log-likelihood function for N i.i.d observations $(x_1, ..., x_N)$ is

$l(\alpha,\beta) = (\alpha-1)\sum_{i=1}^{N}\ln(x_i) - \sum_{i=1}^{N}\frac{x_i}{\beta} - N\alpha\ln(\beta) - N\ln(\Gamma(\alpha))$

Taking the derivative with respect to $\beta$ and setting it equal to zero yields the maximum likelihood estimator of the scale parameter $\beta$:

$\hat{\beta} = \frac{1}{\alpha N}\sum_{i=1}^{N} x_i$, so $\hat{\beta}$ can be estimated by $\frac{\bar{x}}{\hat{\alpha}}$ where $\bar{x}$ is the mean of income and $\hat{\alpha}$ is the maximum likelihood estimator of the shape parameter $\alpha$ that we derive below.

Substituting the maximum likelihood estimator of the scale parameter into the log-likelihood function and then taking the derivative with respect to $\alpha$ and setting it equal to zero yields:

$\ln(\alpha) - \frac{\tilde{\Gamma}(\alpha)}{\Gamma(\alpha)} = \ln(\frac{1}{N}\sum_{i=1}^{N} x_i) - \frac{1}{N}\sum_{i=1}^{N}\ln(x_i)$ , where the right hand side of this relationship (let's call it r) is the natural logarithm of mean of income minus the mean of natural logarithm of income. As there is no close-form solution for $\alpha$, a numerical solution must be found using, for example, Newton's method. An initial value of $\alpha$ can be found using method of moments.[1]

For the estimation of $\alpha$ and $\beta$, a stata module created by Cox and Jenkins is used. As an initial value they use the initial value proposed by Thom (1958) which is $\alpha_0 = \frac{1+\sqrt{1+4r/3}}{4r}$. For the numerical solution for $\alpha$ instead of Newton's method they use an approximation of $\frac{\tilde{\Gamma}(\alpha)}{\Gamma(\alpha)}$ proposed by Mielke (1976).

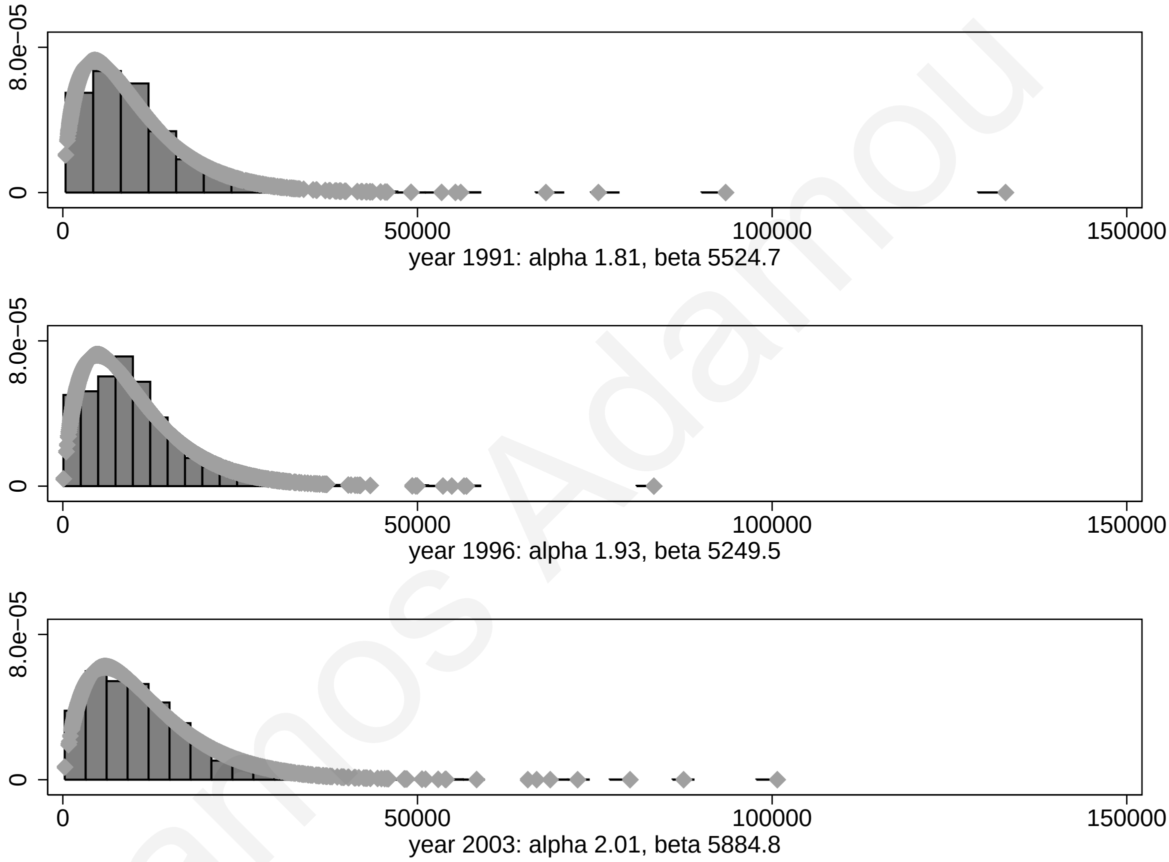



Figure B.1: Income Distribution

Figure B.1 reports the empirical distributions and the gamma distributions using $\hat{\alpha}$ and $\hat{\beta}$ for each of the three years of the survey. Using those parameters, I calculate alphas and betas for years 1989 to 2002 by using GDP per capita as a weight. Instead if, for example, I had assumed that the parameters increase by the same amount each year, then for years 1991 to 1996 alpha increases by 0.024 and beta decreases by 55.04 every year. By using GDP per capita as a weight, I relax the assumption that the parameters increase by the same amount each year. For example, GDP per capita for 1991 was 12157 CP and for 1996 was 15992 CP. Using the assumption of the same-

[1]The first moment of a random variable with this probability density function is $E(x) = \alpha\beta$ and $E(x^2) = \beta^2\alpha(\alpha+1)$. Solving the two equations for $\alpha$ and $\beta$ we get $\alpha = \frac{\bar{x}^2}{Var(x)}$ and $\beta = \frac{Var(x)}{\bar{x}}$ so $\frac{\bar{x}^2}{Var(x)}$ can be used as an initial value of $\alpha$.

amount-increase each year, for 1992 household income should increase by 767 CP. As the actual GDP per capital for 1992 was 13474 (increase of 1317 CP), there was a higher increase than the one predicted by the same-amount-assumption, so using GDP per capital as a weight I calculate an alpha of 1.836 and a beta of 5467,3 instead of 1.834 and 5469,7 for 1992. I did that for all years and then I draw incomes from a gamma distribution using the specific parameters calculated for each year.

## B.3 Estimation of demand for subsample

Table B.1: Demand estimates (subsample)

| Variables | SL | NL | RC-2 |
|---|---|---|---|
| Price | -0,263** | -0,201** | -0,417** |
| | (0,026) | (0,031) | (0,021) |
| Within-share | | 0,302** | |
| | | (0,098) | |
| Engine Capacity | 3,038** | 2,080** | 3,176** |
| (In liters) | (0,312) | (0,437) | (0,456) |
| Standard Deviation | | | 0,111 |
| of Price | | | (0,508) |
| Median Markups | 3.521 | 3.337 | 3.617 |

Significance levels: † : 10%, ∗ : 5%, ∗∗ : 1%. Standard errors are reported in parentheses. Frame and Cylinders are excluded. All the other characteristics are included but are not reported for brevity.

Table B.2: Demand estimates (subsample)

| Variables | SL | NL | RC-1 | RC-2 |
|---|---|---|---|---|
| Price | -0,328** | -0,246** | -1,196 | -0,780** |
| | (0,036) | (0,035) | (0,837) | (0,040) |
| Within-share | | 0,377** | | |
| | | (0,088) | | |
| Czech Rep. | -3,874** | -2,387** | -3,947** | -4,143** |
| | (0,370) | (0,451) | (0,400) | (0,615) |
| England | -0,979** | -0,616** | -0,899** | -0,960** |
| | (0,316) | (0,221) | (0,324) | (0,362) |
| France | 1,042** | 0,782** | 1,279** | 1,230** |
| | (0,245) | (0,174) | (0,297) | (0,272) |
| Germany | 2,698** | 1,953** | 2,823** | 2,781** |
| | (0,231) | (0,237) | (0,242) | (0,244) |
| Italy | -0,679* | -0,246 | -0,539 | -0,535† |
| | (0,341) | (0,222) | (0,335) | (0,325) |
| Korea | -1,941** | -1,134** | -2,162** | -2,104** |
| | (0,302) | (0,286) | (0,340) | (0,311) |
| Russia | -4,570** | -3,228** | -5,970** | -5,684** |
| | (0,456) | (0,531) | (1,014) | (0,594) |
| Spain | -0,434 | -0,111 | -0,256 | -0,305 |
| | (0,458) | (0,336) | (0,454) | (0,444) |
| Sweden | 2,402** | 1,728** | 2,427** | 2,081** |
| | (0,537) | (0,436) | (0,421) | (0,422) |
| Engine Capacity | 2,759** | 1,606** | 3,283** | 3,210** |
| (In liters) | (0,332) | (0,404) | (0,402) | (0,291) |
| Frame | 0,574** | 0,549** | 0,899** | 0,860** |
| | (0,153) | (0,110) | (0,269) | (0,165) |
| Cylinders | 1,874** | 1,408** | 0,692 | 0,896** |
| | (0,414) | (0,345) | (1,122) | (0,343) |
| Constant | -18,778** | -14,976** | -11,729† | -13,989** |
| | (2,075) | (1,881) | (6,595) | (1,878) |
| Price*Income | | | 0,568 | |
| | | | (0,506) | |
| Standard Deviation | | | | 0,195 |
| of Price | | | | (0,558) |
| Sargan-Hansen | 4,64 chisq(3) | 1,53 chisq(1) | 1,65 chisq(3) | 1,36 chisq(3) |
| test | p-value:0,20 | p-value:0,22 | p-value:0,65 | p-value:0,72 |

Significance levels: † : 10%, ∗ : 5%, ∗∗ : 1%. Standard errors are reported in parentheses.

# Appendix C

# Evaluation of the effectiveness of CO2-related taxation: The car market of Greece

Table C.1: Demand and Supply Estimates: Country Dummies Results

| Variables | Demand side parameters | Cost side parameters |
|---|---|---|
| China | -1.163* | -2.739 |
| | (0.471) | (1.724) |
| Czech Rep. | 0.140 | -1.197** |
| | (0.102) | (0.351) |
| England | -0.030 | 0.381* |
| | (0.052) | (0.192) |
| France | 0.017 | -0.674** |
| | (0.045) | (0.166) |
| Germany | 0.506** | 2.55** |
| | (0.050) | (0.149) |
| Italy | -0.176** | -0.869** |
| | (0.055) | (0.198) |
| Korea | 0.00028 | -2.944** |
| | (0.078) | (0.210) |
| Romania | -1.219* | -1.892 |
| | (0.568) | (2.108) |
| Russia | -0.885** | -3.746** |
| | (0.150) | (0.508) |
| Spain | -0.092 | -1.347** |
| | (0.072) | (0.269) |
| Sweden | 0.221** | 2.696** |
| | (0.084) | (0.286) |
| Switzerland | -0.132 | -1.487** |
| | (0.131) | (0.492) |
| USA | -0.278* | -3.692** |
| | (0.132) | (0.409) |

Significance levels: † : 10%, ∗ : 5%, ∗∗ : 1%. Standard errors are reported in parentheses. Variables shown here denote the country of origin of each car model.

# Appendix D

# Environmental and Economic Effects of CO2-based Automobile Taxes in Germany

## D.1 Nested Logit with two nests

The goal of this section is to identify the demand equation for nested logit with two nests.

Following $Verboven$(1996), the specific functional form of the share for a car j, belonging to a subgroup h of a group g, is given by:

$$S_j = \frac{\exp(\frac{\delta_j}{1-\sigma_1})}{\sum_{j\in h}\exp(\frac{\delta_j}{1-\sigma_1})} \frac{[\sum_{j\in h}\exp(\frac{\delta_j}{1-\sigma_1})]^{\frac{1-\sigma_1}{1-\sigma_2}}}{\sum_{h\in g}[\sum_{j\in h}\exp(\frac{\delta_j}{1-\sigma_1})]^{\frac{1-\sigma_1}{1-\sigma_2}}} \frac{[\sum_{h\in g}[\sum_{j\in h}\exp(\frac{\delta_j}{1-\sigma_1})]^{\frac{1-\sigma_1}{1-\sigma_2}}]^{1-\sigma_2}}{\sum_{g\in G}[\sum_{h\in g}[\sum_{j\in h}\exp(\frac{\delta_j}{1-\sigma_1})]^{\frac{1-\sigma_1}{1-\sigma_2}}]^{1-\sigma_2}}$$

With the outside good as the only member of group zero and with $S_{0/h_0} = S_{h_0/g_0} = 1$, the share of the outside good is given by:

$$S_0 = \frac{1}{\sum_{g\in G}[\sum_{h\in g}[\sum_{j\in h}\exp(\frac{\delta_j}{1-\sigma_1})]^{\frac{1-\sigma_1}{1-\sigma_2}}]^{1-\sigma_2}}$$

This concludes to:

$$S_j/S_0 = \frac{\exp(\frac{\delta_j}{1-\sigma_1})}{\sum_{j\in h}\exp(\frac{\delta_j}{1-\sigma_1})} \frac{[\sum_{j\in h}\exp(\frac{\delta_j}{1-\sigma_1})]^{\frac{1-\sigma_1}{1-\sigma_2}}}{\sum_{h\in g}[\sum_{j\in h}\exp(\frac{\delta_j}{1-\sigma_1})]^{\frac{1-\sigma_1}{1-\sigma_2}}} [\sum_{h\in g}[\sum_{j\in h}\exp(\frac{\delta_j}{1-\sigma_1})]^{\frac{1-\sigma_1}{1-\sigma_2}}]^{1-\sigma_2}$$

Define $D_h = \sum_{j\in h}\exp(\frac{\delta_j}{1-\sigma_1})$ and $D_g = \sum_{h\in g}[\sum_{j\in h}\exp(\frac{\delta_j}{1-\sigma_1})]^{\frac{1-\sigma_1}{1-\sigma_2}}$.

I can now derive a simple analytic expression for the mean utility levels that depends on the unknown values of $D_h$ and $D_g$. Taking logs of market shares,

$$\ln(S_j) - \ln(S_0) = \frac{\delta_j}{1-\sigma_1} + \frac{\sigma_2 - \sigma_1}{1-\sigma_2}\ln(D_h) - \sigma_2 \ln(D_g) \tag{D.1}$$

Next, I need to find analytic expressions for $D_h$ and $D_g$ as functions of $S_j, S_0, S_{j/h} and S_{h/g}$. It is known that $S_g = \frac{D_g^{1-\sigma_2}}{\sum_{g \in G} D_g^{1-\sigma_2}}$. So $S_g = D_g^{1-\sigma_2} S_0$ and $\ln(D_g) = \frac{1}{1-\sigma_2}[\ln(S_g) - \ln(S_0)]$. As $S_g = \frac{S_j}{S_{j/h}S_{h/g}}$ then,

$$\ln(D_g) = \frac{\ln(S_j) - \ln(S_0) - \ln(S_{j/h}) - \ln(S_{h/g})}{1-\sigma_2} \tag{D.2}$$

The share of j in subgroup h, $S_{j/h}$, is equal to $\frac{\exp(\frac{\delta_j}{1-\sigma_1})}{D_h}$. By taking logs, an analytic expression for $\ln(D_h)$ can be derived as follows:

$$\ln(D_h) = \frac{\delta_j}{1-\sigma_1} - \ln(S_{j/h}) \tag{D.3}$$

Substituting equations (D.3) and (D.2) into equation (D.1) leads to the demand equation for nested logit with two nests:

$$\ln(S_j) - \ln(S_0) = \delta_j + \sigma_1 \ln(S_{j/h}) + \sigma_2 \ln(S_{h/g}) \tag{D.4}$$

Where $\delta_j = x_j\beta - \alpha P_j + \xi_j$.

## D.2 Extra Tables & Figures

Table D.1: Demand and Supply Estimates: Country Dummies Results

| Variables | Demand side parameters | Cost side parameters |
|---|---|---|
| China | -1.352 | -2.927 |
| | (0.880) | (3.215) |
| Czech Rep. | 0.055 | -0.716$^{\dagger}$ |
| | (0.122) | (0.427) |
| England | 0.096 | 0.447$^{\dagger}$ |
| | (0.066) | (0.239) |
| France | -0.080 | 0.206 |
| | (0.066) | (0.208) |
| Germany | 0.926$^{**}$ | 2.072$^{**}$ |
| | (0.069) | (0.184) |
| Italy | -0.315$^{**}$ | 0.575$^{*}$ |
| | (0.107) | (0.267) |
| Korea | -0.945$^{**}$ | -3.288$^{**}$ |
| | (0.108) | (0.274) |
| Romania | -0.578 | -4.069$^{**}$ |
| | (0.392) | (1.270) |
| Russia | -1.786$^{**}$ | -5.209$^{**}$ |
| | (0.298) | (1.032) |
| Spain | -0.473$^{**}$ | -1.221$^{**}$ |
| | (0.109) | (0.368) |
| Sweden | -0.081 | 1.121$^{**}$ |
| | (0.112) | (0.314) |
| Switzerland | -0.893$^{**}$ | -2.874$^{**}$ |
| | (0.154) | (0.524) |
| USA | -1.511$^{**}$ | -5.990$^{**}$ |
| | (0.212) | (0.519) |

Significance levels: $\dagger$ : 10%, $*$ : 5%, $**$ : 1%. Standard errors are reported in parentheses. Variables shown here denote the country of origin of each car model. See further explanations in table 5.3.

Table D.2: Demand and Supply Estimates with the reverse nesting structure: Country Dummies Results

| Variables | Demand side parameters | Cost side parameters |
|---|---|---|
| China | -0.860** | -8.662** |
| | (0.314) | (3.147) |
| Czech Rep. | 0.068 | 0.229 |
| | (0.044) | (0.421) |
| England | 0.079** | 1.023** |
| | (0.024) | (0.241) |
| France | 0.017 | 0.586** |
| | (0.023) | (0.208) |
| Germany | 0.307** | 2.408** |
| | (0.040) | (0.189) |
| Italy | -0.074† | 0.682** |
| | (0.038) | (0.265) |
| Korea | -0.344** | -3.246** |
| | (0.032) | (0.269) |
| Romania | -0.327* | -4.053** |
| | (0.133) | (1.244) |
| Russia | -0.516** | -4.650** |
| | (0.109) | (1.009) |
| Spain | -0.052 | -0.192 |
| | (0.041) | (0.362) |
| Sweden | -0.031 | 0.800** |
| | (0.037) | (0.312) |
| Switzerland | -0.249** | -2.588** |
| | (0.054) | (0.513) |
| USA | -0.518** | -5.272** |
| | (0.058) | (0.517) |

Significance levels: † : 10%, $*$ : 5%, $**$ : 1%. Standard errors are reported in parentheses. Variables shown here denote the country of origin of each car model. See further explanations in table 5.4.

# Bibliography


ACEA, 2009, "Overview of CO2 Based Motor Vehicle Taxes in the EU," .

Anderson, S. P., A. de Palma, and B. Kreider, 2001, "Tax Incidence in Differentiated Product Oligopoly," *Journal of Public Economics*, 81, 173 – 192.

Berndt, E., Z. Griliches, and N. J. Rappaport, 1995, "Econometric Estimates of Price Indexes for Personal Computers in the 1990s," *Journal of Econometrics*, 68, 243 – 268.

Berry, S. T., 1994, "Estimating Discrete Choice Models of Product Differentiation," *RAND Journal of Economics*, 25, 242–262.

Berry, S. T., J. Levinsohn, and A. Pakes, 1995, "Automobile Prices in Market Equilibrium," *Econometrica*, 63, 841–890.

Besley, T., and H. Rosen, 1999, "Sales Taxes and Prices: An Empirical Analysis," *National Tax Journal*, 52, 157–178.

Braathen, N.-A., 2011, "CO2-Based Taxation of Motor Vehicles. In Zachariadis T. (ed.), Cars and Climate Policy: The European Experience," *Springer publications (forthcoming)*.

Bresnahan, T. F., and R. J. Gordon, 1997, *The economics of new goods*, University of Chicago Press.

Bresnahan, T. F., S. Stern, and M. Trajtenberg, 1997, "Market segmentation and the sources of rents from innovation: personal computers in the late 1980s," *RAND Journal of Economics*, 28, S17 – S44.

Clerides, S., 2008, "Gains from Trade in Used Goods: Evidence from Automobiles," *Journal of International Economics*, 76, 322–336.

COWI, 2002, "Fiscal Measures to Reduce CO2 Emissions from New Passenger Cars," *Final Report to the European Commission.*

de Haan, P., M. G. Mueller, and R. W. Scholz, 2009, "How much do incentives affect car purchase? Agent-based microsimulation of consumer choice of new cars; Part

II: Forecasting effects of feebates based on energy-efficiency," *Energy Policy*, 37, 1083–1094.

Delipalla, S., and M. Keen, 1992, "The Comparison between Ad Valorem and Specific Taxation under Imperfect Competition," *Journal of Public Economics*, 49, 351 – 367.

Diewert, E., 2003, *Hedonic Regressions: A Consumer Theory Approach*, pp. 317-348 in Scanner Data and Price Indexes, Studies in Income and Wealth, Volume 64, R.C. Feenstra and M.D. Shapiro (eds.), NBER and University of Chicago Press. http://www.econ.ubc.ca/diewert/scan.pdf.

EC, 2005, "Proposal for a Council Directive on passenger car related taxes," *European Commission, Document COM(2005) 261 final, Brussels.*

Fershtman, C., and N. Gandal, 1998, "The effect of the Arab boycott on Israel: the automobile market," *RAND Journal of Economics*, 29, 193–214.

Fershtman, C., N. Gandal, and S. Markovich, 1999, "Estimating the Effect of Tax Reform in Differentiated Product Oligopolistic Markets," *Journal of Public Economics*, 74, 151–170.

Greene, D. L., P. D. Patterson, M. Singh, and J. Li, 2005, "Feebates, rebates and gas-guzzler taxes: a study of incentives for increased fuel economy," *Energy Policy*, 33, 757–775.

Griliches, Z., 1990, *Hedonic Price Indexes and the Measurement of Capital and Productivity: Some Historical Reflections*, In Fifty Years of Economic Measurement: The Jubilee of the Conference on Research in Income and Wealth, ed. Ernst R. Berndt and Jack E. Triplett, 185-202. NBER Studies in Income and Wealth, vol. 54. Chicago: University of Chicago Press.

Griliches, Z. e., 1971, *Price Indexes and Quality Change*, Cambridge, MA: Harvard University Press.

Hausman, J., 1997, *Valuation of new goods under perfect and imperfect competition*, in Bresnahan and Gordon, eds. The Economics of New Goods. The University of Chicago Press, Chicago, IL, 209-237.

Hausman, J., 2003, "Sources of bias and solutions to bias in the consumer price index," *Journal of Economic Perspectives*, 17, 23–44.

IEA, 2006, "Summary and Conclusions," *International Energy Agency, World Energy Outlook, Paris, France.*

Kennedy, P., 1981, "Estimation with Correctly Interpreted Dummy Variables in Semilogarithmic Equations," *American Economic Review*, 71, 801.

King, J., 2007, "The King Review of low-carbon cars - Part I: the potential for CO2 reduction," *HM Treasury, London, http://hm-treasury.gov.uk/king.*

MacKinnon, J., H. White, and R. Davidson, 1983, "Tests for Model Specification in the Presence of Alternative Hypothesis: Some Further Results," *Journal of Econometrics*, 21, 53–70.

McFadden, D., 1978, "Modelling the Choice of Residential Location," *In A. Karlqvist et al., eds., Spatial Interaction Theory and Planning Models. New York: North-Holland.*

Mielke, P., 1976, "Simple Iterative Procedures for Two-Parameter Gamma Distribution Maximum Likelihood Estimates," *Journal of Applied Meteorology*, 15, 181–183.

Moulton, B., T. LaFleur, and K. Moses, 1998, "Research on Improved Quality Adjustments in the CPI: the Case Televisions," *Working paper, U.S. Bureau of Labor Statistics.*

Nevo, A., 2000, "A Practitioner's Guide to Estimation of Random-Coefficients Logit Models of Demand," *Journal of Economics and Management Strategy*, 9, 513–548.

Nevo, A., 2001, "Measuring Market Power in the Ready-to-Eat Cereal Industry," *Econometrica*, 69, 307–342.

Nordhaus, W. D., 1997, "Do Real Output and Real Wage Measures Capture Reality? The History of Lighting Suggests Not," *In Bresnahan and Gordon eds. The Economics of New Goods. The University of Chicago Press, Chicago, IL, 29-66.*

OECD, 2009, "Incentives for CO2 Emission Reductions in Current Motor Vehicle Taxes," *Document ENV/EPOC/WPNEP/T(2009)2/FINAL, Organisation for Economic Co-operation and Development, Paris, France.*

Ohta, M., and Z. Griliches, 1976, "Automobile Prices Revisited: Extensions of the Hedonic Hypothesis," *in N. Terleckyj ed., Household Production and Consumption, Studies in Income and Wealth Vol. 40, New York: Columbia University Press for National Bureau of Economic Research, 325-390.*

Pakes, A., 2003, "A Reconsideration of Hedonic Price Indices with an Application to PC's," *American Economic Review*, 93, 1578 – 96.

Pakes, A., 2010, "Hedonics and the Consumer Price Index," *A chapter in Contributions in Memory of Zvi Griliches, 2010, pp 729-748 from National Bureau of Economic Research.*

Peters, A., M. Mueller, P. de Haan, and R. Scholz, 2008, "Feebates promoting energy-efficient cars: Design options to address more consumers and possible counteracting effects," *Energy Policy*, 36, 1355–1365.

Poterba, J. M., 1996, "Retail Price Reactions to Changes in State and Local Sales Taxes," *National Tax Journal*, 49, 165–176.

Rosen, S., 1974, "Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition," *Journal of Political Economy*, 82, 34–55.

Silver, M., and S. Heravi, 2001, "Scanner Data and the Measurement of Inflation," *Economic Journal*, 111, 383–404.

Thom, H., 1958, "A Note on the Gamma Distribution," *Monthly Weather Review*, 86, 117–122.

TIS, INFRAS, Erasmus, and DIW, 2002, "Study on vehicle taxation in the Member States of the European Union," *Final Report to the European Commission*.

Trajtenberg, M., 1989, "The welfare analysis of product innovations, with an application to computed tomography scanners," *Journal of Political Economy*, 50, 647–658.

Triplett, J., 2006, "Handbook on Hedonic Indexes and Quality Adjustment in Price Indexes: Special Application to Information Technology Products," *OECD Publishing*.

Triplett, J. E., 1987, "Hedonic Functions and Hedonic Indexes," *in: John Eatwell, Murray Milgate, and Peter Newman (eds.), The New Palgrave: A Dictionary of Economics, Vol. 2. New York, NY: Stockton Press, 630-34*.

Vance, C., and M. Mehlin, 2009, "Tax Policy and CO2 Emissions: An Econometric Analysis of the German Automobile Market," *Ruhr Economic Papers No. 89, Rhine-Westfalian Institute for Economic Research (RWI Essen), Essen, Germany.*

Verboven, F., 1996, "International Price Discrimination in the European Car Market," *RAND Journal of Economics*, 27, 240–268.