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## *Road accidents and business cycles in Spain*

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# Road accidents and business cycles in Spain[1]

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**Abstract**: As of 2006 Spanish authorities implemented a Penalty Point System (PPS), consisting in a credit system for licensed drivers conditional upon the fulfillment of traffic rules. The PPS has been blessed as responsible for the decline of road fatalities in Spain. In this paper, we argue that part of the decline was due to the occurrence of two confluent facts that affect traffic density: (1st) the Great recession starting in 2008, and (2nd) an increase in fuel prices during the spring of 2008, implying a rise in the operating costs of motor vehicles. Using cointegration techniques, the GDP growth rate and the fuel price appear to be statistically significant with accidents. Importantly, PPS is found to be significant in reducing accidents with mortal victims. In view of these results, we conclude that road accidents in Spain are very sensible to the business cycle, and that the PPS influenced the quality (fatality) rather than the quantity of accidents in Spain.

**Key words**: Road accidents, Penalty Point System, Business cycle, Cointegration, Autoregressive Distributed Lags Models
**JEL codes**: R490, E320, C220

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## 1. Introduction

During the last decade, traffic accidents have dramatically declined in Spain. The magnitude of this problem became an issue of primary political concern by the end of nineties. Compared with other European countries, such as France, Germany or the United Kingdom, Spain evinced the highest fatality rates during the eighties and nineties. As of 2006, the government implemented a Penalty Point System (henceforth, PPS) for licensed drivers, similar to those existing in European countries.

The success of the PPS, as a public policy, has recently been evaluated from an academic viewpoint. In general, there is a wide consensus in the literature concluding that the introduction of PPS in Spain helped to reduce the number of traffic victims in Spain. For an analysis of both the Spanish PPS and those of other countries, see Roca, Montoro and Tortosa (2009), Aparicio et al. (2012), Castillo et al. (2010) and Castillo & Castro (2012), and references therein. These authors, however, disagree around the type of victims. Novoa et al (2010) conclude the main effect evinced in the reduction of injured people (drivers, vehicle occupants or pedestrians) in traffic accidents. Aparicio et al. (2011), on the other hand, concluded that the PPS reduced the number of fatalities on the road. Regarding the duration of the positive impact of the PPS, the literature is far from consensus (Roca, Montoro and Tortosa, 2009): some studies conclude that the PPS had limited transitory effects (see Castillo-Manazano and Castillo-Nuño, 2012; Castillo-Manzano et al., 2010 for Spain, and Farchi el al., 2007 for Italy), while another studies find that the PPS effects have been long lasting (Novoa et al., 2010; Aparicio et al. 2011).

It is not straightforward to isolate the impact of PPS from the effects of other complementary types of traffic standards applied (SWOV, 2010). In this paper, we explore to what extent business cycle fluctuations may account for the decline in traffic accidents in Spain, apart from the PPS. Using econometric techniques, data series of accidents in Spain are regressed on some variables for which Transport Economics provide a theoretical ground. Shortly after the PPS enforcement, Spanish economy was hit by a global crisis occurring after 2007, which downsized GDP for a period spanning from 2008 to 2013. Fuel prices increased during the spring of 2008. These two facts help explain some aspects related to traffic, such as road congestion and car accidents. For these reasons, the variables considered in this work are: the PPS, as a policy that could have affected individuals' incentives (Roca, Montoro and Tortosa, 2009), the GDP to proxy aggregate income, and the fuel price index as proxy for the operating costs of motor vehicles. We estimate both long run and short run equations. In particular, we first apply the Johansen's test and find one cointegrating vector among these series. Second, following Pesaran and Shin (1999), we estimate an autoregressive distributed lag (ADL) structure for the short run behavior.

The main finding of this paper is that the decline in the *quantity* of accidents and accidents without mortal victims should be rather associated to cyclical circumstances (GDP downturn and fuel price fluctuations), rather than the implementation of PPS. Both long run and short run regressions provide evidence that the correlations of GDP and fuel prices with the *quantity* of accidents are statistically significant. By contrast, we do not find a significant correlation between the PPS and total accidents. Importantly, we do find that the PPS has played a crucial role in the decline of accidents with mortal victims in Spain. Thereby, PPS has affected the *quality* of traffic accidents. Differences with earlier studies are likely due to the period of observations. To the extent that fatal collisions are costlier (Parry, Walls and Harrington, 2007), this success should indeed be associated to the PPS.

The rest of the paper is organized as follows. Section 2 briefly describes the PPS and the dataset, analyzes the cyclical component of traffic accidents, identifying leading and lagged indicators. Section 3 presents the methodology and shows the result. Section 4 concludes and provides some policy recommendations.

## 2 Facts and data description

### 2.1 The penalty point System

The Penalty Point System was created and regulated through Law 17/2005 in Spain. Although the Law came into force in August 20th 2005, not until July 1st 2006 was fully applied (Disposición final segunda, Ley 17/2005). For the purpose of our analysis, we therefore consider the third quarter of 2006 as the starting date of the PPS System.

The Law implemented a punitive schedule aimed at reducing road traffic violations classified as serious or very serious. Basically, the PPS System works as follows: drivers are naturally endowed with 12 credit points when the license is older than three year. Otherwise, novel drivers are endowed with 8 credits. A driver may obtain 2 additional credits after two years conditional upon non commission of a traffic offense, with a maximum of 15 credits accumulated. Following the commission of a traffic offense, total credits can be reduced by penalties ranging from 2 to -6 points, depending on the severity of the offense.[2]

The ultimate target of the Law was halving the number of deaths in road accidents, which was set out in the European Commission's White Paper 2001. Analogous PPS Systems had already been introduced in the United Kingdom (1982), France (1992-2001) and Germany (1999).[3]

### 2.2 Data description

We use quarterly observations from different datasets. From the Spanish General Directorate of Traffic (DGT), we download data on road accidents. Accidents statistics differentiates between those with and those without mortal victims. According to the DGT, Traffic accidents "reflects the number of accidents occurring or originating on roads open to public traffic, which result in death or injuries for one or several persons, and involving at least one vehicle". Mortal victims or fatalities "are persons who have died as a consequence of a traffic accident, where both death occurred instantaneously or within twenty-four hours of the accident".

[2] For an overview of possible offences and their consequences in terms of loss of credits: https://sede.dgt.gob.es/Galerias/tramites-y-multas/permiso-por-puntos/informacion-permiso-por-puntos/DGT_Informacion_Puntos.pdf

[3] Unlike France and Spain, the German and British systems are based on accumulation of points, with a driver losing his/her driving license upon accumulation of 18 and 12 points, respectively.

From Spain's National Institute of Statistic (*Instituto Nacional de Estadística*, INE) we download series of Spanish GDP and the fuel price index.[4] For the GDP series, the INE data does not offer a single backward-compatible database that goes back all the way to 1995:1. Instead, we have two different databases to work with. The first (CNTR00) starts in 1995:1 and ends in 2011:2, with base year 2000. The second (CNTR08) starts in 2000:1 and is currently ongoing; the base year is 2008. These databases have been merged, so that we obtain a volume index for real GDP for the complete period under consideration. Finally, from the database BDSICE (Ministry of Economy and Competitiveness), we download series on the fuel price index and monthly series of gasoline fuel and diesel fuel consumption.[5]

Combining all these sets, we construct quarterly data series from 1995:1 to 2013:4. All series have been seasonally adjusted. As a first approximation, Table 1 compiles some basic statistics related to accidents. These moments are reported for different periods, concerning the PPS implementation. The last column of this Table, labeled as Δ, presents the difference between the two selected sub-periods. The first subpanel of Table 1 introduces total number of accidents for three particular years: 1995 (start of the sample), 2005 (one year before PPS), and 2013 (the last observed year). As of 1995, there were 81.5 thousands road accidents in Spain. Out of them, 77.4 thousands were accidents without mortal victims. The remaining 4.1 thousands were collisions with mortal victims. Both total accidents and accidents without mortal victims increased after 1995, peaked on 2005 and reduced as of 2013 (see differences Δ comparing 2013 versus 2005). Figure 1 shows the evolution of the number of traffic accidents in Spain – total and without mortal victims - from 1995 to 2012 (in thousands). The vertical dashed line (in this and in the following figures) marks the PPS implementation date in 2006. Both series follow a similar path since most of accidents do not result in death, fortunately. Contrary to the findings in earlier studies, the bulk of the downturn of accidents started in 2008 rather than 2006, one year and a half after the implementation of the PPS.

Figure 2 shows the number of fatal accidents for Spain in the same period (in thousands). The decline is already visible from 2004 but the decrease rate accelerated after 2006. Indeed, mortal accidents have decreased by 1.9 thousands between 1995 and 2013 (see Table 1).

The second panel in Table 1 reports the shares of collisions, attending to severity (without and with mortal victims). Accidents without mortal victims account for 96.4% of total. After the PPS, the share of accidents with total victims reduced by -1.9%. Figure 3 shows the complete evolution of this share of fatal accidents in Spain from 1995 to 2013. The decline has been continuous over the whole period but more acute since 2006. Parry et al. (2007) report a similar decline for the US since the 60s. These authors compile an estimate of social costs of traffic accidents, which increase with degree of severity, going from accidents only damaging property to fatal collisions. Total social costs amount to 433 billion (4.3% of US 2000 GDP), or equivalently an average of 15.8 cents per kilometer driven. Of all these accidents, those with mortal victims are by far the costlier ones (Parry et al. 2007).

[4] http://www.ine.es/

[5] http://serviciosede.mineco.gob.es/Indeco/BDSICE/HomeBDSICE.aspx

The two lower panels in Table 1 show the mean and standard deviation of accidents growth rates: accidents increased by 1.6% during the period before the PPS and fell by -2.3% after PPS, i.e. a 4% deceleration. This deceleration is stronger for accidents with mortal victims. Interestingly, the volatility of accidents increases with severity: its standard deviation is even higher after the PPS, while it is lower for the other series. Thus, translating the US estimate by Parry et al. (2007) to Spanish figures, this implies a dramatic decline in social costs of traffic accidents.

Recent economic models connect the demand for automobile services with households' income and the operating costs per kilometer. These models include Wei (2013) and Rodríguez, Marrero and González (2015), where fundamental equations are endogenously derived within a dynamic macroeconomic framework. The demand for automobile services increases with income but declines with the operating costs. The price of fuel is part of the operating cost, together with the services of maintenance and repairs, i.e. the marginal cost of an extra kilometer driven. Bento *et al*. (2009), estimate that the elasticity of kilometers driven with respect to the operating cost of vehicles is -0.74 using US data.[6]

The literature on transport Economics estimates that the price elasticity should range between -0.25 and -1. A comprehensive review of literature can be found in Goodwin, Dargay and Harly (2004): For the price effects, the aggregate fuel consumption is more elastic than aggregate kilometers driven. Particularly, while the fuel-price elasticity is -0.25 in the short run and -0.60 in the long run, for kilometers driven these are -0.10 and -0.30, respectively. More recently, Blundel et al. (2012) have found a long run value of -0.92 for the price elasticity and 0.29 for the income elasticity, using standard time series methods. Conditioning on income distribution, they estimate that the price elasticity is lower for low and high income households. These authors survey other estimates of price elasticity and income elasticity of fuel consumption that are larger than those documented by Goodwin, Dargay and Harly (2003): Hausman and Newey (1995) estimate -0.81 and 0.37, respectively; Schmalensee and Stoker (1999) report values within the range [-1.13, -0.72] for the price elasticity, and [0.12, 0.33] for the income elasticity; Yatchew and No (2001) find values of -0.89 for the price elasticity and 0.28 for the income elasticity; West (2004) finds a price elasticity of −0.89. Differences between these estimates can be due to the period and countries considered, the type of data (time series, cross-section, micro-data), the frequency of data, or the methodology employed.

Summarizing, both theoretical models and empirical studies provide grounds linking income and fuel prices with driving decisions and road traffic intensity. Empirical studies find rather rigid elasticities for income and prices.

[6] A number of studies have estimated these operating costs (i.e. fuel expenditures plus maintenance and repairs expenditures), varying from one country to another due to differences in technology or taxation, among other things (for a survey, see Victoria Transport Policy Institute (2009), Chapters II and V.). The U.K. Automobile Association estimates operating costs per mile for gasoline and diesel cars from 1998 (www.theaa.co.uk): fuel costs, tyres, service labor costs, replacement parts, and parking and tolls. Using this information, fuel costs account for 55% of operating costs for diesel cars and 60% for gasoline cars in the U.K.

Figures 4 and 5 represent the Spanish real GDP and the fuel price index, respectively. A fuel price index is used to proxy operating costs. In both figures, log-levels are overlapped with growth rates, each referenced on a separate axis. It is worth noting the fall in GDP in 2008, the start of the Great recession. From 1995 to 2007, the Spanish GDP annually grew by 3.6%, hovering 5.5% in 2000. After 2008, GDP has declined with an average growth rate -0.4% per year. As documented in some empirical studies, the recession starting in 2008 is by far the hugest GDP downturn evinced in Spain over the last 70 years (see Boldrin et al. 2010; and Rodríguez and Solís, 2014). The fall in economic activity has been accompanied by a downturn in the demand for fuel (both diesel –mainly-, and gasoline). The price of fuel (Figure 5) displays a higher volatility than GDP: While the fuel price yearly increased by 12% on 2006:03 and 14% on 2008:02, as of 2009:02 it decreased by -24.5%. Note that these growth rates vary from negative to positive positions in about two quarters.

[**Table 1 and Figures 1 through 5 here**]

**2.3. Business cycle analysis**

This sub-section complements previous description using a business cycle analysis reported in Tables 2 and 3. Variables have been logged and detrended using a Hodrick-Prescott filter System (with adjustment parameter λ=1600). The set of variables includes: real GDP, fuel consumption, fuel prices, registration of (units of) new vehicles, age of the vehicle fleet, and road accidents. Once the trends have been estimated, the cyclical component of each series has been identified and used for our business cycle analysis using a correlogram. Series span from 1995:1 to 2013:4.

Table 2 reports the correlogram with respect to cyclical GDP, i.e. correlations of the cyclical components of these series with respect to fluctuations in GDP. Business cycles in Spain are highly persistent, as evinced by the auto-correlation coefficient for the first lag of GDP, 0.926. This contrasts with the persistency of business cycle observed in other economies, such as the US, Germany, or Japan (Marcet and Ravn, 2003). Second, fuel prices (deflated using a CPI) is also pro-cyclical and a leading indicator of GDP. This positive correlation indicates that price fluctuations are dominated by shocks to the demand for fuel. Third, road accidents are *correlated* to the business cycle.

Table 3 reports an alternative correlogram where road accidents is the pivotal variable, instead of GDP. Fluctuations of total accidents are persistent (0.498) but not as much as the persistency evinced for GDP fluctuations (0.926). The correlations of accidents with GDP show the reverse row reported in Table 2. Fuel prices are weakly correlated with road accidents, although they show some leading indication of fatalities. Albeit the fuel costs affect vehicles operating costs, as commented for Table 2, the fluctuations in the price of fuel might be dominated by income, implying a positive correlation with road accidents.

[**Tables 2 and 3 here**]

## 3. Methodology and results

In this Section, we use time series cointegration techniques in order to explore both short run and long run relations between the series of traffic accidents with GDP, fuel prices and a dummy variable for the penalty point system (PPS) in Spain. The series for traffic accidents have been differentiated according to severity: total traffic accidents, accidents without mortal victims, and extreme fatalities or accidents involving mortal victims.

In a first stage, we use unit roots test to check the order of integration of these series (i.e. the order of differencing that should be applied to a series to become stationary). Table 4 reports the results of unit roots tests. All series have been logged and seasonally adjusted. Panel A of Table 4 presents the results for the levels, while Panel B presents those after first differencing. Panel A also includes the tests for the GDP growth rates, expressed in quarterly terms (first differencing, $1-L$, with $L$ denoting the lag operator), and in yearly terms (with difference operator, $1-L^4$). ADF columns indicate augmented Dickey-Fuller unit root tests, and PP columns do the Phillips-Perron unit root tests. Numbers in parenthesis are the augmentation lags. The last column is the 5% critical lower bound value.

In view of Table 4, we conclude that the three series of accidents are clearly integrated of order 1, I(1): only after first differencing the null hypothesis for the unit root is rejected at the 1% significance level. Secondly and importantly, GDP growth rates are I(1), implying that the null hypothesis of I(2) for GDP cannot be rejected. This result can be due to the fact that our analysis is limited to a period comprising both a huge expansionary period, evincing growth rates from 1995:01 to 2007:4, and a severe output contraction from 2008:01 to the end of observations. Finally, fuel price is clearly I(1).

Hence, in order to estimate a long run relation and a cointegrating vector, requiring a common order of integration for all series involved in a regression, we select the levels of accidents, the growth rate of GDP, and the level of the fuel price index. For that purpose we regress each (logged) series of accidents over a constant, the (quarterly) GDP growth rate and the (logged) fuel price index. The results of these *long run* relations are reported in Table 5 using ordinary least squares (OLS). In all cases, all variables are statistically significant and the coefficients have expected signs, supporting our previous finding under the business cycle analysis: Traffic accidents are procyclical, tend to increase with GDP accelerations and reduce with fuel price positive shocks. Attending to severity of accidents, the elasticity of accidents with mortal victims with respect to GDP growth is more than five times as large as for accidents without mortal victims (8.7 versus 1.6), and the elasticity of accidents with mortal victims with respect to fuel price is more than 9 times as large as for accidents without mortal victims (-1.6 versus -0.18).

Table 5 also contains a lower panel reporting a simple, albeit illuminating, exercise based on the average residuals. This average is calculated for the whole sample, which by definition it must be zero, and for the periods before and after the implementation of the PPS as of the third quarter of 2006. For the period before the PPS, the averages are negative meaning that these long run regressions tend to over-predict total road accidents and accidents without mortal victims: observed accidents are lower than predictions. However, for the period after the PPS implementation, the sign of this average turns out positive: now the long run correlation tend to under-predict car accidents.

However, this analysis is radically different when applied on accidents with mortal victims. While in the period before the PPS the long run relation under-predicts severe accidents (average is positive), this over-predicts for the period after the PPS (average is negative). Overall, given that this last regression exhibits a higher goodness of fit that the other two, this means that there is some hidden information, not captured by the GDP growth rate not the fuel price, which affects the severity of car accidents. Indeed, over-prediction of road accidents involving mortal victims in the after period implies that the incentive generated by PPS helps reduce the *quality* (severity) of accidents. Figure 6 reports the series for three residuals: total accidents, REA_ACC, and road accidents without and with mortal victims, REA_NMACC and REA_MACC, respectively. Following is a regressions analysis in order to uncover whether the moderation in the *quantity* of accidents is also related to the PPS implementation, apart from business cycle considerations.

Table 6 presents a Johansen cointegration analysis for the series under consideration. The Johansen analysis is based on a Vector Autoregression (VAR) of order one (lag selected according to the Schwarz criterion). Critical values were derived assuming no exogenous series in the cointegration analysis. We also test for residual autocorrelation and normality, and they show no signs of serious misspecification problem in the residuals. The VAR specification for Johansen analysis includes an unrestricted constant term and no linear trend in included in the cointegration vector (no-significant). Results are consistent with the existence of 1 cointegration vector.

[**Tables 4, 5 and 6 here**]

Pesaran and Shin (1999) show that the autoregressive distributed lag (ADL) structure remains valid when the underlying variables are non-stationary, and on the basis that they are found to have only one cointegration vector.[7] Additionally, ADL structures allow for a distinction between short run and long run relation among variables within a cointegrating vector, as in our case.

For this reason, we impose a ADL structure to estimate the short run relationship between the three series of accidents, on the one hand, with the GDP growth rate, the fuel price and the PPS. For this latter, we use a dichotomous variable that adopts value zero from the beginning of the sample until the second quarter of 2006, which is the date of the PPS implementation, and value 1 from 2006:3 onwards. We conclude that this dummy variable catches hidden information not content in the other business cycle series. Results for the ADL are reported in Table 7. For the three cases, the regression has been estimated on a constant, the own lag of the dependent variable of accidents, the quarterly GDP growth, the fuel price (contemporaneous plus two lags), and with and without the PPS dummy. This dynamics

[7] For an extension of this idea see Bentzen and Engsted (2001), who apply ADL structures to energy cointegrated series.

specification is selected according to the Schwarz criterion. GDP growth is statistically significant and positively correlated in all cases. Analogously, the price of fuel, which is the main component in the motor vehicles operating costs, is also statistically significant and negatively correlated with road accidents.

Compared with the long run estimations in Table 5, the most remarkable finding is that the dummy for the PPS appears statistically significant only for accidents with mortal victims. The negative sign (-0.094) indicates that the PPS implementation indeed helped reduce mortal events. Yet the persistency of accidents, captured by the lag of the dependent variable, seems to be reduced when the dummy is included: 0.80 versus 0.66. As for the accidents without mortal victims, the PPS does not seem to be statistically significant.

These findings contrast with those reported in previous studies on the PPS incidence in Spain. These studies include the early analysis by Aparicio et al. (2011), using data 3 years after the PPS, or Castillo-Manzano, Castro-Nuño and Pedregal (2010). In all cases, these studies highlight the positive impact of PPS on accidents reduction in Spain, while pointing out that some other economic factors could be likely behind such a reduction.

Our finding, by contrast, remarks that the bulk of road accidents in Spain are related to economic circumstances, such as the business cycle or the fuel prices, which affect individuals' decisions of automobile usage and traffic intensity. The study by Novoa et al. (2010), using a medical perspective, shares with ours in that the reduction due to the PPS is related to numbers of people injured by traffic collisions in Spain. We otherwise do recognize a crucial role played by the PPS in reducing the road accidents severity, but this contribution is related to the quality rather than the quantity of accidents. The aforementioned studies use data that are often limited to a particular phase of the Spanish cycle, probably too early to evaluate long run effects of the PPS.

**4. Conclusions**

There has been a dramatic decline in both the number of accidents and fatality rates in Spain during the last decade. This fact has been related to a success in the Penalty Point System (PPS) implemented in 2006 in Spain. Alongside the PPS implementation, there are two factors that have affected road traffic intensity, fuel demand and the occurrence of automobile accidents: the upcoming of an unprecedented GDP downturn in 2008, and volatile fluctuations in the price of fuels (both increases and increases), which is the bulk of automobile operating costs.

According to elementary business cycle techniques, traffic accidents are found to be GDP procyclical and negatively correlated with fuel prices. Using more sophisticated econometric tools, the Johansen's test reveals one cointegration vector between accidents, GDP growth rate and the fuel price. We exploit Pesaran and Shin's (1999) suggestion to revive the autoregressive distributed lag (ADL) structure under one cointegration equation, which allows estimate the short run relationship. We have found that the decline in both the *quantity* of accidents and accidents without mortal victims should be associated to cyclical circumstances rather than to the PPS, contrary to the findings in other previous studies. We do find a crucial role played by the PPS in the decline of accidents with mortal victims in Spain. Thereby, PPS has affected the *quality* of traffic accidents. To the extent that fatal collisions are costlier, this implies success of the PPS. Differences with earlier studies are likely due to the period of observations.

As of 2015, Spanish GDP has grown by 3.2% and the fuel prices are the lowest ones in the last two decades, both in real and in nominal terms. On the basis of our business cycle analysis, these two circumstances together can contribute to boost automobile usage and road traffic and, as a consequence, to upsurge traffic accidents. Further reductions in fatal collisions can be achieved by proper policy measures affecting drivers' incentives, such as the design of surveillance controls and fines, or education. Notwithstanding, the connection of accidents with cyclical fluctuations in Spain is too strong to be neglected.

**References**


1. Aparicio-Izquierdo F, B. Arenas-Ramírez, JM. Mira-McWilliams and J. Páez-Ayuso (2011). "The endurance of the effects of the penalty point system in Spain three years after. Main influencing factors" *Accident Analyses and Prevention* 43, 911-922.
2. Bentzen, J. and T. Engsted (2001): "A revival of the autoregressive distributed lag model in estimating energy demand relationships". *Energy* 26 (1), 45–55.
3. Blundell, R., J. L. Horowitz, M. Parey: "Measuring the price responsiveness of gasoline demand: Economic shape restrictions and nonparametric demand estimation". *Quantitative Economics* 3 (2012), 29–51.
4. Boldrin, Michele, J. Ignacio Conde-Ruiz, and Javier Díaz-Giménez (2010) Eppur si muove! Spain: growing without a model. FEDEA Documento de Trabajo No. 2010-11.
5. Castillo-Manzano, J.I. and M. Castro-Nuño (2012). "Driving licenses based on points systems: Efficient road safety strategy or latest fashion in global transport policy? A worldwide meta-analysis" *Transport Policy* 21, 191-201.
6. Castillo-Manzano, J.I., M. Castro-Nuño and DJ. Pedregal (2010). "An econometric analysis of the effects of the penalty points system driver's license in Spain". *Accident Analyses and Prevention* 42, 1310–1319.
7. Farchi, S.., Chini, F., Rossi, P.G.,Camilloni, L., Borgia, P. Guasticchi, G. (2007): "Evaluation of the health effects of the new driving penalty point sustem in Lazio Region, Italy, 2001-2004, Injury Prevencion 13, 60-64.
8. Goodwin, P., J. Dargay and Mark Hanly: "Elasticities of Road Traffic and Fuel Consumption with Respect to Price and Income: A Review". *Transport Reviews*, Vol. 24, No. 3 (May 2004), 275–-292.
9. Hausman, J. A. and W. K. Newey (1995): "Nonparametric estimation of exact consumers surplus and deadweight loss". *Econometrica*, 63 (6), 1445--1476.
10. Marcet, A. and Morten O. Ravn (2003). "The HP-Filter in Cross-Country Comparisons" Studies on the Spanish Economy 100, FEDEA.
11. Novoa, A.M., K. Pérez, E. Santamariña-Rubio, M. Marí-Dell'Olmo, J. Ferrando, R. Peiró, A. Tobías, P. Zori and C. Borrell (2010). "Impact of the penalty points system on road traffic injuries in Spain: a time-series study". *American Journal of Public Health* 100, 2220–2227.
12. Parry, I.W.H.; M. Walls and W. Harrington: "Automobile Externalities and Policies". *Journal of Economic Literature*, Vol. XLV (June 2007), pp. 373–399.
13. Pesaran MH, Shin Y: "An autoregressive distributed lag modelling approach to cointegration analysis", in S. Strøm (Editor): *Econometrics and economic theory in the twentieth century: the Ragnar Frisch Centennial Symposium*. Cambridge: Cambridge University Press, 1999.

14. Roca Ruiz, J, L. Montoro González and F. Tortosa Gil: "Valoración de los conductores españoles sobre el permiso por puntos". *Psicothema* 2009. Vol. 21, nº 2, pp. 294-299.
15. Rodríguez-López, Jesús, Gustavo Marrero and Marina González (2015): "Dieselization, $CO_2$ emissions and fuel taxes in Europe". *Universidad Pablo de Olavide Working Paper* UPO WP-15.11 (see also Appendix A).
16. Rodríguez-López, Jesús and Mario Solís García (2014): "Accounting for Spanish Business Cycles". Forthcoming in *Macroeconomic Dynamics* (UPO WP-14.05).
17. SWOV Fact Sheet (2010). Demerit Point System. http://www.swov.nl/rapport/Factsheets/UK/FS_Demerit_points.pdf
18. Schmalensee, R. and T. M. Stoker (1999): "Household gasoline demand in the United States". *Econometrica*, 67 (3), 645--662.
19. U.K. Automobile Association (www.theaa.co.uk): Annual reports from 1998 to 2013 (www.theaa.com/motoring_advice/running_costs/index.html).
20. Victoria Transport Policy Institute (2009): Transportation Cost and Benefit Analysis. Techniques, Estimates and Implications. (www.vtpi.org).
21. Wei, C. (2013). "A dynamic general equilibrium model of driving, gasoline use and vehicle fuel efficiency." *Review of Economic Dynamics* 16, 650-667.
22. West, S. E. (2004): "Distributional effects of alternative vehicle pollution control policies". *Journal of Public Economics*, 88, 735-757.
23. Yatchew, A. and J. A. No (2001): "Household gasoline demand in Canada". *Econometrica*, 69 (6), 1697-1709.

## Appendix A: Tables and Figures

**Table 1: Descriptive statistics, Spain 1995:01-2013:04**

| No. Of accidents (**thousands**) | 1995 | 2005 | 2013 | Δ |
|---|---|---|---|---|
| Total Accidents | 81,5 | 91,2 | 83,1 | -8,1 |
| Without mortal victims | 77,4 | 87,8 | 81,6 | -6,2 |
| With mortal victims | 4,1 | 3,4 | 1,5 | -1,9 |
| Shares | 1995:01-2013:04 | 1995:01-2006:02 | 2006:03-2013:04 | Δ |
| Without mortal victims | 96,4% | 95,7% | 97,6% | 1,9% |
| With mortal victims | 3,6% | 4,3% | 2,4% | -1,9% |
| Growth rates (**mean**) | 1995:01-2013:04 | 1995:01-2006:02 | 2006:03-2013:04 | Δ |
| Total Accidents | 0,1% | 1,6% | -2,3% | -4,0% |
| Without mortal victims | 0,3% | 1,8% | -2,1% | -3,9% |
| With mortal victims | -5,9% | -2,1% | -12,0% | -9,9% |
| Growth rates (**std. dev.**) | 1995:01-2013:04 | 1995:01-2006:02 | 2006:03-2013:04 | Δ |
| Total Accidents | 0,063 | 0,063 | 0,055 | -0,008 |
| Without mortal victims | 0,064 | 0,065 | 0,055 | -0,009 |
| With mortal victims | 0,087 | 0,067 | 0,082 | 0,015 |

*Source: DGT and own calculations.*

**Table 2: Correlogram with respect to log-GDP (HP1600 filtered)**

| | -4 | -3 | -2 | -1 | 0 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|---|---|---|---|
| GDP | 0,341 | 0,570 | 0,773 | 0,926 | 1,000 | --- | --- | --- | --- |
| Fuel prices | 0,229 | 0,356 | 0,490 | 0,573 | 0,535 | 0,377 | 0,156 | -0,032 | -0,186 |
| Total accidents | 0,412 | 0,475 | 0,485 | 0,462 | 0,439 | 0,404 | 0,335 | 0,260 | 0,112 |
| Without mortal victims | 0,412 | 0,472 | 0,485 | 0,466 | 0,442 | 0,410 | 0,341 | 0,270 | 0,119 |
| With mortal victims | 0,270 | 0,245 | 0,202 | 0,159 | 0,101 | 0,077 | 0,040 | -0,073 | -0,176 |
| In urban areas | 0,133 | 0,209 | 0,260 | 0,302 | 0,362 | 0,392 | 0,373 | 0,340 | 0,195 |
| In non-urban areas | 0,544 | 0,579 | 0,553 | 0,487 | 0,394 | 0,314 | 0,214 | 0,119 | 0,013 |

*Source: INE, DGT and own calculations*

**Table 3: Correlogram with respect to Accidents (logged, HP1600 filtered), Spain 1995:1-2013:4**

| | -4 | -3 | -2 | -1 | 0 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|---|---|---|---|
| Total accidents | 0,039 | 0,296 | 0,263 | 0,498 | 1,000 | --- | --- | --- | --- |
| GDP | 0,112 | 0,260 | 0,335 | 0,404 | 0,439 | 0,462 | 0,485 | 0,475 | 0,412 |
| Fuel prices | 0,232 | 0,338 | 0,308 | 0,124 | 0,028 | 0,111 | 0,092 | 0,031 | 0,033 |

*Source: INE, DGT and own calculations*

**Table 4. Unit Root Tests for Accidents, GDP and Fuel Prices. Spain 1995:1-2013:4**

| | ADF(2) | ADF(4) | PP(2) | PP(4) | Crit. Value 5% |
|---|---|---|---|---|---|
| **A**. Levels | | | | | |
| Total accidents | -1.296 | -0.937 | -1.900 | -2.082 | -2.912 |
| Accidents without mortal victims | -1.589 | -1.390 | -2.428 | -2.626* | -2.912 |
| Accidents with mortal victims | 2.315 | 2.847 | 1.973 | 2.600 | -2.912 |
| GDP | -2.269 | -2.438 | -4.242*** | -3.670*** | -2.912 |
| GDP growth (quarterly) | -1.263 | -1.073 | -1.634 | -1.747 | -2.912 |
| GDP growth (yearly) | -1.587 | -0.516 | -0.998 | -1.103 | -2.912 |
| Fuel price index | -1.085 | -0.863 | 1.071 | -1.017 | -2.912 |
| **B**. First differences | | | | | |
| Total accidents | -4.602*** | -3.651*** | -10.182*** | -10.046*** | -2.912 |
| Accidents without mortal victims | -4.525*** | -3.641*** | -10.636*** | -10.404*** | -2.912 |
| Accidents with mortal victims | -5.804*** | -3.167** | -9.832*** | -10.036*** | -2.912 |
| GDP | -1.263 | -1.073 | -1.634 | -1.747 | -2.912 |
| GDP growth (quarterly) | -3.401** | -3.642*** | -4.365*** | -4.229*** | -2.912 |
| GDP growth (yearly) | -3.953*** | -4.650*** | -10.013*** | -10.091*** | -2.912 |
| Fuel price index | -4.414*** | -4.443*** | -5.903*** | -5.804*** | -2.912 |

Reject the null hypothesis of I(1) at 1% (***), 5% (**), 10% (*)

All regressions include a constant. Number in parenthesis are the augmentation lags.

Critical levels are compluted from MacKinnon for rejection of hypothesis of a unit root.

*Source: INE, DGT and own calculations*

**Table 5: Long run relation for accidents, Spain 1995:1-2013:4**

| | *(a)* log(Total Accidents) | | *(b)* log(Accidents without mortal victims) | | *(c )* log(Accidents with mortal victims) | |
|---|---|---|---|---|---|---|
| | **Mean** | **t-Statistic** | **Mean** | **t-Statistic** | **Mean** | **t-Statistic** |
| Constant | 10,02 | 1322,84 | 9,99 | 1298,19 | 6,43 | 329,63 |
| Annual GDP growth | 1,83 | 7,51 | 1,61 | 6,53 | 8,75 | 13,98 |
| log(Fuel price) | -0,22 | -4,27 | -0,18 | -3,41 | -1,61 | -12,18 |
| $R^2$ | 0,694 | | 0,620 | | 0,916 | |
| **Average ressiduals:** | | | | | | |
| Complete sample: 1995:1-2013:4 | 0,0000 | | 0,0000 | | 0,0000 | |
| Before PPS: 1995:1-2006:02 | -0,0027 | | -0,0040 | | 0,0346 | |
| After PPS: 2006:03-2013:04 | 0,0035 | | 0,0052 | | -0,0453 | |

*Source: INE, DGT and own calculations*

**Table 6. Cointegration Analysis: Accidents, GDP and Fuel Prices**

**A**. Set of variables: Total accidents, quarterly GDP growth and fuel price.

| Rank, r | Eigenvalue | Trace test | 5% crit. Value |
|---|---|---|---|
| r = 0 | 0.3244 | 38.13** | 34.91 |
| r ≥ 1 | 0.1841 | 15.39 | 19.96 |
| r ≤ 2 | 0.0599 | 3.58 | 9.24 |

**B**. Set of variables: Accidents without mortal victims, quarterly GDP growth and fuel price.

| Rank, r | Eigenvalue | Trace test | 5% crit. Value |
|---|---|---|---|
| r = 0 | 0.3187 | 37.79** | 34.91 |
| r ≥ 1 | 0.1867 | 15.54 | 19.96 |
| r ≤ 2 | 0.0594 | 3.55 | 9.24 |

**C**. Set of variables: Accidents without mortal victims, quarterly GDP growth and fuel price.

| Rank, r | Eigenvalue | Trace test | 5% crit. Value |
|---|---|---|---|
| r = 0 | 0.2608 | 36.25** | 34.91 |
| r ≥ 1 | 0.1677 | 18.73 | 19.96 |
| r ≤ 2 | 0.1301 | 8.08 | 9.24 |

All variables are I(1); Reject at 1% (***), 5% (**), 10% (*)

"r" denotes the order of the cointegration vector

*Source: INE, DGT and own calculations*

**Table 7: Autoregressive Distributed Lag for Road Accidents in Spain**

| | *(a)* log(Total Accidents) | | *(b)* log(Accidents without mortal victims) | | *( c)* log(Accidents with mortal victims) | |
|---|---|---|---|---|---|---|
| log(Total Accidents(-1)) | 0.5035*** | 0.5037*** | -- | -- | -- | -- |
| | (0.163) | (0.158) | -- | -- | -- | -- |
| log(Accidents without mortal victims(-1)) | -- | -- | 0.4762*** | 0.4699*** | -- | -- |
| | -- | -- | (0.165) | (0.156) | -- | -- |
| log(Accidents with mortal victims(-1)) | -- | -- | -- | -- | 0.8062*** | 0.6616*** |
| | -- | -- | -- | -- | (0.069) | (0.094) |
| Quarterly GDP growth | 1.1854*** | 1.1838*** | 1.132*** | 1.1891*** | 2.0702*** | 2.3687*** |
| | (0.411) | (0.377) | (0.391) | (0.372) | (0.466) | (0.614) |
| log(Fuel price) | -0.1985*** | -0.1983*** | -0.1708** | -0.1762** | -0.4215** | -0.4603** |
| | (0.061) | (0.060) | (0.068) | (0.0673) | (0.202) | (0.193) |
| log(Fuel price(-1)) | -0.0844 | -0.0843 | -0.1115 | -0.1149 | -0.1785 | -0.2391 |
| | (0.149) | (0.148) | (0.172) | (0.174) | (0.194) | (0.196) |
| log(Fuel price(-2)) | 0.2312* | 0.2313* | 0.2491 | 0.2468 | 0.2632* | 0.3321** |
| | (0.138) | (0.142) | (0.154) | (0.158) | (0.146) | (0.159) |
| Dummy PPS | -- | -0.0001 | -- | 0.0048 | -- | -0.0942*** |
| | -- | (0.016) | -- | (0.0163) | -- | (0.028) |
| Constant | 4.9712*** | 4.9699*** | 5.2306*** | 5.2898*** | 1.2238*** | 2.2193*** |
| | (1.639) | (1.586) | (1.645) | (1.564) | (0.448) | (0.619) |
| R2 | 0.824 | 0.824 | 0.771 | 0.772 | 0.974 | 0.978 |
| Std. Dev. residuals | 0.032 | 0.033 | 0.034 | 0.034 | 0.061 | 0.056 |
| Durbin-Watson | 2.188 | 2.188 | 2.235 | 2.235 | 2.308 | 2.193 |
| Schwarz | -3.721 | -3.652 | -3.643 | -3.577 | -2.465 | -2.565 |
| F-statistic | 50.680 | 41.451 | 36.402 | 29.846 | 410.5 | 398.8 |
| Q-stat_(resid) | 11.185 | 11.187 | 10.613 | 10.456 | 6.813 | 6.649 |
| P-val_(Q-stat) | 0.191 | 0.191 | 0.225 | 0.234 | 0.557 | 0.575 |

Figures in parenthesis are Newey-West HAC Standard Errors & Covariance. Sample is limited to 1998:1 2012:4 (60 Obs.)
Significant at: 1% (***); 5%(**); 10%(*)

*Source: INE, DGT and own calculations*

**Figure 1: Traffic accidents in Spain, 1995:1-2013:4**

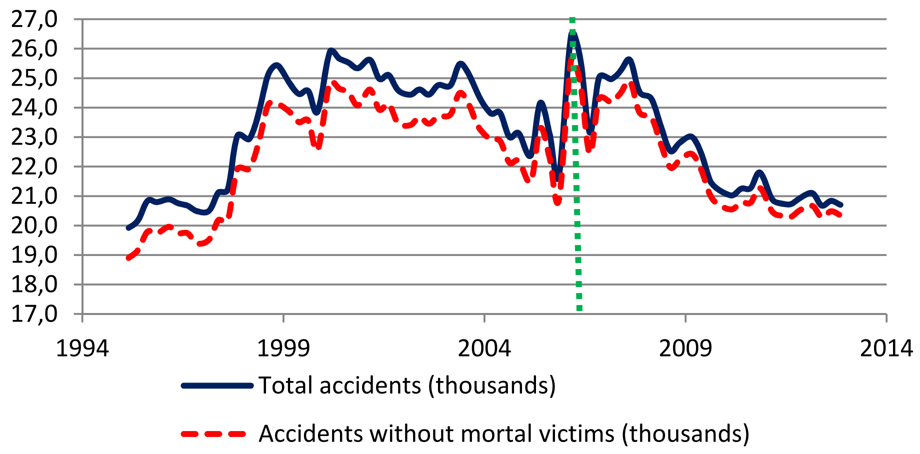


**Figure 2: Traffic accidents with fatalities in Spain, 1995:1-2013:4**

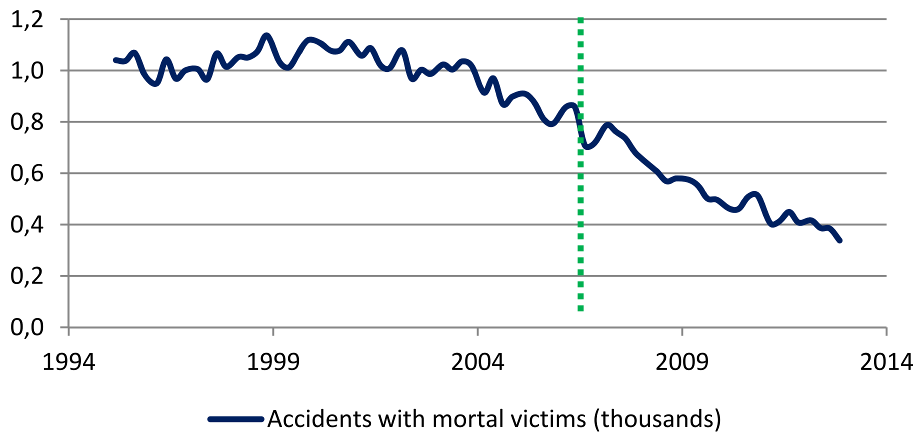


**Figure 3: Share of accidents with fatalities in Spain, 1995:1-2013:4**

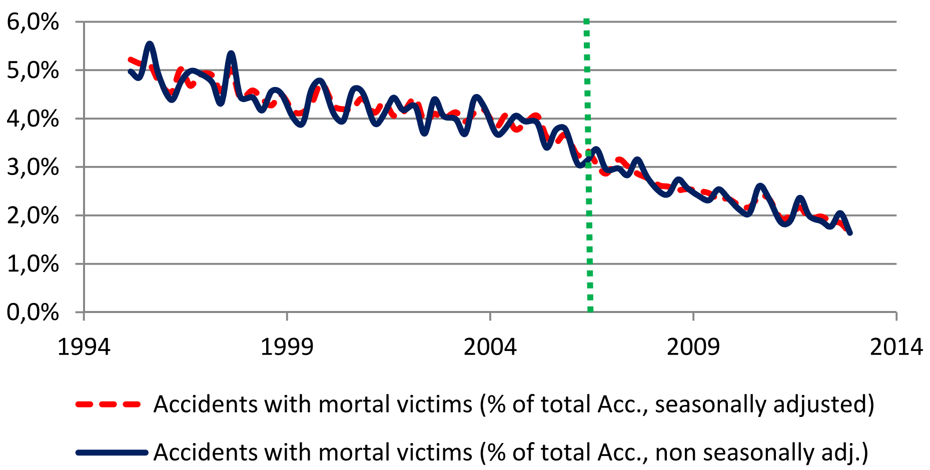

**Figure 4: Spanish GDP annual growth rate, 1995:1-2013:4**

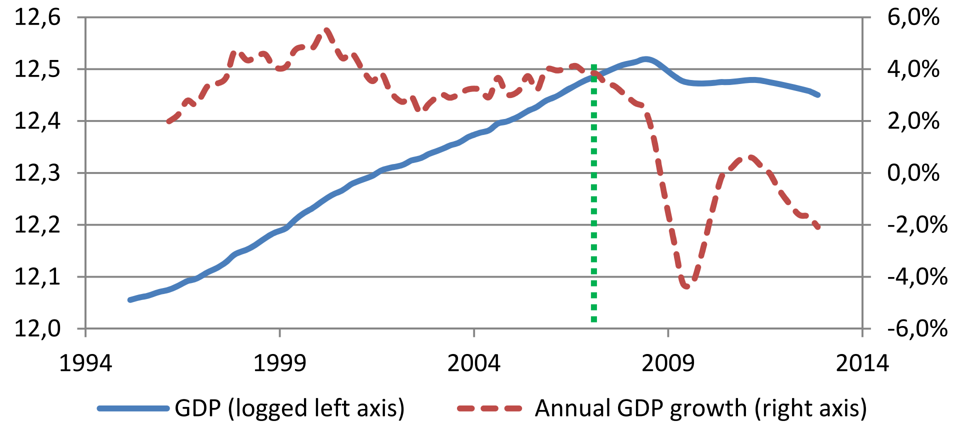


**Figure 5: Fuel prices in Spain, 1995:1-2013:4**