ISCTE Business School
Instituto Universitário de Lisboa

THE IMPACT OF MACROECONOMIC VARIABLES ON THE USED CARS SALE PRICE

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– Spine –

RESUMO

A recessão económica de 2008 desencadeou flutuações relevantes em diversos âmbitos, nomeadamente na indústria automóvel. O objetivo desta dissertação é analisar a influência da atual crise no preço de venda dos carros em segunda mão. Para tal, foi estimada uma regressão linear, recorrendo ao método dos Mínimos Quadrados Ordinários, com base numa amostra de carros usados vendidos em Portugal, entre 2005 e 2012. Variáveis macroeconómicas tais como a Taxa de Desemprego, o Preço do Petróleo, os Empréstimos concedidos a Particulares, o Indicador do Consumo Privado, o Índice Harmonizado de Preços no Consumidor, entre outras, foram testadas na regressão. Para além destas, foram incluídas variáveis que representam as próprias características do veículo. Por fim, foi realizada uma análise *out-of-sample* para testar a validade do modelo de regressão linear. Os resultados revelaram que algumas das variáveis escolhidas têm, de facto, impacto no preço de um automóvel vendido no mercado secundário e que, devido à sua capacidade preditiva, podem ser úteis para procedimentos de *pricing* ou apenas para avaliação de ativos.

Classificação JEL: C21; E31.

Palavras-chave: preço de venda do carro; mercado de carros usados; indústria automóvel; variáveis macroeconómicas.

ABSTRACT

The 2008 economic downturn triggered significant fluctuations in several scopes, namely in the automotive industry. The purpose of this dissertation is to analyse the influence of the current crisis on the sale price of second hand vehicles. A linear regression model was estimated using the Ordinary Least Squares procedure, based on a sample of used cars sold in Portugal, since 2005 to 2012. Macroeconomic variables such as Unemployment Rate, Oil Prices, Loans granted to Private Individuals, Private Consumption Indicator, Harmonized Index of Consumer Prices, among others, were tested in the estimated regression. In addition, some variables representing the own vehicle characteristics were also included. Finally, an out-of-sample analysis was performed to evaluate the predictive ability of the linear regression model. Results suggested that some of the selected macroeconomic indicators actually influence the sale price of an automobile sold in the secondary market and due to its predicting capacity can be useful to pricing procedures or just for asset valuation.

JEL classification: C21; E31.

Keywords: car sale price; used cars market; automobile industry; macroeconomic variables.

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ACRONYMS

ACAP – Associação Automóvel de Portugal (the Portuguese automobile association)

B2B – Business-to-business

B2C – Business-to-consumer

CPI – Consumer Prices Index

CPO – Certified Pre-Owned

ECB – European Central Bank

EURIBOR - Euro Interbank Offered Rate

GDP – Gross Domestic Product

MAPE – Mean Absolute Percentage Error

OECD - Organisation for Economic Co-operation and Development

OICA - International Organisation of Motor Vehicle Manufacturers

OLS – Ordinary Least Squares

UK – United Kingdom

USA – United States of America

VAT – Value Added Tax

1. INTRODUCTION

After a period of a strong economic expansion across the world, the 2008 global economy slowdown triggered many consequences in several different scopes. The crisis in the financial sector restricted the access to credit and shifted the borrowing conditions. As a result, domestic investment and consumption demand declined, affecting the national production in general.

In the majority of countries, the unemployment increased significantly which reduced the households' disposable income and therefore the purchasing power. Consumers needed to become more rational and redefine more carefully their purchasing decisions, not just because of the uncertainty about future income levels but also because of the reduction on the economic growth expectations.

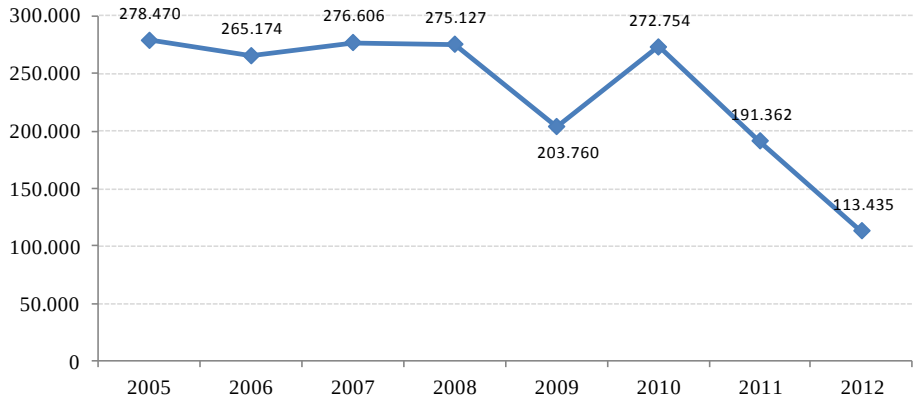
Within this crisis environment, the automotive industry has been one of the most resented sectors.

As a durable good, a car is an acquisition particularly sensitive in times of difficulties to access credit and when disposable income is decreasing, since it needs a certain money amount. When facing a period of such uncertainty, consumers can postpone the decision of acquiring a new car to the future when economic conditions will probably be more stable; instead of buying a brand new car, they can choose to purchase a second hand vehicle or even to sell their current car without replacing it due to the high costs (insurance, maintenance, fuel, among others) of owning an automobile.

Car retailers, renting companies and other businesses related with the automobile industry, did not manage to create appropriate mechanisms to minimize the negative crisis impact. Some products continued to be overpriced, asset valuations were still overestimated and residual values of renting companies, for instance, were not calculated in the proper way. If macroeconomic factors and different scenarios were taken into account earlier, this issue would possibly have been addressed and computed with more accuracy and, even though it could bring immediate losses, the damage caused would probably have been lower.

In Portugal it is estimated that sales of all new vehicles dropped more than 59%, since 2005 to 2012 and this was one of the largest falls in car sales of European countries, which can be observed in appendix A.

Figure 1 – Sales of New Vehicles in Portugal (in units)



Source: chart created by the author, based on the data available on the OICA website.

The information available about the evolution of second hand car sales is scarce since it is very hard to collect accurate data about the total sales by private individuals and used car dealers but it would be interesting to observe whether the impact on used car sales was similar to the decline in new car sales.

As previously mentioned, if by one hand the current crisis can delay consumer's decision of buying a new vehicle, on the other hand it may lead the buyer to prefer acquiring a used car since it is a more affordable choice in times of economic difficulties. But does the global crisis environment influence the sale price of a used car? Which are the factors that better explain the variations on the average sale price in automobiles secondary market? Do the impacts of these factors follow the expected positive or negative pattern?

Although many academic researches have compared the evolution of macroeconomic variables with the volume of car sales, few explored the link between the performance of macroeconomic factors and the automobiles sale price, especially concerning secondary markets.

The aim of this dissertation is to analyse the influence of economic indicators in the average sale price of used cars in Portugal, from 2005 to 2012.

In order to investigate this issue, it will be estimated an econometric model to infer about the effect on the vehicle sale price caused not only by the car's own characteristics but also by fluctuations in macroeconomic variables. The dataset used contains second hand cars sold by the leading company in the operational leasing and fleet management market in Portugal. The sample contains sales since 2005 until 2012, which includes the recent economic downturn.

Regarding vehicle's own characteristics, the brand, the body style, the vehicle kind, fuel type, number of doors, cylinder capacity, the list price of the vehicle when it was bought new, the mileage and the age, will be the variables used in the model. Concerning the economic environment, the macroeconomic variables that will be tested in the regression are: real oil prices, exchange rate, loans to private individuals, long-term and short-term interest rates, EURIBOR, harmonized unemployment rate, sales of new passenger cars, harmonized index of consumer prices, economic activity coincident indicator, private consumption coincident indicator, economic sentiment indicator and consumer confidence indicator.

Other macroeconomic variables would be interesting to test, however there were no monthly available data. Nonetheless, the quantity of indicators and their qualitative characteristics can help to conceive a reliable picture of the country's economic situation.

Since it is important to take into account that the current crisis may have relevant consequences not only in the volume of sales but also in the sale price of a used vehicle, the model estimated in this thesis can be useful to predict more accurately the car pricing and residual values or just for asset valuation purposes.

The remainder of the thesis is organized as follows. Next section provides an overview of previous studies in related areas, such as durable goods, second hand markets, economic crisis and the determinants of car sales. Then, it specifies the dataset and the variables as well as the model and the estimation procedures used in this dissertation. Afterwards, it describes and analyses the model results in section 4. To conclude, the main results are summarized in the final section, where it is also given an insight about the thesis limitations and extensions to pursue in future researches.

2. LITERATURE REVIEW

This section gives a brief bibliography review and aims to address the different research areas related to this study, in order to provide a flowed walkthrough along the explored topics and a further insight on the subject, thus allowing a better understanding of the thesis theme.

2.1. DURABLE GOODS AND SECONDARY MARKETS

There are some useful academic researches that can help to better understand the logic behind the behaviour of consumers towards durable and non-durable goods, the relationship between first and second hand markets as well as the main differences among new and used markets.

Black and Cusbert (2010) examined cycles in spending on durable goods in Australia since 1960 until 2010 which included the recent economic downturn, providing a comparison with USA. The authors define durable goods as a flow of services or utility over time. On the contrary, non-durable goods and services are usually immediately consumed. Then they estimate the correlation between GDP and the consumption of different types of goods and services (see appendix B1), concluding that spending on durable goods is likely to be more cyclical than spending on non-durable goods and services since it can be more easily postponed in times of an economic slowdown. For instance, a household that faces a reduction in income may choose not to acquire a new car since one can continue to use its current car. The same does not happen when deciding to buy food, since this kind of purchase cannot be delayed so easily. By this way, consumer spending on durable goods is more volatile than spending on non-durable goods and services, as can be seen in appendix B2. Also in this paper, we can find two different effects of some governments temporary subsidies targeted as spending on consumer durables: it reduced the price of durables relative to non-durables and the current price became lower regarding its future price; in addition, it boosted inter temporal substitution, with consumers deciding to purchase goods immediately rather than waiting for better future financial conditions.

Heim (2009) developed and tested different macroeconomic consumption demand functions for durable goods, nondurable goods and services, using USA 1960-2000 data. The models explain, respectively, 94%, 86% and 81% of the variance in each

one's demand. The demand for durables, such as automobiles and home appliances, appeared to be driven by the disposable income, wealth, the exchange rate, availability of consumer credit, interest rates on consumer credit, demand for new housing and population growth. Regarding the demand for nondurables, like groceries and clothes, the model revealed to be similar to the durables model, with the exception of new housing demand and exchange rate variables. Finally, the demand for services like laundry and entertainment services proved to be influenced by the disposable income, wealth and population growth as well as mortgage interest rates paid by households.

In order to understand the dependence between new and second hand markets, it is important to fully understand why secondary market exists. Van Cayseele (1993) provides a framework answering this question, by justifying it with the durability and the volatility of the durable.

Goods give utility to the consumer over a number of periods. Hence, as soon as the consumer gets enough of it, he wants to replace the good for superior performance or to better serve more urgent needs. Consequently, he will try to resell the commodity. The author argues that secondary markets re-allocate durables from agents taking out a low utility, to agents that at the moment can extract a higher usefulness. If the durability of a good is longer, the probability for a consumer to drop the asset and decide to buy another one will increase in order to provide more utility. So, durability constitutes the first condition to the existence of second hand markets since over the time it will diminish the utility for some consumers.

As a second condition, the good quality needs sufficient volatility. For instance, an economic depreciation could appear if the costumer has no further need of the good or just because of an increase on the car's maintenance cost. If the quality of the durable and the user income varies throughout time, it will probably create a secondary market for such a good.

As Van Cayseele (1993) but with a macroeconomic approach, Scitovsky (1994) explained the existence of the secondary markets by investigating its impact on the overall economy and probing it through Keynes approach and Say's law.

Consumers frequently react to a variation of their income by shifting their demand between new markets and secondary ones which are cheaper. For instance, owners of

second hand cars are more or less prone to hold their vehicles according to the variation of prices. A change on income can lead to a transfer of demand from secondary markets to cheaper goods of new markets, and therefore accelerate the initial fall or rise in the incomes. Hence, when the elasticity of substitution between the durables traded in a first and a second hand market is relatively high, their prices turn out to be interdependent and a disruption of their market equilibrium can affect both their prices. Thus, secondary-markets usually unsettle the economy's macro equilibrium, by stimulating or depressing it.

Therefore, second hand markets comprise two main roles: it mitigates the inequalities by allowing poorest individuals to buy cheaper commodities whilst it stimulates the economy by facilitating the replacement of obsolete durable goods.

In the short term, an effect in one of the markets generates a temporary obstacle to a price change and triggers a movement on the other market in the same direction. On a subsequent period, the used market's disequilibrium slowly releases the restrictions to an equilibrating price modification. The result depends on the size of the second hand market and it becomes more significant in countries with high standard of living.

Concerning the difference in the quality of new and used markets, Akerlof (1970) developed the lemons model. An automobile may have a good or a bad quality (which in America is called as "lemons") and initially a buyer knows that with probability *q* it is a good car and with probability *(1-q)* it is a lemon. Nevertheless, cars of different qualities have been selling at a common price since it is impossible to distinguish one from another. Buyers tend to look for statistics to judge and to get more information about the quality of prospective purchases but only the seller knows the difference. Hereupon, there is an incentive for sellers to supply poor quality durables and, as a result, there tends to exist a reduction of the average quality of goods, which implies a price adjustment.

So, the lemons model basically assumes that owners of used cars have an informational advantage over potential buyers with respect to the quality of their vehicles. Consequently, the average quality of traded automobiles is thus lower than the average quality of the whole population of cars, which suggests that bad used cars drive out the good ones of the market because they sell at an equal price to good cars.

With these conclusions, Akerlof explains why used cars valuation is so much lower than new cars valuation since there is a significant lack of perfect information among dealers and consumers and he also explains why this quality uncertainty may lead to significant economic costs of dishonesty.

In response to the lemons model, leasing automobiles and Certified Pre-Owned (CPO) programs can help to lighten the costs of asymmetric information about the quality uncertainty of second hand durable goods. Sultan (2010) examined the possible impacts of these both solutions to the lemons problem and his results reveal that leasing and CPO cars actually supply good quality used cars to the market and improve substantially the info mechanism between sellers and buyers, reducing the adverse selection.

The substitution of commodities is commonly made among primary and secondary markets. Prado (2009) aimed to analyze its interdependence on a macroeconomic perspective, in France, UK and USA. The author also tried to check the accuracy of the following mechanisms (2009: 10):

> *"The new market feeds the used market"* – Past new markets may be positively correlated with today's second hand car market, regarding volume and prices.
>
> *"Renewals"*– Drivers have to renew their automobiles after some years, which may create cycles on both markets.
>
> *"Volume effect"* – An increase in transaction volumes caused by the supply side could lower the price. If an increase in transaction volumes is caused by a greater demand, it could higher the prices.
>
> *"Price effect"* – A price increase could negatively impact the demand side, and could either have a positive impact on supply side
>
> *"Arbitration"* – A buyer can purchase a car on the new market or on the used market, but a car cannot be bought on both markets at the same time.
>
> *"Reallocation"* – Since high prices in new cars lead buyers to move to the second hand market, the used car prices increase as well. In the short term, volume and prices move in the same direction in both markets.

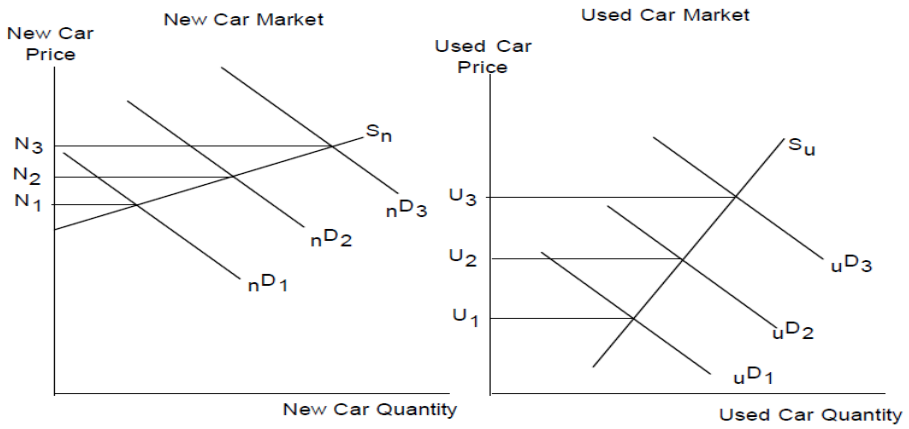
"Income Effect" – A decline of income reduces the demand, the transaction volumes and by this way the prices go down in both markets. On the other hand, it could shift consumption from new to the used market.

Results can be seen in appendix C and the main conclusion is that the interrelations between both markets are not strong enough to entirely explain patterns but in some way the used market of the present is linked to the new market of the past, not just through volumes but also through prices. It is also highlighted that interactions differ in the three countries studied according to a short-term or a long-term perspective but it does experience rigidity of both used car volumes of transactions and new car prices.

Pashigian (2001) observed that USA used car prices index has much more volatility than new car prices index. The author believes that while the new cars price volatility has been lowering through decades, the decline for used cars has been imperceptible regarding the updates in car price index, despite the fact that used cars prices are the more volatile in the Consumer Prices Index.

Second hand automobile markets tended to have less elastic supply curves and to face larger demand shocks compared to those noticed in the first hand cars market and other durable goods markets.

Figure 2 – New and Used Car Price Volatility Caused by demand Shifts



Source: Pashigian, 2001.

The correlation found between annual price ratio for used cars and the annual price ratio for new cars was 0.3, which indicates that a raise in the demand for first-hand cars is positively related with an increase in the demand for second hand cars.

Although there has been a significant amount of academic researches on the subject of durable goods, there are still many questions regarding the existence and organization of secondary markets.

2.2. Economic Crisis and the Automotive Industry

There is a long-standing literature investigating the impact of the current economic crisis on the automobile industry. Over the last years, consumers and companies were forced to respectively rethink their patterns of standard of living and their strategies in a context of a new and a more adverse financial and economic environment.

Using historical data on currency crisis across the world, Dutt and Padmanabhan (2010) analysed the consumer's response to crisis and points out compelling patterns in consumer behaviour. When experiencing a crisis, the consumer behaviour is defined by a consumption smoothing at different levels (inter-temporal, inter-category and intra-category) which by turn reallocate consumption expenses. The authors find out that a crisis main immediate impact is on consumption indicators and the effect persists longer in developing economies when compared to developed economies. They also find that consumption expenditure declines more than income in more than 70% of developing countries. Considering both economies, examining the decline in expenses in the year of the worldwide crisis, on average, the consumption decreased 20% in durable goods, 14,5% in services, 9,5% in semi-durables and a 7% in non-durables. Once more, this leads us to the conclusion that income elasticity of demand is the highest for durables and the lowest for non-durables.

Within this crisis environment, the automotive industry has been also experiencing a downturn. Sturgeon and Van Biesebroeck (2010) stated that with the crisis, the credit market froze and consequently orders were cancelled, the suppliers didn't receive their payments and many plants were forced to shut down, at least temporarily. The debt increased dramatically, the labour costs and fixed-capital costs also became higher, and pension and health care plans turned the situation even worse. Since the automobile market is more expensive and with a growing longevity, buyers in a crisis period tend to postpone their purchases, which they would probably have made within better economic conditions. As the authors mentioned (2010: 6), *"Consumers, especially in the world's largest national passenger vehicle market, the United States, found it difficult to obtain loans for purchase and, driven by fear of job loss, moved aggressively to increase their*

rate of saving. Vehicle sales plunged and as a result, beginning in the fall of 2008, pushing the industry into its most severe crisis since the Great Depression."

Haugh, Mourougane and Chatal (2010) also studied the consequences of the financial crisis in the automobile industry, analyses the evolution through time in different regions and makes a comparison between some countries.

Using econometric estimations, they find out that the current credit constraints could explain more than 80% of the downfall in automobile sales at the end of 2008 in Canada and in USA. The difficulties in accessing to credit led numerous households to delay their car purchases, which in turn resulted in a sharp decline of demand and, consequently, in an excess of the production capacity in major car manufacturers' countries. Hereupon, the authors make some projections (2010:2):

"While a rebound in car sales is likely in North America, Japan and the United Kingdom, car sales in Germany have been pushed significantly above trend and may weaken going forward. Over the medium term, in mature markets such as Europe and North America, trend sales are likely to remain stagnant. By contrast, rapid increases are foreseen in China and to a lesser extent in India" (see appendix D).

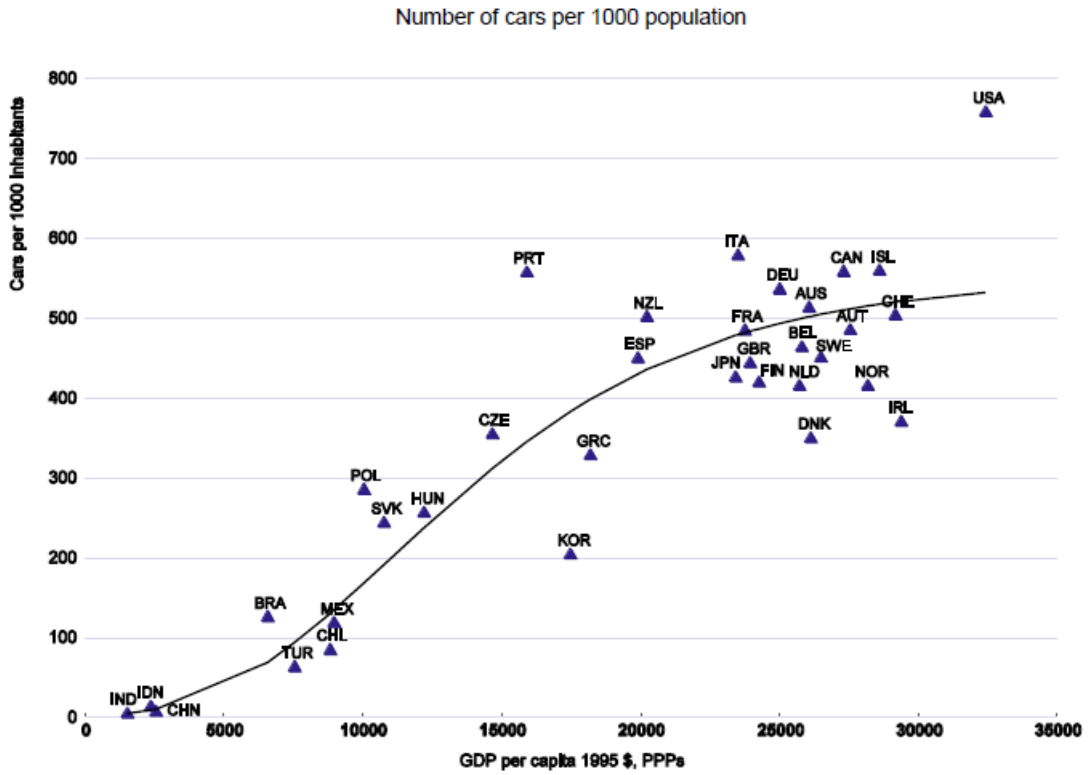
The authors also show a strong correlation between private consumption and car sales and, when comparing to other countries, Portugal is the third with the highest correlation coefficient, after USA and Denmark.

Figure 3 – Correlation between Private Consumption and Car Sales

Source: Datastream; OECD Economic Outlook 86 database (Haugh et al., 2010).

And, although Portugal appears to have a medium/low GDP *per capita*, the country is still on the Top 5 of the countries with the largest number of cars per 1000 inhabitants (Figure 4).

Figure 4 – Car ownership and GDP per capita



Source: Denatran Brazil; United Nations; OECD calculations (Haugh et al., 2010).

2.3. DETERMINANTS OF AUTOMOBILE SALES

Based on the review of researches, several factors have been recognized as influencing car sales, such as the fluctuation in fuel prices, the disposable income and the unemployment rate variations, the new constraints to credit availability, among other issues of concern.

Heim (2008) checked econometrically the relative influence of diverse variables in the consumption function, using USA data from 1960 to 2000. He comes to the conclusion that the current income is undoubtedly the main determinant of consumption, explaining 68% of its variance, followed by a crowd-out variable (14%) - that measures the effect of government deficits on the availability of consumer credit - , wealth (5%), consumer interest rates (2%) and exchange rate changes (1%). The author also compares Keynes to the Friedman/Modigliani hypotheses of consumption function.

While Keynes argued that the demand for goods and services was basically determined by current income and possibly, with smaller effects, by wealth, interest rates, taxes and potential savings; Friedman/Modigliani developed the Permanent Income/Life Cycle Hypotheses, where the desire to keep rationally constant living standards influences the consumption function, since it relies on current income (as Keynes defended), as well as on a person's sense of what their annual average income will be over a longer time horizon. Heim accomplishes that the majority of the fluctuation in consumption is linked with the current income but that the Permanent Income/Life Cycle hypotheses also helps to explain an additional, albeit a minor part of consumer behaviour.

Cruceru and Micuda (2010) drove an analysis of the linkage between lending and the volume of cars sold. To acquire durable goods, such as automobiles, the consumer needs to resort to a certain amount of income, which may arise from the salaries they currently earn or from previously accumulated wealth. Using a Pearson correlation coefficient, they note that since 2009, due to job uncertainty and the decreasing of revenues, buyers turned less to credit. In this paper, we can also find a comparison of the correlation between bank loans and car registrations of different brands, which leads them to conclude that the cars with lower prices are more accessible to low and medium income consumers, who finance their car purchases with credit. By contrast, more expensive or luxury cars were bought with cash by customers with high financial resources.

Gasoline prices are also one of the major factors influencing the decision-making of acquiring a vehicle. Busse, Knittel and Zettelmeyer (2009) investigated whether customers have adjusted to its variations by changing their car purchases not only regarding new and used markets, but also in the prices they pay. As an example, a common driver at early-1999 spent around $758 per year on gasoline and at mid-2008 the same driver would have had to spend up to $ 2968 to travel the same distance in the same car.

Since automobiles are durable goods, potential consumers must take into account not only the initial cost of purchasing a car but also the ongoing costs of using the car and since fuel is one of the largest costs of owning an automobile, it is expectable to be one of the most important determinants in the decision making of acquiring a new one. Consumers can also adjust these usage cost variations by taking advantage of the variety

in fuel efficiency of available vehicles. For instance, the authors found that a $1 increase in gasoline prices changes the market share of the most fuel-efficient type of new cars in +20% and of the least fuel-efficient cars in -24%, while on the other hand, the same increase in gasoline prices changes the market shares of the most and the least fuel-efficient used cars in +3% and -7%, respectively.

The main conclusion of the paper is that changes in usage costs result in larger market changes than price variations regarding new car markets, while in the used car market, the adjustment is primarily made and larger in prices. Thus, it is expected that, in response to fuel price changes, sellers of used cars adjust its price and dealers of new cars choose not to change prices, and experience market share changes instead.

It was very hard to find researches about the influence of different vehicle characteristics on used car pricing. Shing (2002) investigated it, as well as depreciation. The author computed three different econometric models to test the effects of the variables and results showed that both age and mileage caused the value of a car to deteriorate, while original price, horse power and the global origin of the vehicle contributed positively.

Since, average quality of new passenger cars in the Portuguese market is growing at a fast pace and that this phenomenon has to be considered in the estimation of price indexes, Reis and Silva (2002) examined the effects of quality change on the price index for new passenger cars in Portugal since 1997 to 2001. Results revealed that the quality of new cars sold in Portugal during the period studied improved on average 4.8 per cent per year and that the overall CPI may have been overestimated by about 0.15 percentage points per year, which led the authors to suggest the price indexes to be regularly updated since the alterations on the quality of such goods are clearly growing.

An estimation of hedonic prices was also made for cars in Spain (Matas and Raymond, 2009), addressing the instability of coefficients over time. According to the authors, despite car prices index deflated car prices between 1981 and 2005, real car prices fell by 40%, once quality improvements were taken into account in the research. In order to solve the limitation of the instability of the coefficients, which can be found in the majority of other regressions, two alternative estimation procedures were proposed: one based on a moving sample of observations and the other based on moving average of estimation coefficients in single period equations.

There are also many other factors that can influence a car purchasing decision, which are not so visible, such as information availability to consumers, promotional environments and a customer's trade-in (Zeng, Dasgupta and Weinberg, 2012). This research showed that consumers who used the Internet to search for a good and those that were offered a manufacturer rebate saved, on average, $481 and $2,126, respectively. Also, consumers who traded-in their old automobiles ended up paying, on average, $159 more on the new car than consumers who did not trade-in. Another interesting result is that the higher the bargainers' ability, the more price reductions they will achieve since they have greater tendency to search for price information and thus are better at identifying suppliers that offer a lower initial price.

But, as expectable, each variable can have a different impact on the average price and on volume car sales depending upon the country we are studying. Smusin and Makayeva (2009) studied the relationship between ten macroeconomic variables and national car sales based on a sampling from three different countries namely Belarus, Russia and Ukraine. With basic instruments like correlation and the observation of theoretical hypotheses tested with linear regressions, they find that real estate prices are the most strongly correlated variable with car sales. The R^2 of the different models shows that a great portion of car sales fluctuations can be explained by macroeconomic fluctuations - R^2 values were calculated to be 83%, 84% and 75% for Belarus, Russia and Ukraine, respectively. A similar study was made by Muhammad, Hussin and Razak (2012), for five Asian countries: Malaysia, Singapore, Thailand, Philippines and Indonesia. Results showed that GDP, inflation, unemployment rate and loan rate have significant long term correlation with automobile sales and that each country is influenced by different variables in the short term period. Thus, they suggested financial and fiscal policies to prevent such an impact since the sales rate in the automotive sector is one of the most important reference to economic growth in any particular country.

Regarding Portuguese automobile sales, Monteiro and Moutinho (2010) analysed its evolution using a database of 24 years and estimating an econometric model with eleven different variables, such as population, GDP, household disposable income, consumer confidence indicator, unemployment rate, inflation rate, interest rate, fuel prices, VAT rate, loans to firms and rewards to deliver the old car. The authors concluded that there was no statistical evidence about the relationship between car sales and the economic environment. Only inflation rate, unemployment and household disposable income

proved to be statistically relevant. Yet, the factors that influenced automobile sales tended to be different for each vehicle kind, except the unemployment rate and the oil prices, which influenced car sales in every type of automobiles.

3. METHODOLOGY

This section describes the main features of the cross-section data employed in this thesis, as well as the treatment applied in order to make it more manageable and to get a more standard sample. Moreover, it is also referred the statistical methods used to construct a linear regression model and the tests applied in order to investigate the hypotheses of macroeconomic variables impacting on the sale price of a used car.

3.1. DATA SOURCES AND DATA TREATMENT

The dataset used in this dissertation contains vehicles sold by LeasePlan Portugal, in the secondary-market during January 2005 until December 2012. The data was kindly provided by the company, a global fleet and vehicle management enterprise which sells its cars at the end of the renting car contract.

The automobiles included in this sample are only the vehicles sold as a common second hand car. The cars bought with the buyback option for the driver were not included. Despite this, firstly it is better to take into account that some of the vehicles were sold through different types of channels, such as in a B2B or a B2C approach, in auctions, among others, which may have an impact on the average sales price. Secondly, a large part of the cars is sold with only a few years of usage. If by one hand consumers suspect that vehicles being sold with short ages can be due to the bad quality of the car (Akerlof, 1970), on the other hand, they may not have the same felling about short age cars when sold by a renting car company because they know that it happens only due to the end of the vehicle's contract and, consequently consumers can be more disposed to pay a higher price for the automobile. Finally, LeasePlan Portugal offers a two-year warranty, which can positively influence the price that the buyer is willing to pay, as well. However, the average prices of the automobiles are similar to the ones sold in the usual secondary market and to its market value indicator.

The initial number of observations was 70,605. Due to the lack of information for certain variables, a few cars were excluded from the dataset, ending up with 69,810. A subsample was randomly selected with the purpose of testing afterwards the predictive ability of the model, representing less than 10% of the total observations.

For every observation, information is available about the vehicle characteristics, for instance, the model of the car, the extras value, the registration and the sale date as well as the sale price (excluding VAT), among many other features. In the next subsection the reader can find the variables chosen for the model to evaluate the impact of the own nature of the car on its sale price.

Regarding the external forces that could also have impact on the sale price, several economic and financial variables were collected, in the majority from the websites of the Portuguese national bank, the Portuguese automobile association (ACAP), Eurostat, OECD and the European Central Bank.

For each vehicle in the sample it was assigned the respectively value of the different macroeconomic variables, according to the date that the car was sold.

3.2. VARIABLES DESCRIPTION

The variables selected to test in the regression model were mainly divided by the information that represents the specific characteristics of the own car and by the values of macroeconomic factors at the date of sale of the car.

3.2.1. CHARACTERISTICS OF THE OWN VEHICLE

When considering what car to buy, there are many aspects to consider in the decision-making process.

One that has very impact on this decision is the **Brand** that the consumer prefers and that one can afford. The different trademarks of the cars represented in the dataset used in this thesis can be found in Table 1.

Table 1 – Car brands represented in the sample – Absolute (#) and Relative (%) Frequency

Brand	*#*	*%*	*Brand*	*#*	*%*	*Brand*	*#*	*%*
ALFA ROMEO	338	0,48%	*JAGUAR*	58	0,08%	*PORSCHE*	7	0,01%
AUDI	3006	4,31%	*JEEP*	6	0,01%	*RENAULT*	13687	19,61%
BMW	3028	4,34%	*KIA*	19	0,03%	*ROVER*	38	0,05%
CHEVROLET	24	0,03%	*LANCIA*	56	0,08%	*SAAB*	76	0,11%
CHRYSLER	34	0,05%	*LAND ROVER*	31	0,04%	*SEAT*	2069	2,96%
CITROEN	3264	4,68%	*LEXUS*	45	0,06%	*SKODA*	250	0,36%
DODGE	6	0,01%	*MAZDA*	401	0,57%	*SMART*	250	0,36%
FIAT	1226	1,76%	*MERCEDES*	1963	2,81%	*SUZUKI*	36	0,05%
FORD	6603	9,46%	*MINI*	37	0,05%	*TOYOTA*	2091	3,00%
HONDA	358	0,51%	*MITSUBISHI*	640	0,92%	*VOLVO*	733	1,05%
HYUNDAI	135	0,19%	*NISSAN*	595	0,85%	*VW*	7197	10,31%
ISUZU	19	0,03%	*OPEL*	14052	20,13%			
IVECO	101	0,14%	*PEUGEOT*	7331	10,50%	***Total***	*69810*	*100%*

Source: the author.

The **Body Style** is another issue that is very relevant in the buyer's choice. A customer may want to buy a cabriolet car to meet his personal preferences or a minivan to better fit the family needs. He can also wish to buy a small van, for instance, to fulfill the needs of his company.

Hereupon, the **Vehicle Kind** also varies between distinct vehicles inasmuch as the sale price of a passenger car is certainly different from a commercial car. Other aspects to take into account are: the **Fuel Type**, since a diesel automobile is more expensive than a gasoline vehicle; the **Number of Doors** because usually a car with three doors, in Portugal, has less demand than a car with five doors, for instance; and also a car with low **Cylinder Capacity** is cheaper than one with a higher.

Another variable used in the regression model was the car **List Price**, which is the price of the automobile when sold for the first time by the manufacturer to the buyers, including the base price, the price of the options (extras in the vehicle such as leather upholstery, parking sensors, etc.) and the tax on vehicle charged at the moment of the acquisition. The List Price does not include the VAT.

Since the purpose is to analyse the price variations of used cars, it is also relevant to consider depreciation variables such as **Mileage** (in kilometres) and **Age** (in months), at the moment of the vehicle sale. Regarding the mileage, the values were all divided by 1,000 in order to reduce the scale of the variable, when compared with other ones. Concerning the automobile's age, since the devaluation of the car is greater during its first years and smaller when the car has already a higher age, the natural logarithm of this variable was computed and used in the model because the depreciation of the vehicle regarding its age does not seem to be linear.

The color of the vehicle would also be interesting to include in the regression because the demand varies according to the different colors (for instance, black or grey cars have more demand than yellow cars). Therefore, there was not standard information in the sample.

Another interesting variable would be the vehicle's model life-cycle, in other words, it describes whether the car is a facelift of its model or if it was sold before another new version, but it was also not possible to include it in the regression due to the lack of information.

3.2.2. MACROECONOMIC VARIABLES

There were some difficulties when finding macroeconomic variables with daily and monthly frequency since a large part are calculated quarterly and annually, which would not be the desirable for this dissertation since the length of the period represented in the sample (2005-2012) is not so wide to create a significant variation in the variables. It was also challenging to choose the most representative variables of the current conjecture since there are several and also because the majority of them influence each other or indirectly represent the same issue.

Concerning the monthly data, for each observation it was assigned the correspondent value to the month of the date of sale and, regarding the daily data, it was assigned the day in which the car was sold. Vehicles that were sold at the weekend or in day holidays received the previous working day available value.

As mentioned in Busse et al. (2009), one of the larger costs when operating a car is the fuel, which makes it an important issue to take into account when deciding to own one. Hereupon, the variable **real oil prices** was selected to reflect its variations. The higher the oil price, the lower will be the car sales price since consumers will look for less expensive ways of transportation, which will consequently decrease the demand of automobiles. This indicator is represented by the Europe Brent Spot Price (in dollars per barrel).

Another obstacle that has been imposed when making the decision of buying a car is the decreasing access to credit. Most of the automobiles in Portugal are bought with **loans granted to private individuals** whereby the lower the availability of credit to finance the vehicle's purchase, the lower will be the demand as well as the sale price of automobiles. The values represent the annual growth rate of loans granted to households by other monetary financial institutions, in Portugal.

With the same rationale, the higher the **long-term** or the **short-term interest rates** as well as the **three months EURIBOR**, the more expensive will be resorting to credit which in turn also impact negatively on the sale price.

With the global financial crisis, the **unemployment rate** also increased significantly, reducing the disposable income of households and their purchasing power. By this way, consumers delay even more a possible acquisition of a car.

The reduction of the purchasing power might have influenced not only the demand of used cars but especially the volume of new automobile sales. New vehicles are clearly more expensive than used ones and if a buyer does not hold conditions to buy a brand new car, he can choose between keep using the car that he already owns or to purchase a car in the second hand market. Therefore, this thesis also tests the impact of the downturn on **sales of new vehicles** in the price of the cars sold in the Portuguese secondary market. In order to keep it simpler and because the majority of the vehicles in the dataset are passenger cars, only the value of new passenger automobiles are included in the regression model.

Additional economic indexes such as the **Economic Activity**, the **Private Consumption Coincident Indicator**, the **Consumer Confidence** and the **Economic Sentiment Indicators** may also influence the evolution of the average sale price of used automobiles, in a positive way if they increase or negatively if they decline.

The global **harmonized index of consumer prices** can have two counteracting effects: on the one hand the rise of prices in an economy also includes the increase of car prices and the inflation often coincides with the rising of average wages and, consequently, the purchasing power of consumers; on the other hand, if global prices increase, the demand can decrease and, as a result, the car sale price tend to decline. Thus, the inflation is probably one of the less clear intuitive effects on vehicle prices.

Another variable that does not have a very intuitive effect regarding used cars is the e**xchange rate**. If the foreign currency depreciates in relation to the domestic currency, imported cars will also become cheaper (although a large portion is usually bought in countries with the same currency as Portugal). Thus, the demand for new cars will raise and probably the demand for used cars will decrease, lowering its average sale price. On the other hand, the higher the value of the Euro, the greater will be the power purchasing to acquire raw materials, such as oil. By this way, fuel becomes more affordable and automobile's demand raise, thereby increasing the average sale price, even of used vehicles.

Other variables such as disposable income, gross domestic product, private consumption, tax burden, purchasing power and saving rates of households would be also interesting to include in the model, despite some of them are related to each other, but there were not daily nor even monthly information available.

It is expected that some of the aforementioned selected variables to test will eventually be excluded from the regression, since they probably influence each other or even because they basically explain the same issue, leading to multicollinearity problems.

In appendix E, the reader can find the frequency, the units, the expected signs as well as the sources of each macroeconomic variable selected to test in the regression and can also find some graphics about its evolution since 2005 until 2012, in appendix F.

3.3. THE MODEL AND THE ESTIMATION PROCEDURE

In order to examine which variables may have influenced the variations in the sale price of used automobiles from 2005 to 2012 in Portugal, it was considered a linear regression model, where the dependent variable was the sale price of the used car.

The model is presented as follows:

$$\begin{aligned} SP_i = {} & \beta_0 + \beta_1 LP_i + \beta_2\, ALFAROMEO_i + \ldots + \beta_{37} VW_i + \beta_{38} MILEAGE_i + \beta_{39}\, LOG\,(AGE_i) + \\ & \beta_{40} DOORS_i + \beta_{41} DIESEL_i + \beta_{42} CC_i + \beta_{43} CABRIO_i + \ldots + \beta_{57} VAN_i + \beta_{58}\, COMMERCIAL_i \\ & + \beta_{59}\, OILPRICES_i + \beta_{60} LOANS_i + \beta_{61} LONGIR_i + \beta_{62} SHORTIR_i + \beta_{63} EURIBOR_i + \\ & \beta_{64} UNEMP_i + \beta_{65} SALESNEW_i + \beta_{66} ECONACT_i + \beta_{67} PCIND_i + \beta_{68} CONSCONF_i + \\ & \beta_{69} ECONSENT_i + \beta_{70}\, HIPC + \beta_{71}\, EXCRATE_i + \varepsilon_i \end{aligned} \qquad (I)$$

Where,

SP_i	Sale Price of the vehicle *i*
LP_i	List Price of the vehicle *i*
$ALFAROMEO_i$	A dummy variable which assumes the value 1 if the Brand of the vehicle *i* is Alfa Romeo and the value 0, otherwise
VW_i	A dummy variable which assumes the value 1 if the Brand of the vehicle *i* is Volkswagen and the value 0, otherwise There are 36 dummy variables representing the same number of sold brands.
$MILEAGE_i$	Mileage of the vehicle *i* at the moment of sale
$LOG\,(AGE_i)$	Natural logarithm of the age of the vehicle *i* at the moment of sale
$DOORS_i$	Number of doors of the vehicle *i*
$DIESEL_i$	A dummy variable which assumes the value 1 if the fuel type of the vehicle *i* is diesel and the value 0 if gasoline
CC_i	Cylinder Capacity of the vehicle *i*
$CABRIO_i$	A dummy variable which assumes the value 1 if the body style of the vehicle *i* is cabriolet and the value 0, otherwise

VAN_i	A dummy variable which assumes the value 1 if the body style of the vehicle *i* is van and the value 0, otherwise There are 15 dummy variables representing the same number of different body styles.
$COMMERCIAL_i$	A dummy variable which assumes the value 1 if the *i* is a commercial vehicle and the value 0 if *i* is a passenger car
$OILPRICES_i$	Price of imported oil barrel to European countries, at the date of sale of the vehicle *i*
$LOANS_i$	Loans granted to private individuals by other monetary financial institutions in Portugal, at the date of sale of the vehicle *i*
$LONGIR_i$	Long-term Interest Rate in Portugal, at the date of sale of the vehicle *i*
$SHORTIR_i$	Short-term Interest Rate in Portugal, at the date of sale of the vehicle *i*
$EURIBOR_i$	Three months EURIBOR, at the date of sale of the vehicle *i*
$UNEMP_i$	Harmonized Unemployment Rate in Portugal, at the date of sale of the vehicle *i*
$SALESNEW_i$	Sales of New Passenger Vehicles in Portugal, in the month of sale of the vehicle *i*
$ECONACT_i$	Economic Activity Coincident Indicator in Portugal, at the date of sale of the vehicle *i*
$PCIND_i$	Private Consumption Coincident Indicator in Portugal, at the date of sale of the vehicle *i*
$CONSCONF_i$	Consumer Confidence Indicator in Portugal, at the date of sale of the vehicle *i*
$ECONSENT_i$	Economic Sentiment Indicator in Portugal, at the date of sale of the vehicle *i*
$HICP_i$	Harmonized Indicator of Consumer Prices in Portugal, at the date of sale of the vehicle *i*
$EXCRATE_i$	Reference Exchange Rate US dollar to Euro, at the date of sale of the vehicle *i*
ε_i	The error term.

Initially the model was estimated in SPSS using the stepwise procedure, in order to determine which of the variables explained the most variation of the dependent variable and also to obtain multicollinearity diagnostics. Thereafter, without the variables whose estimated coefficients are not statistically significant and the variables excluded because of the possible aforementioned problems, the regression was estimated in EViews, by the Ordinary Least Squares (OLS) method, to detect and to test other problems related with errors of the model, specially the heteroskedasticity.

Also, in order to identify possible outliers when analysing the OLS regression residuals, the following criterion was applied: the observations whose residual absolute value was higher than three standard deviations were excluded from the estimation process.

Having the regression procedures finalized, certain out-of-sample analyses were made with the purpose of testing the performance of the regression. The results of the econometric model, the tests procedures and the out-of-sample analysis can be found in the next section.

4. RESULTS

In this section the estimation procedure and the econometric tests will be described almost step-by-step and the results obtained will be revealed. Also, the out-of-sample results will be analysed in order to conclude about the predictive ability of the estimated regression.

4.1. ECONOMETRIC TESTING PROCEDURE

As described in the previous section, it was used a criterion to exclude some outliers based on the absolute value of residuals since it could bias or distort the OLS estimates. The impact of this decision in the estimation results can be observed in appendix G. Only a few outliers were identified and the model was estimated with the suspected outliers excluded.

When using the stepwise method in SPSS there was evidence of multicollinearity problems, as expected, which means that one or more predictor variables in the regression were highly correlated. Hence, the explanatory variables Economic Sentiment Indicator, Short-term Interest Rate, Three Months EURIBOR, Harmonized Index of Consumer Prices, Private Consumption Coincident Indicator and Harmonized Unemployment Rate have been excluded from the regression due to its statistically insignificance or due to multicollinearity problems.

After the estimation procedure in SPSS, the regression was also estimated in EViews in order to perform other statistical specification tests[1].

The result of the White test showed that there was evidence of heteroskedasticity, which means that we cannot assume the constant variance for the errors, given the explanatory variables. Hence, despite heteroskedasticity does not cause bias or inconsistency in the OLS estimators, the usual OLS standard errors were no longer valid for constructing confidence intervals and statistics such as *t*, *F* or *LM*, even though we are dealing with a large sample size.

[1] Due to the data cross section nature, autocorrelation tests were not performed.

Table 2 – Heteroskedasticity Test: White

F-statistic	189.6809	Prob. F(55,62138)	0.0000
Obs*R-squared	8819.416	Prob. Chi-Square(55)	0.0000
Scaled explained SS	11521.01	Prob. Chi-Square(55)	0.0000

Source: Eviews output.

To handle this problem, the regression was reestimated with White's heteroskedasticity robust standard errors which allow us to resort to the usual statistical inferences regardless of the absence of homoskedasticity.

4.2. EMPIRICAL FINDINGS

After estimating the model both in SPSS and in EViews with the aim of diagnosing possible problems such as multicollinearity and heteroskedasticity, the linear regression and its output was prepared to be analysed.

The coefficient of determination, is quite high (R^2 = 0.925823), which means that, for this sample, the explanatory variables included in the model explain almost 92,6% of the total variation in a used car sale price and only 7,4% of the variation of dependent variable is not explained in the regression. Thus, the independent variables selected for the regression are actually good predictors of second hand car prices. The adjusted R-squared is also very similar ($\bar{R}^2$ = 0.925758) to the R^2.

The output with the model estimated coefficients can be observed in Table 3.

Table 3 – Linear Regression Output

	Coefficient	Std. Error	t-Statistic	Prob.
C	11158.90	145.7636	76.55477	0.0000
AUDI	2409.623	41.14559	58.56335	0.0000
BMW	2398.990	47.48849	50.51729	0.0000
CHRYSLER	-3149.331	347.4787	-9.063378	0.0000
CITROEN	-771.9160	26.87103	-28.72670	0.0000
FIAT	-998.2858	36.05489	-27.68794	0.0000
FORD	-397.7688	19.79568	-20.09372	0.0000
HONDA	232.9632	68.98803	3.376863	0.0007
HYUNDAI	-1312.148	71.92558	-18.24313	0.0000
JAGUAR	852.3758	295.2434	2.887028	0.0039
JEEP	-6767.093	296.9955	-22.78517	0.0000
KIA	-1782.144	312.4893	-5.703058	0.0000
LANCIA	-1447.341	240.4237	-6.019961	0.0000
LAND_ROVER	962.7512	481.9386	1.997664	0.0458
LEXUS	958.3688	325.0830	2.948074	0.0032

MAZDA	-225.5645	73.21552	-3.080829	0.0021
MERCEDES	2571.026	62.95885	40.83661	0.0000
MINI	3861.298	271.0871	14.24375	0.0000
OPEL	-623.2089	16.85546	-36.97372	0.0000
PORSCHE	8537.166	119.5546	71.40809	0.0000
RENAULT	-268.1776	16.23690	-16.51655	0.0000
ROVER	-1738.735	169.3407	-10.26768	0.0000
SAAB	-1469.390	201.1253	-7.305844	0.0000
SEAT	276.6364	31.14046	8.883502	0.0000
SKODA	-346.4122	79.42836	-4.361316	0.0000
SUZUKI	-703.0728	194.7766	-3.609636	0.0003
TOYOTA	816.4546	31.92086	25.57746	0.0000
VOLVO	372.9600	65.34692	5.707384	0.0000
VW	956.3935	24.77699	38.60006	0.0000
CABRIO	1729.983	202.5157	8.542462	0.0000
WAGON	204.8322	12.97848	15.78245	0.0000
CHASSIS_CABIN	-714.2399	69.81659	-10.23023	0.0000
COMBI	1105.965	319.3305	3.463387	0.0005
COUPE	1975.522	95.58601	20.66748	0.0000
SMALL_VAN	-703.5520	30.26037	-23.24995	0.0000
HARDTOP_RETRACTIL	1788.358	164.2990	10.88477	0.0000
MINIVAN	806.6357	33.15088	24.33226	0.0000
PICK_UP	1627.055	51.76052	31.43428	0.0000
ROADSTER	3096.696	580.5448	5.334120	0.0000
STATIONWAGON	-364.1375	50.49825	-7.210893	0.0000
CROSSOVER	1407.045	100.0234	14.06715	0.0000
VAN	718.5952	25.05935	28.67573	0.0000
COMMERCIAL	-1824.117	28.44320	-64.13191	0.0000
DIESEL	2057.625	24.54102	83.84429	0.0000
DOORS	124.8407	12.43517	10.03933	0.0000
CYLINDER_CAPACITY	0.611431	0.038934	15.70428	0.0000
LIST_PRICE	0.302238	0.001797	168.1947	0.0000
MILEAGE	-16.82352	0.118483	-141.9911	0.0000
LOG(AGE)	-2644.265	20.09529	-131.5863	0.0000
OILPRICES	-8.472942	0.416302	-20.35289	0.0000
LOANS	14.56981	2.409755	6.046179	0.0000
LONGIR	-26.85940	3.898600	-6.889500	0.0000
SALESNEW	-0.004415	0.001409	-3.133621	0.0017
ECONACT	217.1968	4.976032	43.64859	0.0000
CONSCONF	14.82682	1.003872	14.76964	0.0000
EXCRATE	1224.335	78.67537	15.56186	0.0000

R-squared	0.925823	Mean dependent var	9351.784
Adjusted R-squared	0.925758	S.D. dependent var	4693.359
S.E. of regression	1278.821	F-statistic	14101.61
Sum squared resid	1.02E+11	Prob(F-statistic)	0.000000
Log likelihood	-533155.4	Durbin-Watson stat	1.271392

Source: Eviews output.

As one can notice, results suggest that all the estimated coefficients associated to explanatory variables that represented the vehicle's own characteristics are statistical significant for a 5% significance level.

The dummies' estimated coefficients can be interpreted as follows: on average, if the used car is a commercial vehicle, it is expected to worth approximately less €1824.12 than a passenger car as well as if the automobile's fuel type is diesel it is estimated to worth around €2057.63 more, on average, than a gasoline car.

Regarding quantitative variables, the linear functional form was estimated.

Its interpretation should be made as, for instance, if the car List Price increases €1000, the expected variation on the sale price of the used car will be approximately €302.24, on average, if everything else remain constant. The same happens with the automobile's mileage: on average, the used car sale price is expected to decrease around €168.24 per each 10,000 miles driven, *ceteris paribus*. Regarding the age, since the variable was assessed with the natural logarithm, its interpretation should be as follows: if the vehicle's age (in months) increases 1%, the car sale price is expected to decrease around €26.44, on average, if all the rest remain constant.

Just for the sake of curiosity, some descriptive statistics of the quantitative variables representing the own vehicle's features can be found in the following table:

Table 4 – Descriptive statistics of some explanatory variables, concerning the vehicle's own characteristics

Variable	*Mean*	*Standard Deviation*	*Minimum*	*Maximum*
List Price (in euros)	22.683,09	10.735,36	6.120,17	164.531,06
Cylinder Capacity (in units)	1.660,81	370,11	599,00	5.439,00
Mileage (in thousands of units)	113,51	49,16	10,00	269,99
Age (in months)	44	11	12	97

Source: the author.

The macroeconomic factors that at the end showed to have influence on the used car sale price were: Real Oil Prices; Loans granted to Private Individuals; Long-term Interest Rates; Sales of New Passenger Vehicles; Economic Activity Coincident Indicator; Consumer Confidence Indicator; and, finally, Exchange Rate. All the variables assumed the initially expected signs and the Exchange Rate, which seemed to be less intuitive, assumed a positive sign which means that, on average, the higher the exchange rate, the higher will be the sale price of a used car.

The interpretation of the macroeconomic variables coefficients estimated in the regression should be also made according to the way it was previously described. In other words, if the price of the barrel imported to European countries increases $1, the used car sale price is estimated to decline €8.47, on average, *ceteris paribus*, as well as if Consumer Confidence Indicator raises by one unit, the dependent variable is expected to increase, on average, €14.83, if all the rest remain constant. By the same way, the expected variation on the used car sale price in response to more 10,000 new passenger vehicles sales, is a reduction of approximately €44.15, on average, if everything else remain constant. If long-term interest rates raise one unit, the second hand car sale price is expected to decrease, on average, €26.86, *ceteris paribus,* for instance.

Other variables such as Economic Sentiment Indicator, Short-term Interest Rate, three months EURIBOR, Harmonized Index of Consumer Prices, Private Consumption Coincident Indicator and Harmonized Unemployment Rate were dropped from the regression, because they proved to have multicollinearity problems, as previously expected.

4.3. Out-of-Sample Analysis

As previously mentioned, 6,810 vehicles were randomly selected and removed from the initial sample in order to further test the regression model proposed in this dissertation. This out-of-sample include automobiles with sale dates spread over the years from 2005 to 2012 and almost all the different Brands and Body Styles used in the estimated model.

For each used car in the out-of-sample, the predicted sale price was computed using the estimated regression and then this result was compared with the sale price actually observed. Also, some measures based on prediction errors were computed in order to investigate the predictive capacity of the estimated model.

The mean error result was -27.00895, which means that the predicted values are somewhat biased because the estimated values of the sale price are higher in €27.01, on average, than the observed values. This difference is very small taking into account the independent variable scale. But, since the errors tend to nullify each other (some are negative and other are positive), other adjusted measures were calculated with the

purpose of better evaluating the closeness between the predicted values and the values actually observed.

The Mean Absolute Percentage Error (MAPE) gives an insight of the weight of the errors percentage and is given by:

$$MAPE = \frac{\sum_{t=1}^{T} \frac{|y_t - \hat{y}_t|}{y_t}}{T} \quad (\text{II})$$

where y_t and $\hat{y}_t$ represents the observed values and the estimated values of the dependent variable, respectively. Its result was 13.65%, which leads to the conclusion that, taking into account that the sample size is large, the weight of the percentage errors is small.

Another performance measure used was Theil's inquality coefficient, also known as Theil's U, was computed as follows:

$$U = \frac{\sqrt{\frac{1}{T}\sum_{t=1}^{T}(y_t - \hat{y}_t)^2}}{\sqrt{\frac{1}{T}\sum_{t=1}^{T} y_t^2 + \frac{1}{T}\sum_{t=1}^{T} \hat{y}_t^2}}, \quad (\text{III})$$

The obtained result was U = 0.1016. The Theil's U statistic is bounded between 0 and 1 where the more accurate the forecasts, the lower will be the value of the U statistic. Since the result is low and the value is closer to zero, the adjustment between the observed and the estimated values is quite good.

The following formulas were also computed:

$$U^M = \frac{(\bar{y} - \bar{\hat{y}})^2}{\frac{1}{T}\sum_{t=1}^{T}(y_t - \hat{y}_t)^2} \quad (\text{IV})$$

$$U^S = \frac{(s_o - s_a)^2}{\frac{1}{T}\sum_{t=1}^{T}(y_t - \hat{y}_t)^2} \quad (\text{V})$$

$$U^C = \frac{2(1-r)s_o s_a}{\frac{1}{T}\sum_{t=1}^{T}(y_t - \hat{y}_t)^2} \quad (\text{VI})$$

Where $\bar{y}, \bar{\hat{y}}, s_o$ and s_a are respectively the sample means and standard-deviation of y_t and $\hat{y}_t$ and r represents the linear correlation coefficient between the observed and the estimated values.

The value of U^M measures systematic errors and if a high value is observed (greater than 0.1 or 0.2), this means that there is a systematic bias. Since the U^M result, regarding the out-of-sample, is 0.0003 it leads us to conclude that there is no evidence of systematic errors in the difference between the observed and the estimated values.

U^S provides an insight about the difference between the standard deviations among the observed and the estimated values. The value obtained was 0.025. If the result was high, it would mean a greater variability between each series, explaining a large portion of the inequality between the values.

U^C measures the unsystematic error and the lower the correlation coefficient between the observed and the estimated values, the higher will be U^C. The result of U^C was 0.975.

The ideal allocation of inequality among these three measures would be $U^M = U^S = 0$ and $U^C = 1$. As one can see, despite the results obtained are not perfect, its values seem to be good, which can lead us to conclude that the estimated regression has a certain predictive capacity and a somewhat forecasting accuracy.

5. DISCUSSION

5.1. MAIN CONCLUSIONS

In a context of a global economic and financial crisis, many macroeconomic factors have taken a different course: the difficulties felt in the banking system tightened the access to credit not only for private individuals but also for companies; the majority of consumers had to reconsider their consumption habits and to reallocate their income and expenditures in order to maximize their benefits; national production resented and generated a high unemployment level; among many other aspects.

Specifically, the automobile industry in Portugal suffered many consequences and registered a fall of more than 59% regarding the Portuguese new vehicles sales, from 2005 until 2012. When facing such a stressful financial situation, the buyer can decide to postpone its new car purchasing or can even prefer to buy a car in the secondary market instead of acquiring a brand new car. Therefore, if by one hand the sale of new automobiles fell significantly, on the other hand sales of used cars may have benefited from it.

The purpose of this thesis was to examine the impact of the current economic environment on the sale price of second hand vehicles sold in Portugal, since 2005 to 2012. In order to achieve this goal, a linear regression model was estimated using OLS procedures and this estimation was based on a sample of used cars sold by the major Portuguese renting company. The regression was comprised with the own characteristics of the vehicle (such as Brand, Body Style, Cylinder Capacity, Age at sale, Fuel Type, etc.) and with some macroeconomic variables. The dependent variable was the used car sale price.

Results suggest that not only the vehicle's own features are statistically significant, but there is also evidence that macroeconomic factors actually have impact on the dependent variable. Variables such as Real Oil Prices, Exchange Rate, Long-term Interest Rates, Loans granted to Private Individuals, Economic Activity Coincident Indicator, Consumer Confidence Indicator and Sales of New Passenger Vehicles proved to influence used automobile sale price and all of them assumed the expected signs.

An out-of-sample was used to analyse the predicting capacity of the estimated regression and some measures based on prediction errors were computed in order to

evaluate this issue. Even though results are not perfect, they seem to be good, which can lead to conclude that the estimated model has a relevant predictive capacity and a somewhat forecasting accuracy.

The conclusion of the research is that in fact macroeconomic variables may have influence on the sale price of a second hand vehicle and an econometric model comprised with the car's own characteristics and macroeconomic variables can have a great predictive capacity, which may be useful to pricing purposes or just for asset valuation.

5.2. Limitations and Further Researches

One of the major limitations of the thesis was the difficult access to macroeconomic variables. Other factors such as the households' disposable income, the saving rates and the tax burden, for instance, would also be interesting to test in the regression model but they were not all available mainly because they are just computed quarterly or even annually. The data available about second hand cars in Portugal is also scarce and restricted.

At the predictive level, there are no available forecasts for the values of the macroeconomic variables included in the regression which constraints the predictive capacity of the model for the future. One possible solution is to conceive three different scenarios: one optimistic, one pessimistic and one somewhat in the middle.

Another limitation was the fact that there may be a lag between the variables time and the moment that the buyer actually takes its values into consideration. Many times, consumers (households or companies) do not react immediately to variations in the macroeconomic explanatory variables but tend to do it only after a certain period of time. For example, if the buyer decides to buy a car at time *t,* he can only take into consideration the values of the indicators of *t-1*.This would be an important issue to address in further researches.

An additional interesting research would be to investigate which macroeconomic variables may impact on new vehicle sale price and it would also be stimulating to study more deeply the relationship between new automobile and used vehicles sales, in volume and in prices, during the last years within an environment of economic crisis.

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Associação Automóvel de Portugal (the Portuguese automobile association)
www.acap.pt

Banco de Portugal (the Portuguese national bank)
www.bportugal.pt

Bank of Finland
www.suomenpankki.fi/en

ECB Statistical Data Warehouse
sdw.ecb.europa.eu

Eurostat
ec.europa.eu/eurostat

International Organisation of Motor Vehicle Manufacturers
www.oica.net

Organisation for Economic Co-operation and Development
www.oecd.org

U.S. Energy Information Administration
www.eia.gov

APPENDIXES

Appendix A

Table 5 – Sales of New Vehicles by country 2005-2012

REGIONS/COUNTRIES	2005	2006	2007	2008	2009	2010	2011	2012	Variation rate 2005-2012	Annual growth rate
EUROPE - Top 15 declines	21.141.298	21.972.212	23.075.368	21.923.546	18.661.876	18.799.111	19.731.905	18.650.167	-11,8%	-1,8%
1. GREECE	295.266	294.060	306.875	292.865	237.118	153.842	104.682	62.518	-78,8%	-19,9%
2. HUNGARY	219.461	209.280	193.581	174.837	70.808	55.221	60.993	68.168	-68,9%	-15,4%
3. ROMANIA	248.462	282.985	356.577	325.867	133.561	104.090	95.508	80.723	-67,5%	-14,8%
4. SPAIN	1.959.488	1.953.134	1.939.298	1.362.586	1.074.222	1.114.119	931.404	790.991	-59,6%	-12,2%
5. PORTUGAL	278.470	265.174	276.606	275.127	203.760	272.754	191.362	113.435	-59,3%	-12,0%
6. ICELAND	20.870	20.198	19.305	10.579	2.471	3.395	5.471	8.507	-59,2%	-12,0%
7. IRELAND	213.706	225.723	236.353	185.620	68.031	99.986	102.443	91.728	-57,1%	-11,4%
8. CROATIA	79.675	89.092	94.695	100.415	50.859	42.031	45.935	35.654	-55,3%	-10,9%
9. CYPRUS	20.986	22.383	27.517	27.533	18.419	17.920	15.958	11.563	-44,9%	-8,2%
10. ITALY	2.495.436	2.606.375	2.777.175	2.421.918	2.357.443	2.164.153	1.942.949	1.534.889	-38,5%	-6,7%
11. BULGARIA	34.940	45.300	55.336	57.927	26.813	20.082	22.910	23.419	-33,0%	-5,6%
12. FINLAND	168.121	166.673	147.842	160.998	103.016	126.396	144.425	126.505	-24,8%	-4,0%
13. UKRAINE	348.767	511.788	607.256	705.926	207.258	189.701	230.890	263.604	-24,4%	-3,9%
14. UNITED KINGDOM	2.828.127	2.734.360	2.799.619	2.485.258	2.222.542	2.293.576	2.249.483	2.333.763	-17,5%	-2,7%
15. SLOVENIA	67.856	67.836	78.398	81.631	63.286	66.871	67.451	57.042	-15,9%	-2,4%
AMERICA	23.276.227	23.287.602	23.546.381	20.854.880	17.494.287	19.655.177	21.499.758	23.597.495	1,4%	0,2%
NAFTA	20.206.239	19.854.707	19.250.526	16.192.207	12.838.518	14.176.013	15.566.720	17.489.861	-13,4%	-2,0%
UNITED STATES OF AMERICA	17.444.329	17.048.981	16.460.315	13.493.165	10.601.368	11.772.219	13.040.613	14.785.936	-15,2%	-2,3%
MEXICO	1.131.768	1.139.718	1.099.866	1.025.520	754.918	820.406	905.886	987.747	-12,7%	-1,9%
CENTRAL & SOUTH AMERICA	3.069.988	3.432.895	4.295.855	4.662.673	4.655.769	5.479.164	5.933.038	6.107.634	98,9%	10,3%
ARGENTINA	380.189	441.420	558.547	599.950	507.794	652.402	846.851	832.026	118,8%	11,8%
BRAZIL	1.714.644	1.927.738	2.462.728	2.820.350	3.141.240	3.515.066	3.633.253	3.802.071	121,7%	12,0%
ASIA/OCEANIA/MIDDLE EAST	19.878.503	21.423.412	23.220.428	24.012.039	28.071.003	34.897.706	35.304.821	38.027.738	91,3%	9,7%
JAPAN	5.852.034	5.739.520	5.309.200	5.082.233	4.609.333	4.956.148	4.210.224	5.369.721	-8,2%	-1,2%
AUSTRALIA	988.269	962.666	1.049.982	1.012.164	937.328	1.035.574	1.008.437	1.112.132	12,5%	1,7%
INDIA	1.440.455	1.750.892	1.993.721	1.983.071	2.266.269	3.040.390	3.287.737	3.576.756	148,3%	13,9%
CHINA	5.758.189	7.215.972	8.791.528	9.380.502	13.644.794	18.061.936	18.505.114	19.306.435	235,3%	18,9%
AFRICA	1.135.659	1.338.354	1.350.442	1.285.751	1.188.074	1.276.521	1.390.462	1.463.696	28,9%	3,7%
ALL COUNTRIES	65.431.687	68.021.580	71.192.619	68.076.216	65.415.240	74.628.515	77.926.946	81.739.096	24,9%	3,2%

Source: table designed by the author, based on information available on the OICA website.

Appendix B

Appendix B1

Table 6 – Cyclical Properties of Consumption and Investment

Chain volumes; quarterly percentage changes in trend measures; 1960 to 2010

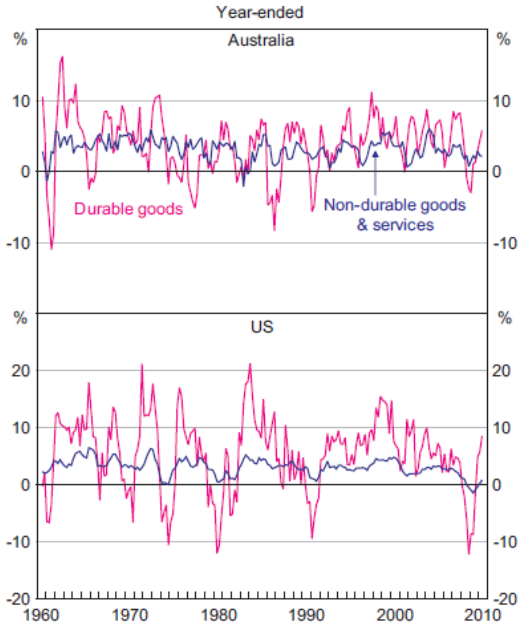
	Durable goods consumption	Non-durable goods consumption	Services consumption	Machinery & equipment investment
Correlation with GDP[a]				
Australia	0.63	0.20	0.34	0.50
US	0.79	0.75	0.67	0.82
Volatility relative to GDP[b]				
Australia	1.9	0.9	0.7	4.6
US	2.7	0.8	0.6	3.4

(a) The correlation coefficient shows how much two variables co-vary compared to their standard deviations. It ranges between –1 and 1 (where 1 indicates the series have proportional changes in the same direction)
(b) This is expressed as the ratio of the standard deviation of the series to the standard deviation of GDP growth

Source: ABS; Bureau of Economic Analysis (Black and Cusbert, 2010).

Appendix B2

Figure 5 – Consumption Volumes Growth in Australia and USA



Source: ABS; Bureau of Economic Analysis (Black and Cusbert, 2010).

Appendix C

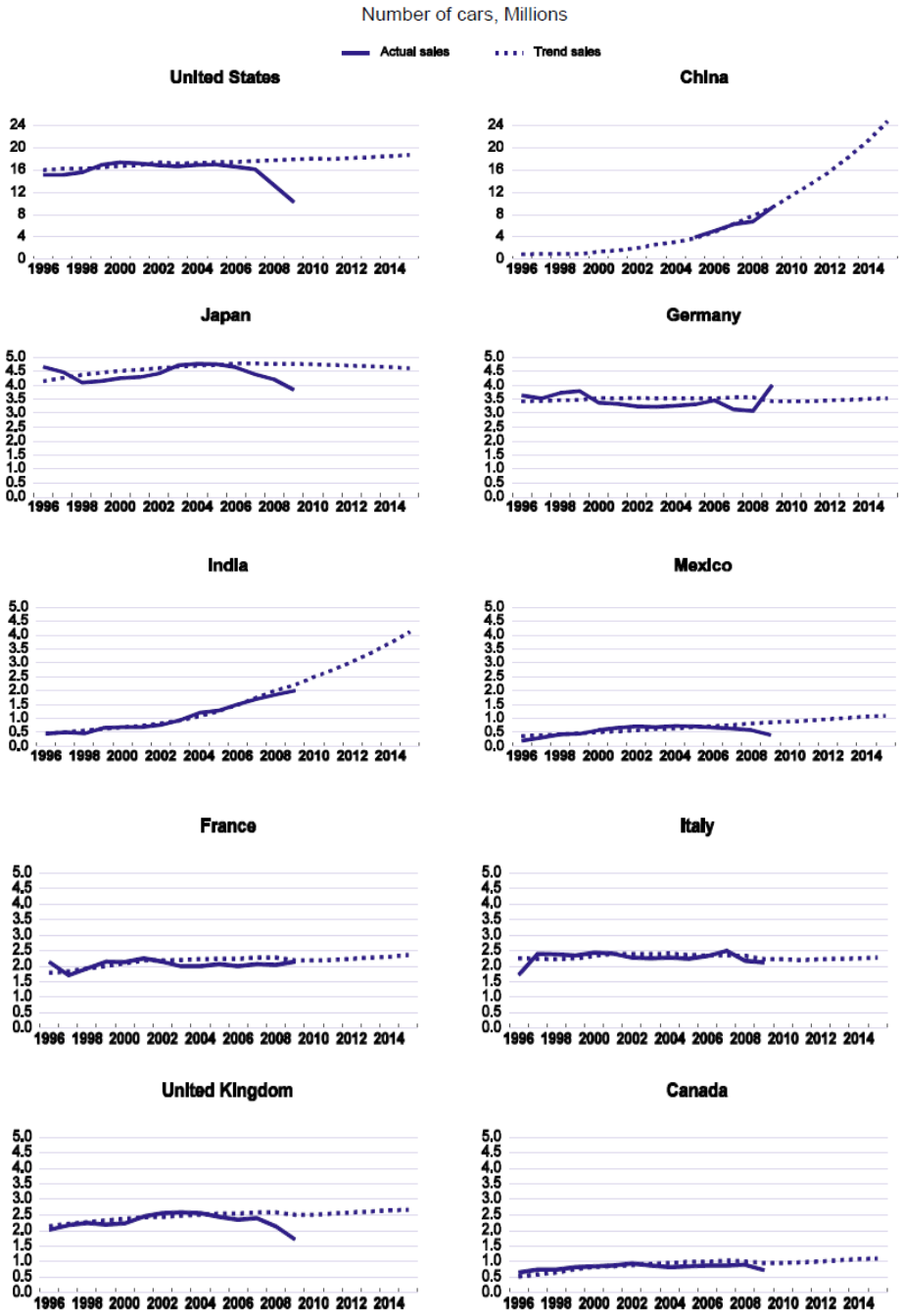
Table 7 – General Conclusions on Basics Mechanisms

Mechanisms	Results and Comments
New market feeds used market	The trend analysis illustrates a feed effect on a volume perspective in all markets. For the US market, new and used car sales time series are cointegrated. Additionally, the Hodrick-Prescott filter suggests that used car prices of today are related to new car prices of yesterday.
Reallocation	Correlation calculations suggest an instantaneous Reallocation effect, between the new and the used market, on volumes in France and on prices in the US
Arbitration	Correlation calculations suggest an instantaneous Arbitration effect, between the new and the used market, on prices in France and on volumes in the US.
Renewals	The Hodrick-Prescott filter did not allow a clear identification of a renewal effect in any of the three countries, neither in the new or the used market. It is may be due the limited sample (ten years) used in the study.
Price effect / Volume effect	They are no significant results for France and the UK. Regarding the US market, we noticed that in line with Scitovsky theory, prices impact volumes in both directions.
Income effect 1 / Income effect 2	Although our results suggest some income effects, it needs to be confirmed through a proper analysis of the relations between disposables incomes and car market volatility.

Source: Prado, 2009.

Appendix D

Figure 6 – Actual and trend Car Sales 1995 - 2015



Source: OECD calculations; Datastream; China Association of Automobile Manufacturers (Haugh et al., 2010).

Appendix E

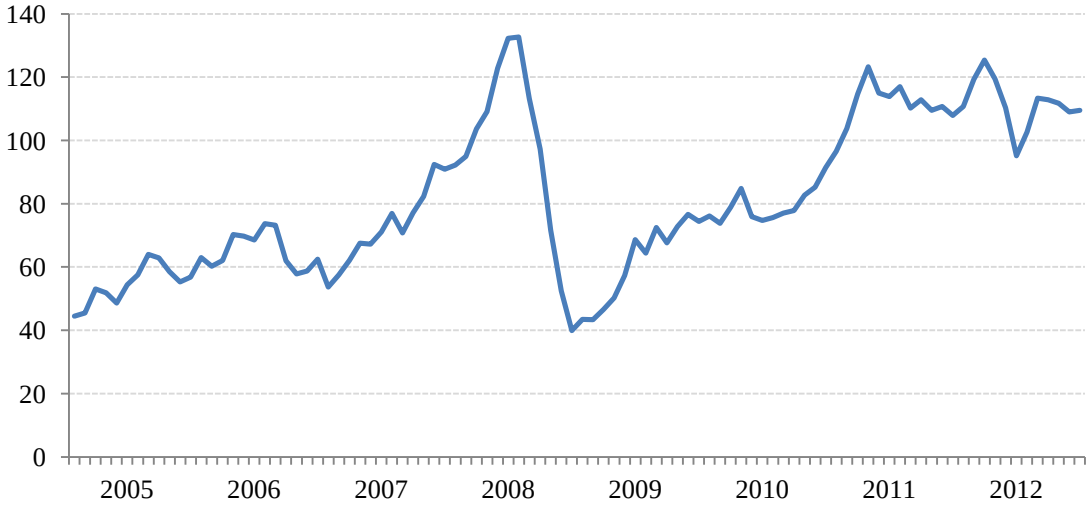
Table 8 – General information about the macroeconomic variables tested in the linear regression model

Variable	Variable Name in the Regression	Frequency	Units	Expected Sign	Source
Real Oil Prices	OILPRICES	Daily	US Dollars per Barrel	Negative	U.S. Energy Information Administration
Loans to Private Individuals	LOANS	Monthly	Annual Growth Rate	Positive	Banco de Portugal
Long-term Interest Rates	LONGIR	Monthly	Rate	Negative	OECD
Short-term Interest Rates	SHORTIR	Monthly	Rate	Negative	OECD
Three Months EURIBOR	EURIBOR	Daily	Rate	Negative	Bank of Finland
Harmonized Unemployment Rate	UNEMP	Monthly	Percent	Negative	OECD
Sales of New Passenger Vehicles	SALESNEW	Monthly	Units	Negative	ACAP
Economic Activity Coincident Indicator	ECONACT	Monthly	Year-on-year Rate of Change	Positive	Banco de Portugal
Private Consumption Coincident Indicator	PCIND	Monthly	Year-on-year Rate of Change	Positive	Banco de Portugal
Consumer Confidence Indicator	CONSCONF	Monthly	Index	Positive	Banco de Portugal
Economic Sentiment Indicator	ECONSENT	Monthly	Index	Positive	Banco de Portugal
Harmonized Index of Consumer Prices	HICP	Monthly	Index	Positive/Negative	EUROSTAT
Exchange Rate	EXCRATE	Daily	US Dollar to Euro	Positive/Negative	European Central Bank

Source: the author.

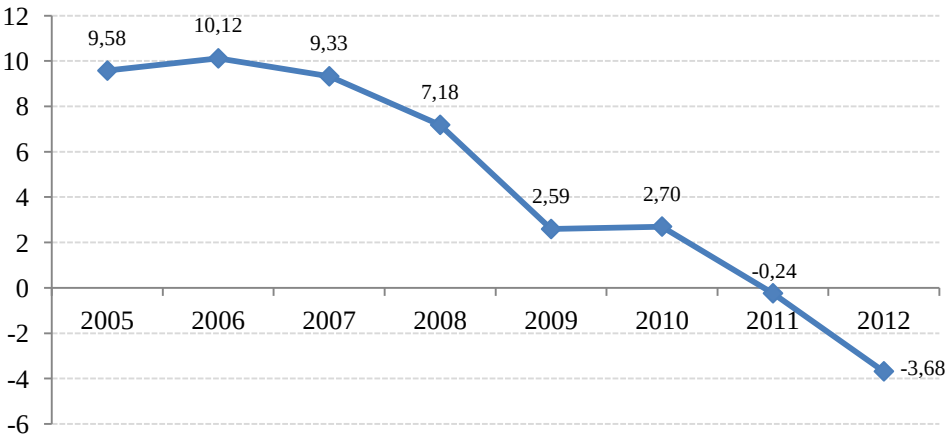
Appendix F

Figure 7 – Real oil Prices – Europe Brent Spot Price FOB (dollars per barrel)



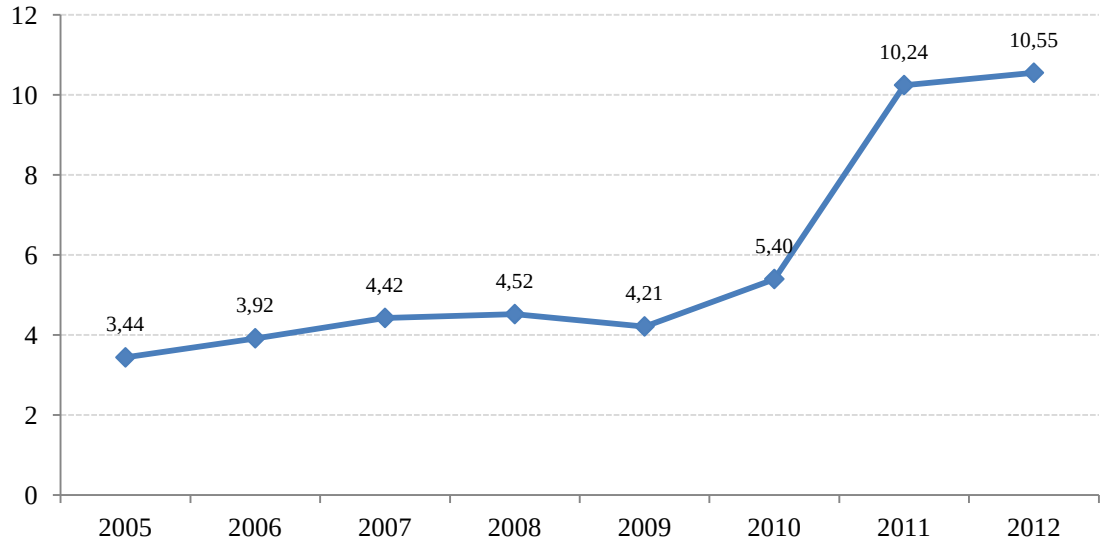
Source: chart created by the author, based on the data available on the U.S. Energy Information Administration website.

Figure 8 – Loans of OMFIs to private individuals, in Portugal (annual growth rate)



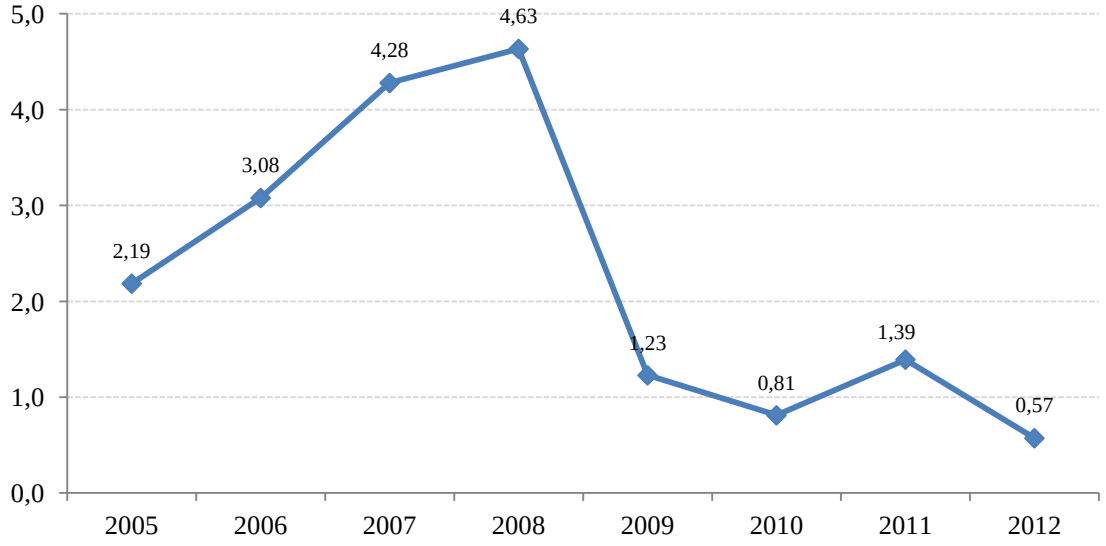
Source: chart created by the author, based on data available on the Banco de Portugal website.

Figure 9 – Long-term interest rates, in Portugal



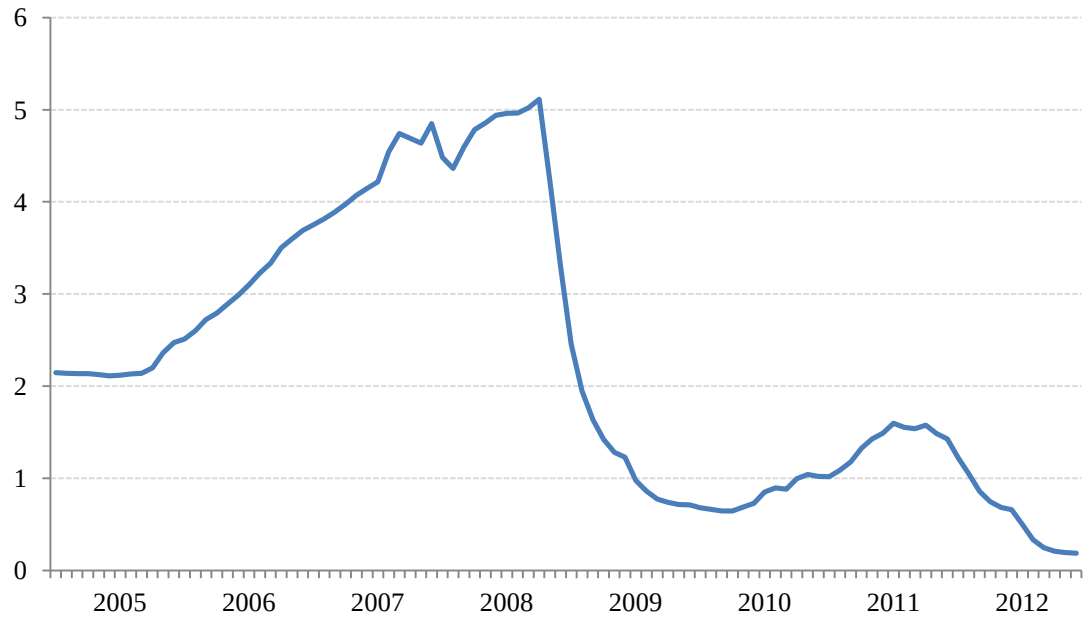
Source: chart created by the author, based on data available on the OECD website.

Figure 10 – Short-term interest rates, in Portugal



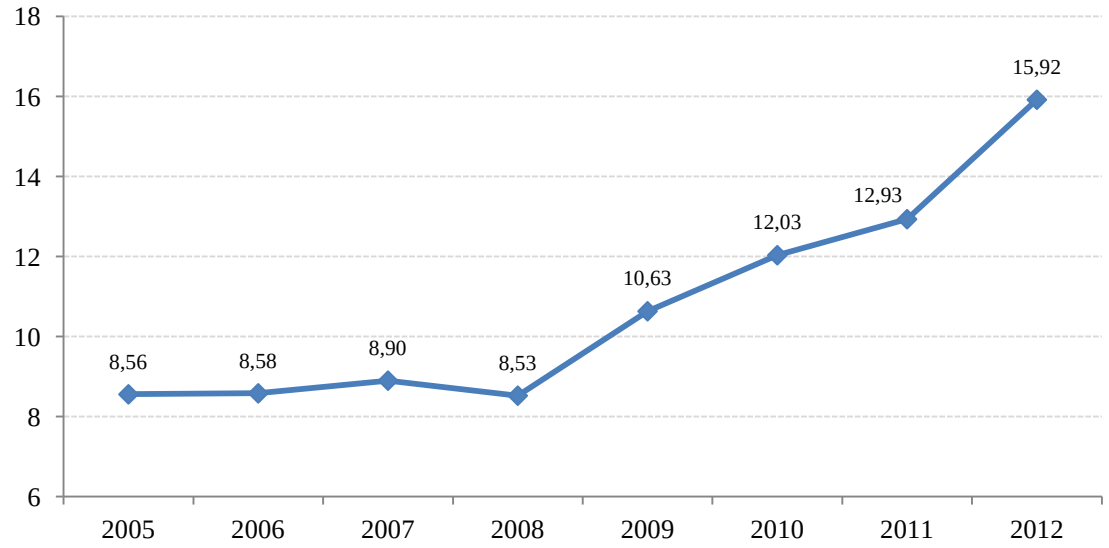
Source: chart created by the author, based on data available on the OECD website.

Figure 11 – Three Months EURIBOR



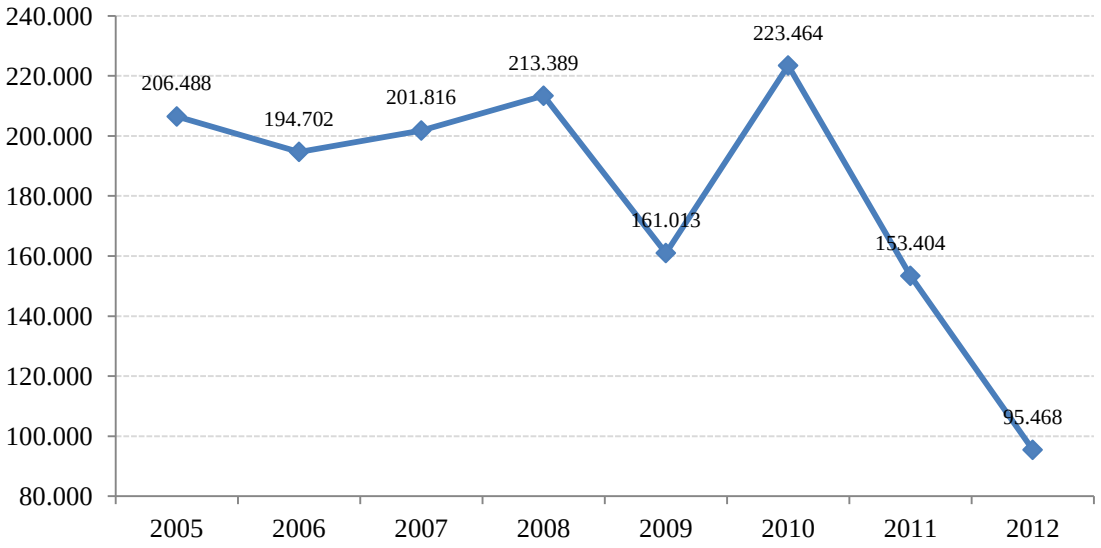
Source: chart created by the author, based on data available on the Bank of Finland website.

Figure 12 – Harmonized Unemployment Rate, in Portugal (percent per annum)



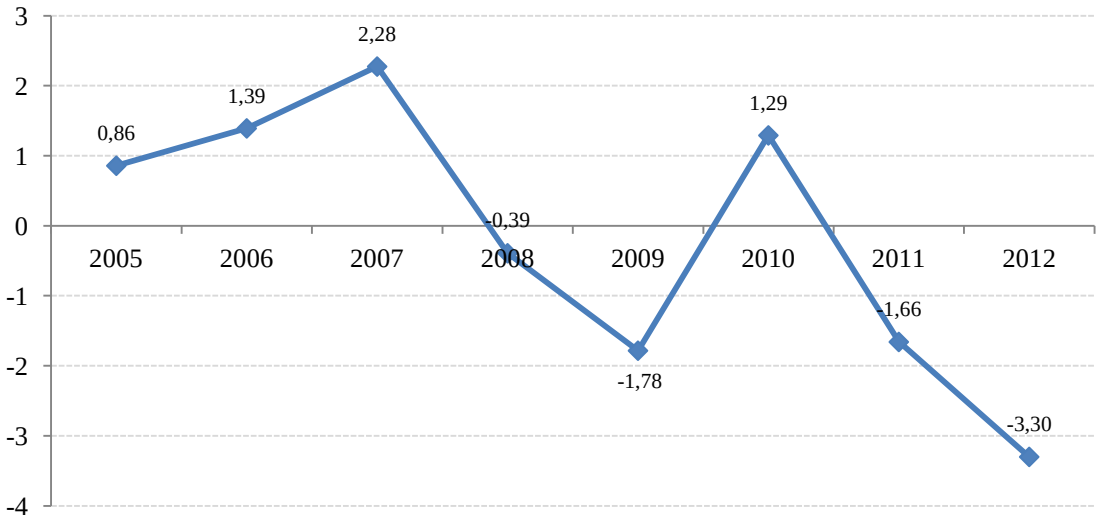
Source: chart created by the author, based on data available on the OECD website.

Figure 13 – Sales of New Passenger Vehicles, in Portugal (in units)



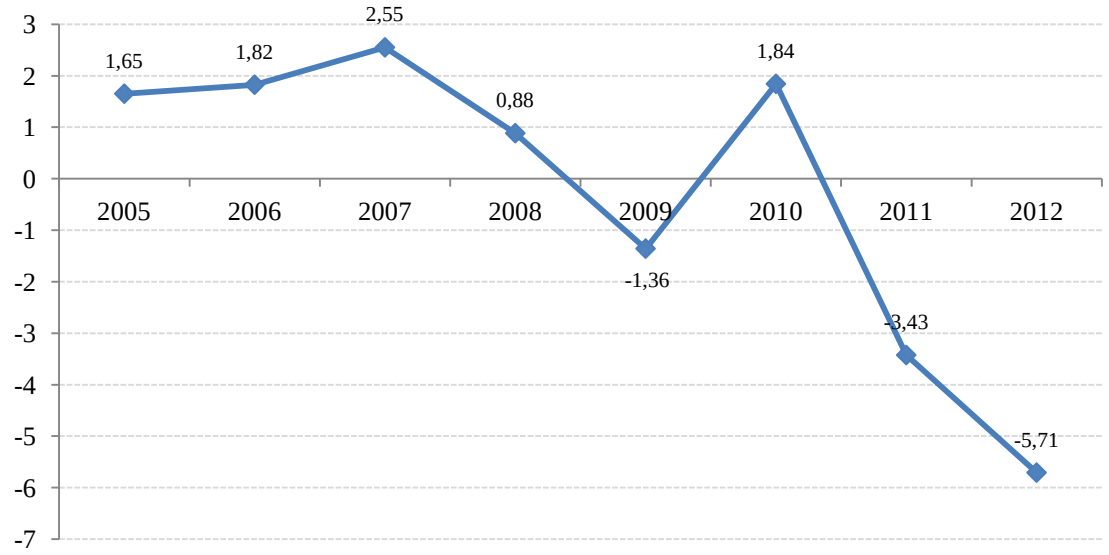
Source: chart created by the author, based on data available on the ACAP website.

Figure 14 – Economic Activity Coincident Indicator (year-on-year rate of change)



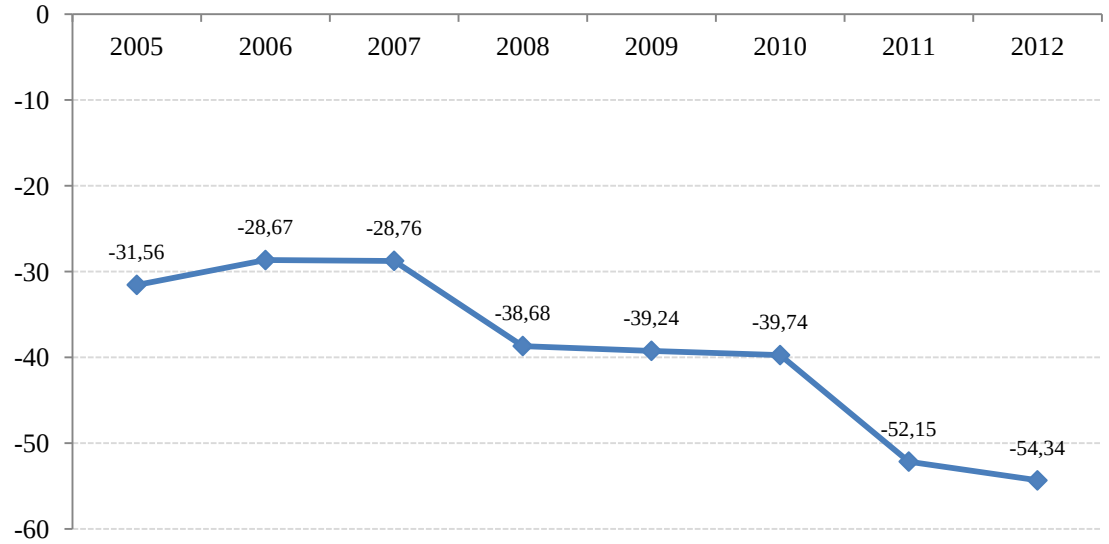
Source: chart created by the author, based on data available on the Banco de Portugal website.

Figure 15 – Private Consumption Coincident Indicator (year-on-year rate of change)



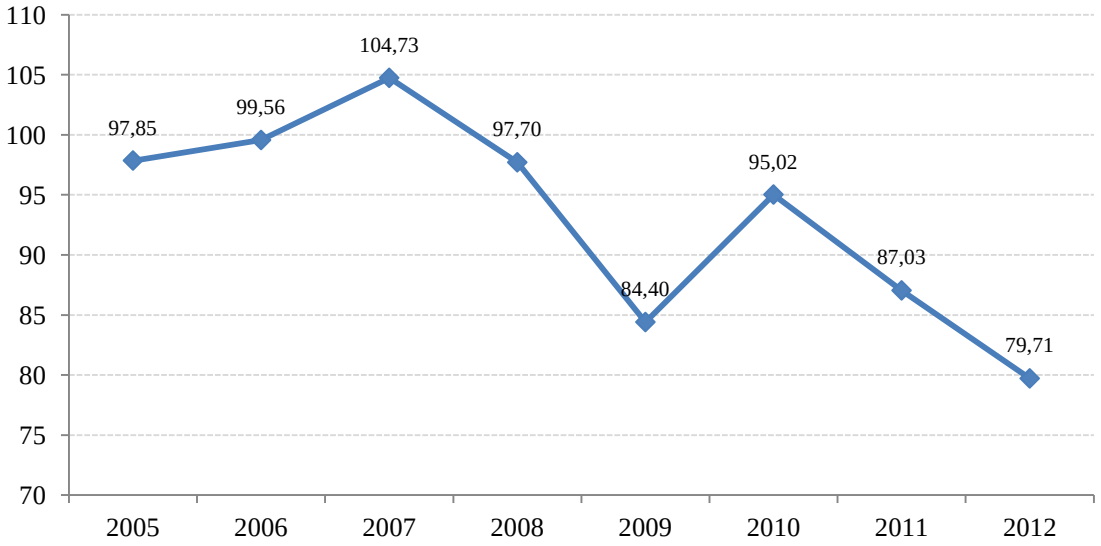
Source: chart created by the author, based on data available on the Banco de Portugal website.

Figure 16 – Consumer Confidence Indicator - Portugal



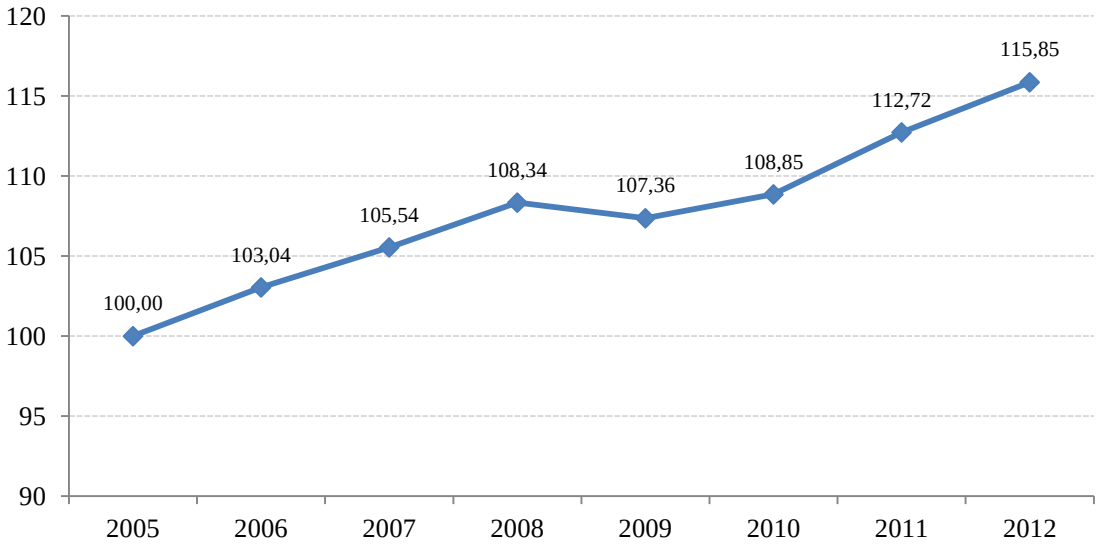
Source: chart created by the author, based on data available on the Banco de Portugal website.

Figure 17 – Economic Sentiment Indicator – Portugal



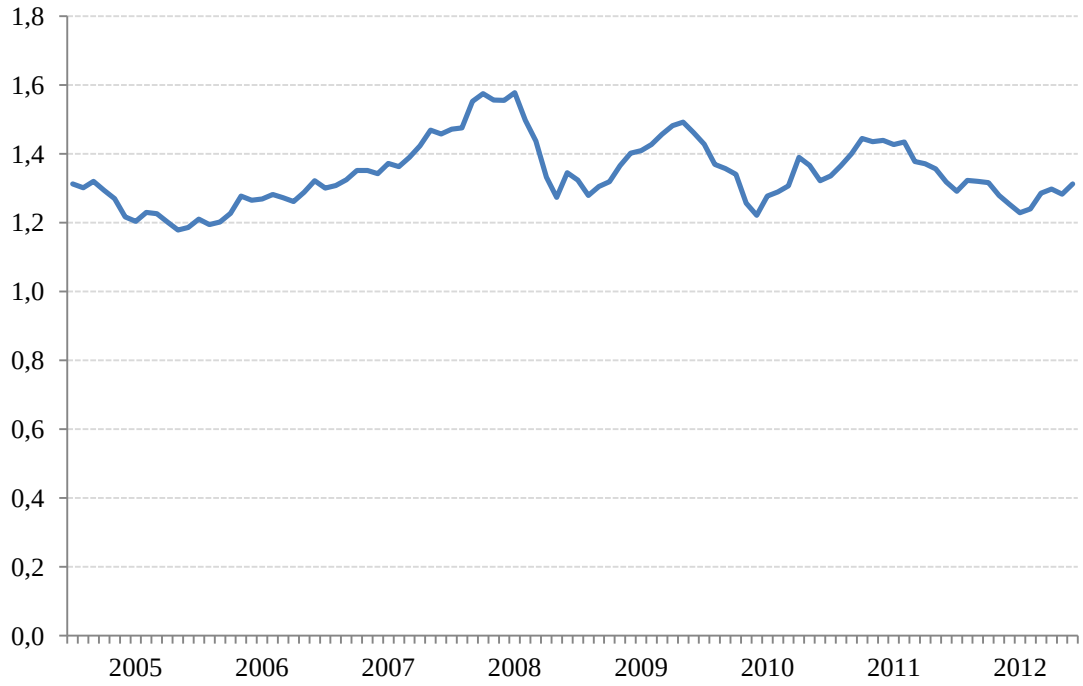
Source: chart created by the author, based on data available on the Banco de Portugal website.

Figure 18 – HICP (Harmonized Index of Consumer Prices) - Global Index in Portugal



Source: chart created by the author, based on data available on the Eurostat website.

Figure 19 – ECB Reference Exchange Rate, US dollar/Euro

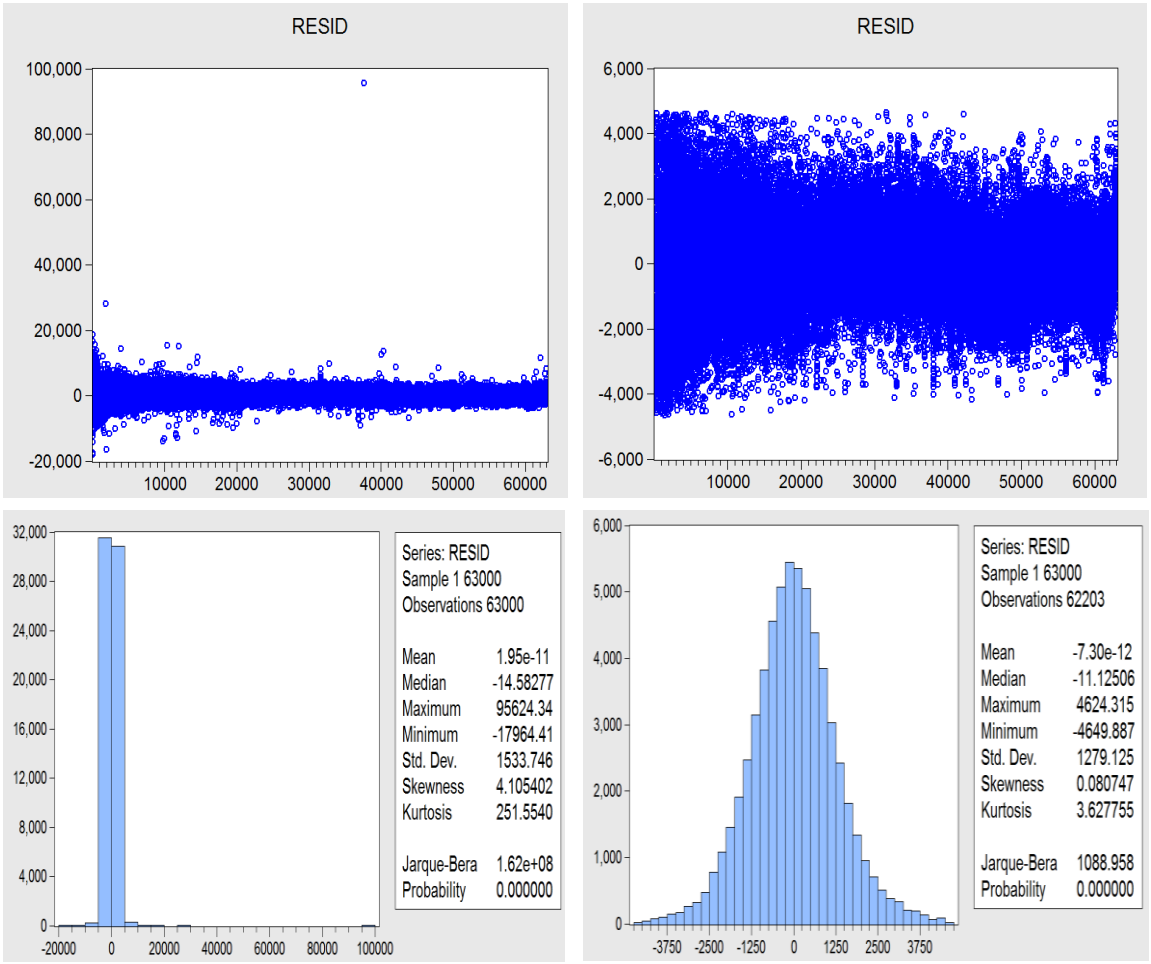


Source: chart created by the author, based on data available on the ECB Statistical Data Warehouse website.

Appendix G

Figure 20 – Residuals graph representation, before and after outliers exclusion

Before **After**



Source: Eviews output.