Points To Save Lives:

The Effects of Traffic Enforcement Policies on Road Fatalities

Miguel Almunia* Gonzalo Gaete

University of Warwick and CAGE University of Warwick

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Abstract

Traffic accidents cause more than one million annual deaths worldwide and yield substantial economic costs to society. This paper studies the effects of a penalty points system (PPS) introduced in Spain in 2006. We find a 20% decrease in cumulative road fatalities in the five years after the reform, compared to a synthetic control group constructed using a weighted average of other European countries. Evidence suggests that the persistent reduction in road fatalities might not only be driven by deterring risky-driving behavior, but also by taking reckless drivers out of the roads. Using estimates of the value of a statistical life, we calculate that the PPS yielded a net economic benefit of €4.6 billion ($6 billion) over this period, equivalent to 0.43% of Spain's GDP.

JEL codes: I18, R41, K32.

Keywords: road fatalities; traffic enforcement; penalty points system (PPS); synthetic control; Spain.

*Contact information: m.almunia@warwick.ac.uk (corresponding author) and g.gaete@warwick.ac.uk. Mailing address: Department of Economics, University of Warwick, Coventry CV4 7AL, United Kingdom. We thank Clément de Chaisemartin for useful comments and suggestions. We also thank the International Road Federation (IRF), especially Dr. Cristian Gonzalez, for providing data on traffic statistics for all EU-15 countries. Finally, we acknowledge financial support from the Centre for Competitive Advantage in the Global Economy (CAGE). The interpretation of the results reflects the opinions of the authors and not those of CAGE or the IRF.

1 Introduction

Certain public policies aim to influence individual behavior to discourage harmful activities such as crime, tax evasion or traffic violations. In this paper, we study the effects of a change in traffic enforcement policies for two reasons. First, reducing the incidence of traffic accidents is a first-order public health issue in most countries. According to recent estimates from the World Health Organization, more than one million people die in car accidents each year worldwide (WHO, 2013), generating an economic cost of approximately 1.5% of global GDP. Hence, better enforcement policies have the potential to yield large economic and social gains at a potentially low cost. A second reason to study the impact of traffic enforcement policies is that the key outcome variables in this setting, such as the number of accidents or road fatalities, are directly observable and collected in a standardized way across many countries. This is in contrast with tax evasion or crime, which are only imperfectly observed and therefore much harder to quantify.

In recent decades, many countries have implemented penalty points systems (PPS) to administer driving licences. Under a PPS, drivers are allocated a fixed number of points that they can lose if they commit traffic violations. Losing all points can result in the suspension of the driving licence for a period of time, or its permanent withdrawal.[1] According to the theoretical analysis of Bourgeon and Picard (2007), the PPS contributes to reducing the gap between the private and social valuation of the cost of traffic accidents, which the judicial system and the insurance market fail to address. By doing this, the PPS achieves two social objectives. First, it screens reckless drivers to ensure that they lose their licence. Second, it acts as a deterrence mechanism for normal drivers. Their analysis also shows that complementing this nonmonetary sanction system with moderate fines, as is usually done is most countries, is likely to increase overall welfare.

We study the effects of the introduction of a penalty points system in Spain in 2006 on road fatalities. Since the reform was introduced at the national level, it is challenging to

[1] In some countries, the policy is called "Demerit Points System" (DPS), where drivers start out with zero points and they accumulate them with traffic offenses. In that case, the licence is withdrawn when a certain number of points is reached.

find a suitable counterfactual to estimate the effect on drivers' behavior and mortality rates. Traditionally, case studies have chosen a set of "reasonably" similar units (e.g., cities or States) to form a counterfactual (for example, Card (1990), Card and Krueger (1994)). A problem with these case studies is that the choice of the counterfactual group is to some extent arbitrary.

We use the synthetic control method developed by Abadie and Gardeazábal (2003) and Abadie et al. (2010). The basic idea of this method is to build a counterfactual using a weighted average of all potential control units for which data is available. The set of potential controls is called the "donor pool". Each of the units in the donor pool is assigned a nonnegative weight in the synthetic group and, by construction, these weights must add up to one. Following this procedure, the method makes explicit the contribution of each comparison unit to the counterfactual of interest. Having constructed the counterfactual, measuring the impact of the policy simply requires comparing the evolution of road fatalities in Spain to the same aggregate variable for the *synthetic* Spain.

The main advantage of the synthetic control method over traditional case studies is the rigorous way in which the control group is chosen. By requiring only the use of pre-intervention data, the method is "blind" about the impact of the choices made to select the counterfactual on the final estimates. Moreover, the restriction that the weights of each unit must be nonnegative and add up to one implies that there is no use of extrapolation to build the counterfactual, something that often occurs in linear regression analysis (sometimes inadvertently). Under certain assumptions that we describe in more detail in section 3, the synthetic control method provides a compelling identification strategy to evaluate the impact of the PPS in Spain.

To build the synthetic control group, we use data on several predictors of road fatalities for all EU-15 countries, excluding Spain.[2] Our newly-constructed dataset includes annual data on alcohol consumption, road density, GDP per capita, fuel consumption, and the stock of vehicles, among other variables, for the period 1990-2011. The main source of data is the World Road

[2] The term EU-15 refers to the members of the European Union during the period 1995-2004, namely: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden and the United Kingdom.

Statistics report, produced by the International Road Federation.[3] We describe the dataset in more detail in section 2.2.

Our main finding is that annual road fatalities in Spain declined substantially between 2006 and 2011 as a result of the introduction of the PPS. By 2011, there were 4.4 road fatalities per 100,000 people in Spain, compared to 7.2 in the synthetic control group (a 39% difference). We estimate the cumulative reduction in road fatalities over that period to be approximately 20%, a very substantial effect. This is an interesting result, given that previous research has found short-run effects of traffic enforcement policies on drivers behavior, but these effects start to decline rapidly (Abouk and Adams, 2013). Following the implementation of the PPS, it was a sharply increase in the number of driving licenses suspended by the judiciary authority. This evidence might suggests that the persistent reduction in road fatalities could not only be driven by deterring a risky-driving behavior, but also by taking reckless drivers out of the roads.

We conduct two placebo exercises to check the robustness of this result. First, we evaluate the estimated effect under the assumption that the PPS was adopted by Spain in the year 2000 (six years before the actual implementation). We find no effect of this placebo policy on road deaths in Spain. As a second placebo test, we estimate the effect of a hypothetical adoption of the PPS in 2006 in each of the countries in the donor pool. We would expect the gap between road fatalities in each of these countries and their synthetic controls to be zero on average. Indeed, we find that the negative effect on road fatalities estimated for Spain stands out as the largest of all. These two placebo tests strongly suggest that our main findings are not due to pure chance.

Finally, we use our year-by-year estimates of the number of lives saved due to the PPS to calculate the economic benefits derived from this policy. During the five-year period after its adoption, the PPS prevented approximately 3,500-4,000 road fatalities (depending on the donor pool used in the estimation). According to Abellán et al. (2009), the value of a statistical life (VSL) in Spain is estimated to be in the vicinity of €1.3 million ($1.82 million). Therefore, we

[3] The International Road Federation is a non-profit organization based in Switzerland focused on "promoting the development and maintenance of better, safer and more sustainable roads and road networks". In consultation with national statistical institutes, it collects comprehensive data on road networks, traffic and inland transport all over the world. For more information, see www.irfnews.org.

estimate that the PPS yielded an economic benefit of €4.6-5.1 billion ($6.0-6.7 billion) in its first five years of implementation, which corresponds to 0.43-0.48% of Spain's GDP.

Previous Literature

Economists have long been interested in the effects of traffic enforcement policies on individual behavior. Since the pioneering work of Peltzman (1975), researchers have analyzed the effects of mandatory seat belt laws (Evans, 1986; Cohen and Einav, 2003), minimum legal drinking age (Lovenheim and Slemrod, 2010), minimum wage policies and alcohol-related traffic accidents (Adams et al., 2012), banning text messaging while driving (Abouk and Adams, 2013), fines and experience-rated insurance premiums (Dionne et al., 2011), motorcycle helmet mandates (Dee, 2009), smoking bans in bars (Adams and Cotti, 2008), and the regulation of bar's opening hours (Green et al., 2014), among others.

Some studies have focused specifically on the effects of penalty points system in different countries. DePaola et al. (2013) study the effects of the PPS in Italy, using a regression discontinuity design in which the assignment variable is time. They compare the number of road accidents and fatalities just before and after the introduction of the new law, estimating a 9% fall in traffic accidents and a 18-30% reduction in road fatalities. Several studies have attempted to evaluate the effects of the penalty points system (PPS) in Spain. These studies use monthly traffic statistics[4] and employ a variety of time-series techniques to address the issue of seasonality in the road fatalities data, such as controling nonlinearly for long-run trends and other variables associated to traffic accidents. Castillo-Manzano et al. (2010) estimate that the PPS led to a 12.6% reduction in the number of deaths on highway accidents (not weighted by population). Novoa et al. (2010) find a 10% reduction in the risk of death or serious injury in highway accidents for *drivers*. Pulido et al. (2010) estimate a 14.5% reduction in the number of road fatalities in the 18 months following the implementation of the PPS. Even though the outcome variable is slightly different in each study, the general conclusion from this set of studies

[4] Specifically, the monthly data on traffic accidents and fatalities in Spain is published by the General Directorate of Traffic (*Dirección General de Tráfico*, DGT).

is that the PPS reduced mortality in traffic accidents by 10-14% in the 18-24 months after the introduction of the policy.

The time-series methods used in these early analyses of the Spanish PPS have several limitations. First, they may not control adequately for long-run trends in road fatalities that are unrelated to the introduction of the PPS, for example a change in the pace of improvement in vehicles' safety features or road quality. During the decade starting in 2000, there was a generalized decline in the number of road fatalities across all countries in the EU-15. Failing to account for this trend could introduce a negative bias in the estimated effects of the Spanish PPS on fatalities, i.e. overestimating the effects of the policy. Even though we do not observe the factors behind these trends directly, we effectively control for them by using other EU-15 countries (likely affected by similar shocks as Spain) to build the synthetic control group. Second, controling for seasonality in road fatalities is difficult unless the time series used is very long, but the studies mentioned above focus on the period between January 2000 and December 2007, which is not long enough to accurately capture the seasonal swings in road fatalities. In this study, we use annual frequency data so we avoid having to deal with the varying seasonal patterns across EU-15 countries (e.g., due to differences in weather conditions and holiday schedules).

The key contribution of this paper to the literature is to use the synthetic control method, which provides a more reliable estimate of the medium-term effect of the penalty points system in Spain. A second contribution of the paper is the cost-benefit evaluation of the PPS, using estimates of the value of a statistical life. In the Spanish case, the cost-benefit analysis indicates that the PPS yielded substantial economic as well as human benefits with a very low cost of implementation (DGT, 2011), suggesting that countries without such a system should consider adopting it in the future.

The rest of the paper is organized as follows. Section 2 describes the institutional background and the dataset. Section 3 summarizes the synthetic control method. Section 4 presents the main results. Section 5 provides some additional discussion of the results, including the cost-benefit analysis using estimates of the value of a statistical life (VSL). Section 6 concludes.

2 Institutional Background and Data

2.1 The Spanish Penalty Points System (PPS)

The penalty points system (PPS) reform was enacted by the Spanish parliament on July 19th, 2005 and became effective on July 1st, 2006. The reform was widely discussed in the media, received almost unanimous support from all political parties, and was publicized through an extensive information campaign in the media (DGT, 2011).

In the Spanish PPS, drivers start out with 12 points (eight for newly-licensed drivers) that they can lose if they commit traffic violations. Some examples are speeding violations (two to six points depending on the severity of the offense), drunk driving (four to six points) or using the mobile phone while driving (three points). If a driver loses all points, their driving licence is suspended for a period of six months. Until 2011, 107,000 drivers had lost their licence, corresponding to 0.4% of all existing licences (DGT, 2011). Penalized drivers can recover their licence after going through traffic safety workshops organized by the traffic authorities. Losing all points for a second time may result in the permanent withdrawal of the driving licence.

Official government reports state that the main goal of the policy was to modify driving behavior through non-monetary penalties, seen as a necessary complement to the existing (and essentially unchanged) regime of monetary penalties (DGT, 2011). Additionally, they expressed the intention of shifting to individual drivers the responsibility of retaining their licence through good behavior.

Several other EU-15 countries have implemented similar points programs, as shown in Table 1 below. West Germany was the first country to implement such a system in 1974, followed by France in 1992, Greece in 1993, and the United Kingdom in 1995. As we explain below, we exclude some countries where the PPS was introduced around the same time as in Spain fromt the donor pool to ensure that they do not bias the results.

2.2 Data

We construct a new dataset of traffic-related statistics for EU-15 countries using multiple data sources, for the period 1990-2011. For data on traffic fatalities,[5] road network quality, the stock of four- and two-wheeled vehicles and other characteristics at the country level, we use the World Road Statistics (WRS), a report published by the International Road Federation.[6] For all these variables, we calculate the outcomes per 100,000 people, using population from the World Bank Open Data. We also use GDP figures in US dollars from the same source. Finally, we collect data on alcohol consumption per capita, a strong predictor of road accidents, from the OECD iLibrary.

The final dataset has some limitations. Even though the IRF makes an effort to collect homogeneous data across countries, there is a substantial proportion of missing values for certain variables that would have been good predictors of road accidents. For example, incomplete information about the annual volume of road traffic in each country prevents us from using this variable in the set of predictors of road fatalities. For some other variables, the number of missing values is limited to some specific country-year observations. In all cases where there are no more than two consecutive missing values, we use linear extrapolation to fill the gaps in the data so that we can include those variables in the analysis.

Another limitation is the relatively small sample size, as we have data for 15 countries over 22 years ($N = 330$). This is not uncommon in the synthetic control literature. For example, in the seminal paper by Abadie and Gardeazábal (2003), the sample size consisted of 17 Spanish regions, and the synthetic group included only two regions. As we explain below in more detail, this is less critical in this setting than in a linear regression context. The reason is that we are using aggregate data, so there is no statistical uncertainty about the representativeness of the sample, as noted by Abadie et al. (2010). Therefore, we do not construct confidence intervals around the point estimates in same way that we would when using a sample of data.

5 Fatalities are measured under the internationally standardized "30-day" measure, which counts any deaths within the first 30 days after the accident.

6 See foonote 2 above.

However, there is a different source of uncertainty regarding the precision of the estimates and their statistical significance, which depends on the validity of the sythetic control group. As we show below, the results are robust to a number of placebo checks.

Finally, our data has annual frequency instead of monthly. Even though this may seem to be a limitation because it reduces the effective sample size, notice that annual data does not feature seasonality, removing a potential source of bias from the estimation. For this reason, we argue that the advantages of monthly data are somewhat overstated in the earlier studies on this topic reviewed above. Having 15 years of complete pre-intervention data allows us to construct the counterfactual for Spain using the synthetic control method.

3 Synthetic Control Method

In this section we provide a formal description of the synthetic control method. For a more comprehensive treatment, please see Abadie et al. (2010).

Assume we observe $J + 1$ countries over T periods, and let country 1 (in this case, Spain) receive an intervention in period $t_I < T$, so that this country is exposed to the treatment during periods $t_I + 1, ..., T$. Let Y_{it} be the value of the outcome for country i in year t, and let Y_{it}^N be the value that would have been observed in the absence of the intervention. The goal is to estimate the effect of the intervention on the treated country, that is $\alpha_{1t} = Y_{1t} - Y_{1t}^N$, for the post-intervention periods $t \in (t_I + 1, ..., T)$. Since Y_{1t}^N is not observed in the post-intervention period, we need to estimate a counterfactual.

The key idea of the synthetic control method is to construct this counterfactual using a linear combination of the potential control units. For this purpose, we define the vector $W' = (w_2, ..., w_{J+1})$, which contains the weights that will be assigned to each unit in the donor pool. We impose that these weights must be nonnegative and sum up to one:

$$w_j \geq 0, \quad \forall \ j \in (2, ..., J + 1) \tag{1}$$

$$\sum_{j=2}^{J+1} w_j = 1 \tag{2}$$

These two conditions guarantee that the comparison group is constructed without using extrapolation, as emphasized by Abadie et al. (2010). The optimal vector of weights is chosen to minimize the distance between the characteristics of the synthetic control and the treated country. Let X_1 be a $(k \times 1)$ vector of pre-intervention characteristics of the treated country. Similarly, define the $(k \times j)$ matrix X_0, which contains the same variables for the untreated countries. Thus, the vector $W^{*'} = (w_2^*, ..., w_{J+1}^*)$ is chosen to minimize:

$$\min \quad ||X_1 - X_0 W||_V = \sqrt{(X_1 - X_0 W)' V (X_1 - X_0 W)} \quad \text{s.t. eqs. (1) and (2)} \tag{3}$$

where V is a $(k \times k)$) symmetric and positive semidefinite matrix. In general, V is a diagonal matrix with main diagonal elements $(v_1, ..., v_k)$, where v_l represents the relative weight assigned to the l-th pre-intervention variable when measuring the distance between the treated country and the synthetic group. Thus, if X_{jl} represents the value of the l-th pre-intervention variable for country j, the optimal weights $w_2^*, ..., w_{J+1}^*$ minimize:[7]

$$\sum_{l=1}^{k} v_l \, (X_{1l} - \sum_{j=2}^{J+1} w_j X_{jl})^2 \tag{4}$$

In other words, the weights are chosen to minimize the difference in pre-intervention characteristics between the synthetic control and the treated country. Under the assumption that a large-enough period of pre-intervention data is available (i.e., $t_I \gg 0$), an approximately unbiased estimator for the parameter of interest α_{1t} is given by:

$$\widehat{\alpha}_{1t} = Y_{1t} - \sum_{j=2}^{J+1} w_j^* Y_{jt} \quad for \quad t = (t_{I+1}, ..., T) \tag{5}$$

[7] In order to ensure that the counterfactual resembles the treated country, both in terms of the pre-treatment characteristics and the outcome of interest, Abadie et al. (2010) suggest the use of lagged values of the outcome variable in the process of obtaining the optimal weights.

We can also express the cumulative effect in the k years after the intervention as:

$$\sum_{t=t_I}^{t_{I+k}} \widehat{\alpha}_{1t} = \sum_{t=t_I}^{t_{I+k}} \left(Y_{1t} - \sum_{j=2}^{J+1} w_j^* Y_{jt} \right) \tag{6}$$

4 Results

We implement the estimation routine outlined above using the `synth` command for Stata, developed by Abadie et al. (2010).[8]

4.1 Composition of the Synthetic Control Group

We consider two alternative donor pools: (i) all EU-15 countries excluding Spain and (ii) the subsample of countries that do not have a penalty points system (PPS) or adopted it before the year 1996. The reason for restricting the donor pool in (ii) is that the subset of countries that adopted the PPS around the same time as Spain could potentially contaminate the synthetic group, because we expect the policy to have an effect on their road fatalities. We keep in the data countries that had adopted the PPS before 1996 because it is unlikely that the policy still has a relevant effect on *changes* in road fatalities more than ten years after its introduction (although we would expect it to have an impact the *level* of that outcome).

Table 2 reports the weights assigned to each country under the two alternative donor pools. The first column shows the weight when all countries are included in the donor pool. The country with the highest weight in the *synthetic* Spain is Portugal (0.35). This is not surprising, given that Portugal is a neighboring country that shares many geographic and cultural characteristics with Spain. Other countries with substantial weights are Belgium (0.25), Sweden (0.17), Italy (0.16), Greece (0.07) and Luxembourg (0.006).

The second column of Table 2 reports the weights when the donor pool is restricted to avoid

[8] More information about the command for Stata and other software platforms is available at http://web.stanford.edu/~jhain/synthpage.html.

contamination from the introduction of similar penalty points systems in other countries. This reduces the donor sample to eight countries, and it changes significantly the composition of the *synthetic* Spain. France, another country that shares a border with Spain, receives a high weight (0.30), although the highest goes to Belgium (0.42). Portugal's weight reduces to only (0.02), while Finland (0.18) and Greece (0.09) also receive a positive weight.

Table 3 reports summary statistics for all the predictors of road deaths in the pre-intervention period (1990-2005). We also report the average of the main outcome variable, road deaths per 100,000 people, for the years 1995, 2000 and 2005. The first column reports the actual values for Spain, the second for the synthetic Spain constructed using all potential control countries, the third for the synthetic Spain using only the uncontaminated subset, and the fourth shows the (unweighted) averages for all 14 potential donors.

The two synthetic controls do a reasonably good job at matching the values of the predictors of the *true* Spain. This is partly due to the fact that EU-15 countries are fairly homogeneous on many socioeconomic characteristics. However, the limited size of the donor pools implies that some of the values do not match perfectly. The differences between Spain and synthetic Spain are below 10% (which we consider a good match) for log GDP per capita, alcohol consumption per capita, kilometers of total and secondary roads, number of four-wheel vehicles and diesel consumption. The match is less precise for the number of motorcycles, petrol consumption and road density. For these three variables, Spain has lower values than the two synthetic controls. Despite these differences, the average values of the main outcome of interest–road deaths per 100,000 people–are matched almost perfectly at three different years in the pre-intervention period (1995, 2000 and 2005). This provides reassurance that the synthetic control method is performing quite well in both cases, despite the sample size limitations.

4.2 Main Results

Figure 1 shows that the two alternative synthetic control groups track the evolution of road fatalities per 100,000 people in Spain for the entire pre-intervention period. The top panel compares Spain against the synthetic Spain constructed using all other EU-15 countries. The two trend lines follow each other closely in the pre-intervention period (1990-2005), featuring a pronounced decline of road deaths per 100,000 people from about 17.9 in 1990 to 9.4 in 2005. After the PPS was introduced in Spain (in July 2006), the country experienced an even further decline in road deaths down to 4.4 fatalities per 100,000 people in the year 2011, compared to a value of 7.2 for the *synthetic* Spain.

The bottom panel of Figure 1 shows the trends for Spain and the second *synthetic* Spain, constructed using the restricted donor pool. As in the top panel, the pre-intervention trends in road deaths are very similar. The evidence of an effect of the PPS starting in the year 2006 is clear, and the divergence between Spain and the synthetic control by the year 2011 is essentially the same, as the alternative synthetic Spain has 7.1 deaths per 100,000 people.

These results imply that the PPS led to a large reduction in road fatalities in Spain during the first five years of application of the penalty points system. Table 4 reports the evolution of road fatalities per 100,000 people in Spain and the two alternative synthetic control groups for the period 2007-2011. By 2011, the incidence of road fatalities in Spain was 39% lower than that of *synthetic* Spain (4.41 vs. 7.23). The percentage difference is very similar regardless of the donor pool used.

If we focus on the cumulative difference over the first five years of implementation of the PPS, the difference is approximately 20% (30.78 vs. 38.43). These are substantial point estimates of the medium-term impact of the policy. The cumulative impact is almost twice as large as that estimated by earlier studies (discussed in the introduction), which focused on the short-term impact 18-24 months immediately after the introduction of the PPS. The last two columns of Table 4 report the annual difference in road fatalities per 100,000 between Spain and the two synthetic controls. We use these estimates of the number of lives saved due to the PPS to calculate the economic benefits of the policy in section 5.

Following the implementation of the PPS, it was a sharply increase in the number of driving licenses suspended by the judiciary authority. Figure 4 shows the number of driving licenses suspended between 2000 and 2009, adjusted by population size. Table 5 lays out the number of driving licenses suspended during the same period separately by the length of the suspension.[9] After 2006, the number of suspensions suddenly rose from approximately 77 to 121 driving licenses per 100,000 people, representing a 63.63% increment in 4 years. This evidence might suggests that the persistent reduction in road fatalities could not only be driven by the impact of the PPS on deterring a risky-driving behavior, but also by its effect on taking reckless drivers out of the roads.

4.3 Placebo Tests and Statistical Significance

We now turn to analyzing the robustness of the results using a series of placebo tests as suggested by Abadie et al. (2010). First, we test whether we would find an effect by assuming that the PPS was introduced in Spain in the year 2000, six years before its actual introduction. Figure 2 shows the trends for Spain and synthetic Spain using the two alternative donor pools, as before. Recall that the method uses pre-intervention data to match the behavior of the main outcome variable in the treated country with the synthetic control.[10] In both cases, the match before 2000 is reasonably good. If the penalty points system had actually been passed in 2000, we would have expected the two lines to start diverging right after that year. However, in the two panels of Figure 2 we observe that both synthetic controls continue following the trend for Spain quite closely until 2006, when the policy was actually enacted. After that year, the two lines start diverging significantly, with the *true* Spain featuring a steeper downward trend after 2006. This suggests that the large effect obtained for the 2006 reform was not due to chance.

Second, we compare the gap in road fatalities in Spain vs. synthetic Spain against the gaps that we obtain by assuming that the policy had been introduced in each country in the donor pool exactly in the same year, 2006. For this exercise, we only use the subset of countries that do not have a PPS or adopted it before 1996. Hence, Figure 3 shows the gap between road deaths per

[9] This information is provided by the Spanish Directorate General for Traffic (DGT (2009)).

[10] This implies that the composition of the synthetic control changes (and therefore, the weights assigned to each unit in the donor pool), given that we moved the implementation date of the policy. Table 6 reports the sets of weights used in this placebo test.

100,000 people in each country vs. its synthetic control, assuming that a penalty points system (PPS) was enacted in the year 2006 (marked by the vertical dotted line). Since the policy was only enacted in that year for Spain, for the other eight countries shown in the figure we would expect the gap to be zero even after 2006. Despite the fact that there are large swings in the gap for two of the countries,[11] by far the largest negative gap in 2011 corresponds to Spain (marked with the red solid line in the graph).

Following Abadie et al. (2010), we interpret this second placebo exercise to be *prima facie* evidence that the estimated effect of the policy is statistically significant. The argument is that, of all possible countries to which we could have applied the same estimation strategy, the effect found for Spain is the largest. Since there were nine countries (Spain plus the eight countries in the restricted donor poll), the statistical significance in this case is approximately 11% (= 1/9).

5 Discussion of Economic Benefits of the Policy

Our estimate of a 20% reduction in road fatalities in the five years after the adoption of the PPS in Spain is substantially larger than earlier estimates (Castillo-Manzano et al., 2010; Novoa et al., 2010; Pulido et al., 2010), which found reductions in road mortality in the vicinity of 10-15%. As discussed in the introduction, these studies were not able to adequately control for other factors that may have affected road safety over time in all EU countries simultaneously, such as the pace of improvements in vehicle safety technology. By providing a more compelling counterfactual, the synthetic control method removes the attenuation bias present in previous studies. It is also worth noting that these studies focus on the short-run effects of the policy, since they only use data for the two years after its adoption. In this study, we use data until 2011, which allows us to focus on the medium-term effects of the policy. This difference in the length of the evaluation period could also explains the discrepancy between previous estimates and our findings. Evidence regarding driving license suspensions suggests that the persistent reduction in road fatalities could be partly driven by taking reckless drivers out of the roads, which might

[11] The country with a large positive gap is Greece, the one with a large negative gap is Portugal.

explains even larger effects in the reduction in road fatalities in later years.

In order to do a cost-benefit analysis of the PPS, we separately estimate the benefits and costs of the policy for society as a whole. On the benefit side, we use estimates of the value of a statistical life (VSL) to obtain an economic equivalent of the number of lives saved. The value of a statistical life is the amount of money that individuals or societies are willing to spend to save a human life. This concept has a long history in the economics literature, and there are multiple estimates for many countries (see Viscusi (1993), Viscusi and Aldy (2003), Orley Ashenfelter (2004), Ashenfelter (2006)). Estimates of the VSL are used extensively by governments to evaluate public policies related to health and other risks.

In Spain, the Directorate General for Traffic (DGT) commissioned a report to estimate the VSL in order to perform cost-benefit analyses of their policies (Abellán et al., 2009). The central estimates of the VSL obtained by this team of researchers is €1.3 million per life ($1.69 million at the 2011 exchange rate).

Multiplying these values by the number of lives saved each year between 2007 and 2011 (for the complete donor pool), we obtain a total benefit of €4.6 billion ($6 billion) over this five-year period. This is equivalent to 0,43% of the annual Spanish GDP. The figures for the restricted donor pool are slightly larger: 5.1 billion ($6.7 billion), which is equivalent to 0,48% of GDP. These economic benefits are close to 0.1% of GDP each year. The figures suggest an extremely high return of this policy in economic and human terms.

Even though there are no official estimates of the cost of implementing the penalty points system in Spain, the available information suggests that the cost was an order of magnitude smaller than the estimated benefits. A report by the Directorate General of Traffic (DGT, 2011) explains that the information campaign at the time of introduction of the policy received a substantial amount of free publicity in the media (especially on TV and the written press), which allowed the DGT to make large savings on advertising. Moreover, the traffic re-education courses through which where offending drivers can recover their points charge tuition fees, so the net cost of these courses for the authorities is also limited.[12] Therefore, we argue that the

[12] One could also argue that the costs for sanctioned drivers of attending the courses or having their license

economic benefits estimated above can be considered a good approximation of the net benefit of the penalty points system.

6 Concluding Remarks

This paper has studied the impact of the introduction of a penatly points system in Spain on mortality from traffic accidents. We have found a large and significant reduction in road fatalities by 20% over a five-year period, about twice as large as the estimates from earlier studies. Evidence suggests that the persistent reduction in road fatalities might not only be driven by the success of the PPS in deterring a risky-driving behavior, but also by taking reckless drivers out of the roads.

The results suggest that other countries, especially those currently in the middle and low-income categories, should consider adopting similar policies in order to reduce the mortality on their roads. Of course, this conclusion must come with the caveat that the context also matters: Spain is a highly-developed country with modern infrastructure and government institutions capable of managing sophisticed information systems to monitor millions of drivers.

More research is needed to understand the specific mechanisms that made the penalty points system so effective in Spain. Researchers could exploit some variation in traffic enforcement across regions in order to identify the relative importance of these mechanisms. For this purpose, it would be necessary to have access to high-frequency individual-level data on traffic violations, e.g. speeding, seat belt use, or alcohol consumption, which are not currently in the public domain.

withdrawn should be included in the overall welfare calculation, but these costs are likely to be dwarfed by the benefits to society of having fewer accidents.

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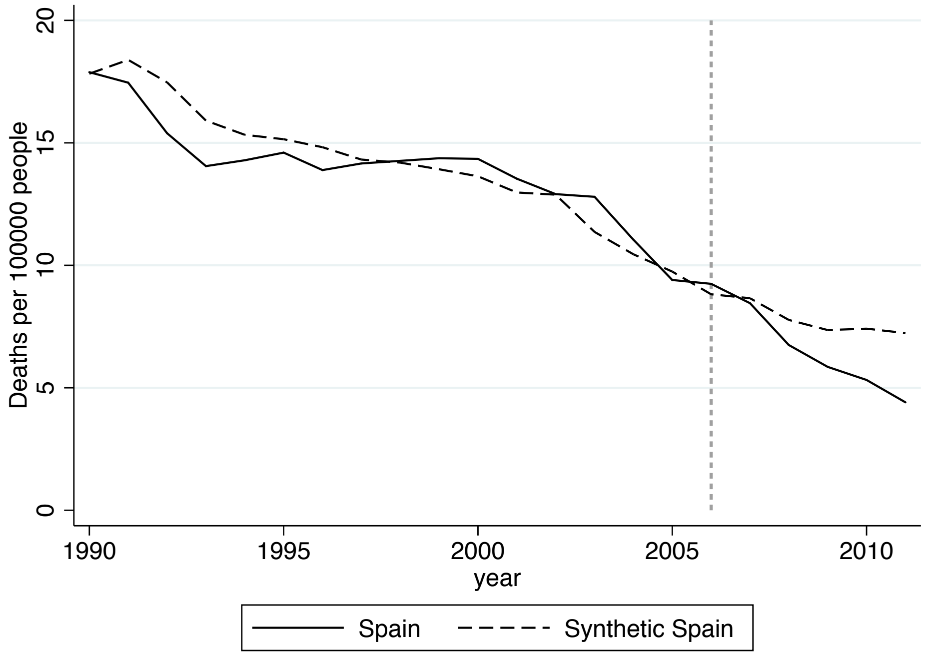
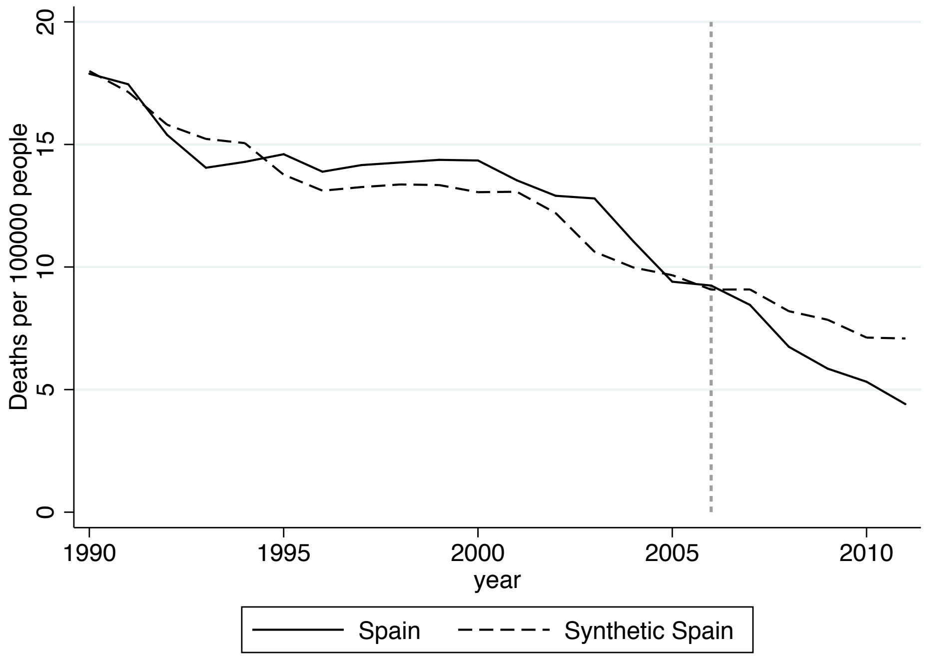
Figures

Figure 1: Road Deaths over Time: Spain vs. "synthetic" Spain.

Donor Pool: All Countries



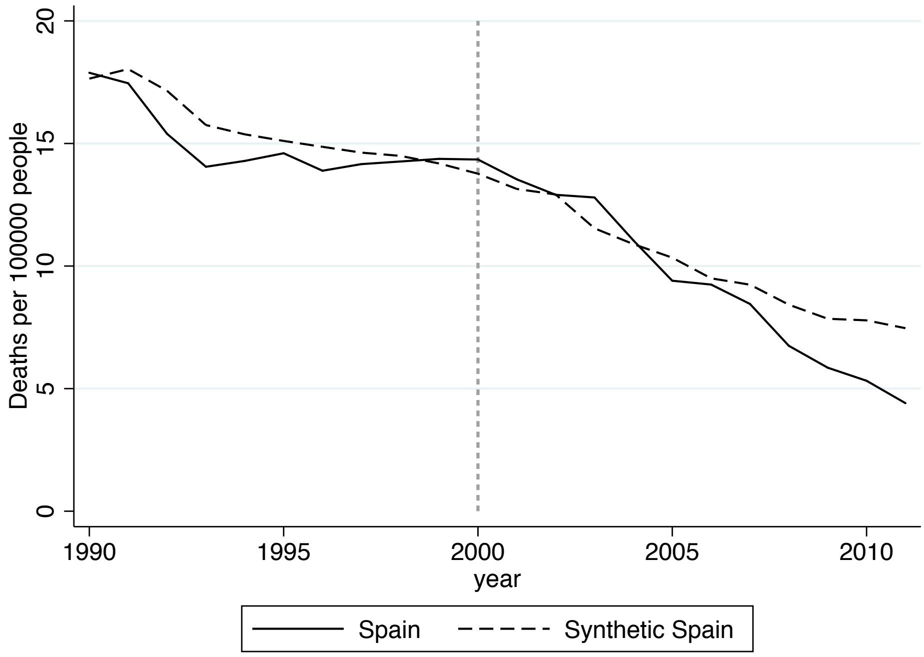
Donor Pool: No PPS, or adopted before 1996



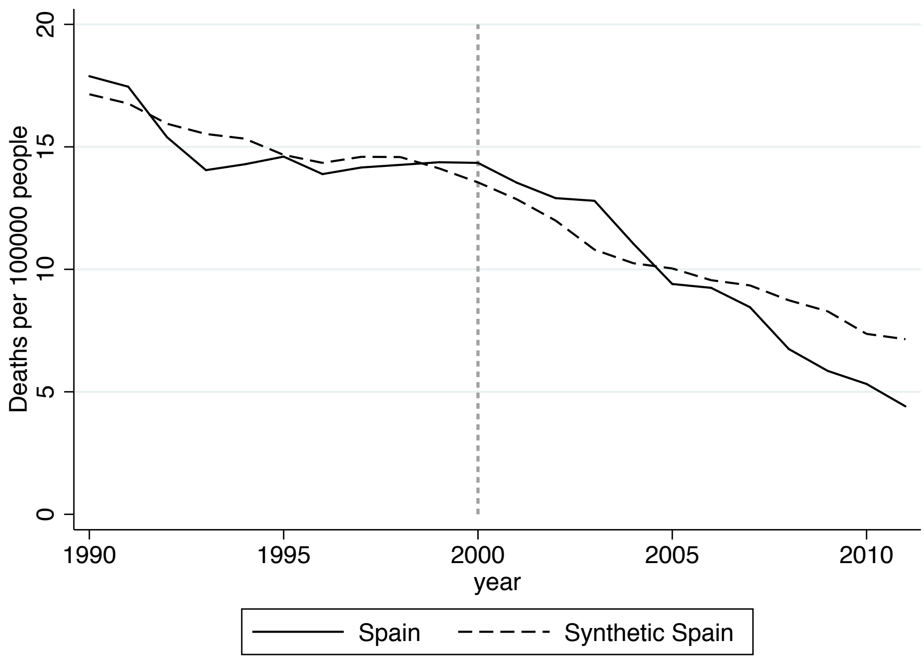
Note: to construct the top figure, we construct the synthetic control using all EU-15 countries excluding Spain. For the bottom panel, we use only the 8 countries without a penalty points system (PPS) and those that adopted it before 1996. The vertical dotted line indicates that the policy was enacted the year 2006.

Figure 2: Placebo Test: Moving the Policy to 2000

Donor Pool: All Countries

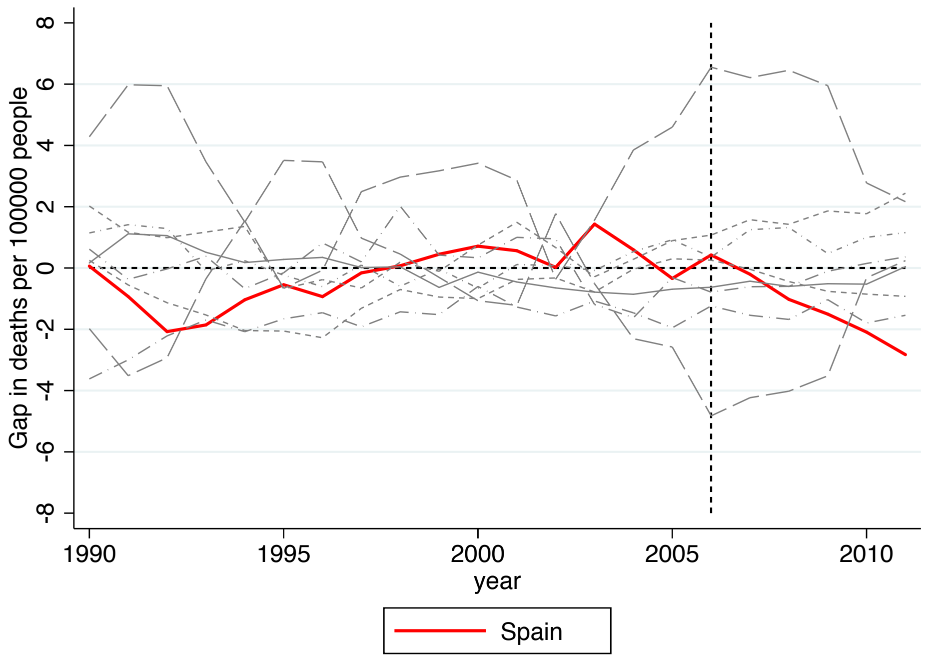


Donor Pool: No PPS, or adopted before 1996



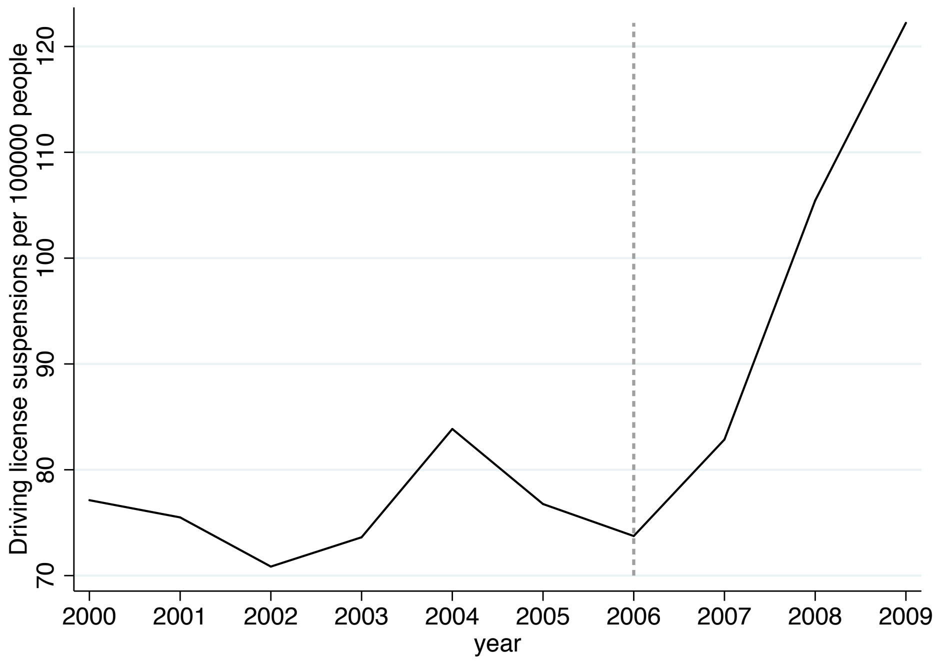
Note: in the top figure, we construct the synthetic control using all EU-15 countries excluding Spain. For the bottom panel, we use only the 8 countries without a penalty points system (PPS) and those that adopted it before 1996. The vertical dotted line indicates that the policy is assumed to have been enacted the year 2000 in Spain for this placebo test.

Figure 3: Effect of PPS in Spain vs. Placebo Effects in Other Countries



Note: this figure shows the gap between road deaths per 100,000 people in a country vs. its synthetic control, assuming that a penalty points system (PPS) was enacted in the year 2006 (marked by the vertical dotted line). The policy was only enacted in that year for Spain, whereas the other eight countries shown in the figure either do not have a penalty points system (PPS) or adopted it before 1996. For this countries, this is just a placebo exercise and we would expect the gap to be zero.

Figure 4: Driving Licenses Suspended by the Judiciary Authority.



Source: Spanish Directorate General for Traffic (2009).

Tables

Table 1: Penalty Points Systems by Year of Adoption

Country	Year of Adoption	Type of System
Germany (West)	1974	Demerit
France	1992	Demerit
Greece	1993	Gain
United Kingdom	1995	Gain
Ireland	2001	Gain
Luxembourg	2002	Demerit
Italy	2003	Demerit
Netherlands	2003	Gain
Austria	2005	Take into account recidivism
Denmark	2005	Gain
Spain	2006	Demerit
Belgium	-	-
Finland	-	-
Portugal	-	-
Sweden	-	-

Source: European Transport Safety Council (2011).

Table 2: Country weights for Synthetic Spain

Country	Donor Pool: All countries	Donor Pool: No PPS (or adopted before 1996)
Austria	0	-
Belgium	0.245	0.415
Denmark	0	-
Finland	0	0.176
France	0	0.300
Germany	0	0
Greece	0.070	0.093
Ireland	0	-
Italy	0.162	-
Luxembourg	0.006	-
Netherlands	0	-
Portugal	0.351	0.016
Sweden	0.166	0
United Kingdom	0	0

Note: this table reports the weights assigned to each country using the synthetic control method explained in section 3. By construction, the weights are nonnegative and must add up to one. In the first column, the pool of donors contains all EU-15 countries excluding Spain. In the second column, the pool of donors contains the subset of countries that have never adopted a penalty points system (PPS) or adopted it before the year 1996.

Table 3: Summary Statistics: Spain vs. Synthetic Spain

	Spain	Synthetic Spain		Average of all potential donors
		All countries	No PPS (or adopted before 1996)	
Log GDP per capita (USD)	9.71	10.08	9.86	10.13
Alcohol consumption per capita (lts.)	11.34	11.60	10.47	11.24
Total roads (km. per 100,000)	1,211.45	1,427.75	1,158.04	1,283.57
Secondary roads (km. per 100,000)	344.30	311.73	325.79	313.46
Road density, (sq. km. per 100,000)	0.002	0.022	0.018	0.049
Four-wheel vehicles (per 100,000)	48,009.24	47,910.01	45,699.48	46,941.76
Motorcycles (per 100,000)	4,453.86	4,790.38	5,603.44	4,727.66
Diesel consumption (lts. per 100,000)	43.31	41.20	37.79	49.60
Petrol consumption (lts. per 100,000)	20.83	26.68	29.24	44.13
Road deaths, 2005 (per 100,000 people)	9.40	9.67	9.74	8.44
Road deaths, 2000 (per 100,000 people)	14.35	13.05	13.63	11.38
Road deaths, 1995 (per 100,000 people)	14.60	13.77	15.15	12.58
Road deaths, 1990 (per 100,000 people)	17.88	17.99	17.82	14.89

Notes: All variables are averaged for the 1990-2005 period, except road deaths which is evaluated in three specific years. GDP per capita is measured in US dollars. Alcohol consumption is measured in litres per person/year. Total and secondary roads are measured in kilometers per 1,000 people. Road density is measured in squared km. per 100,000 people. The number of four-wheel vehicles and motorcycles is measured in units per 100,000 people. Diesel and petrol consumption are measured in litres per 100,000 people and year. Road deaths are measured under the standardized 30-day measure, which counts any deaths due to traffic accidents in the 30 days after the accident. In the second column, the pool of donors contains all EU-15 countries excluding Spain. In the third column, the pool of donors contains the subset of countries that do not have a penalty points system (PPS) or adopted the policy before 1996. The fourth column shows the (unweighted) averages for all 14 potential donors.

Table 4: Road Fatalities after PPS Adoption: Spain vs. “synthetic” Spain.

		Synthetic Spain		Difference Spain vs. Synthetic Spain	
Year	Spain	All countries	No PPS (or adopted before 1996)	All countries	No PPS (or adopted before 1996)
2007	8.45	8.66	9.09	-0.20	-0.63
2008	6.75	7.77	8.20	-1.02	-1.45
2009	5.85	7.36	7.85	-1.50	-1.99
2010	5.32	7.41	7.12	-2.09	-1.80
2011	4.41	7.23	7.09	-2.83	-2.68
2007-2011	30.78	38.43	39.34	-7.65	-8.56

Notes: Road deaths are measured per 100,000 people under the standardized 30-day measure, which counts any deaths due to traffic accidents in the 30 days after the accident. “All Countries” indicates that the donor pool contains all EU-15 countries excluding Spain. “No PPS (or adopted before 1996)” indicates that the donor pool contains the subset of countries that do not have a penalty points system (PPS) or adopted the policy before 1996, i.e. at least ten years before Spain.

Table 5: Licenses Suspended by the Judiciary Authority.

	Length of Suspension				
Year	< 6 months	6 months - 1 year	1 year - 3 years	> 3 years	Total
2000	5,049	449	25,413	142	31,053
2001	3,511	280	26,826	153	30,770
2002	2,531	188	26,475	160	29,354
2003	1,837	2,888	26,164	170	31,059
2004	1,248	9,461	25,046	237	35,992
2005	817	11,176	21,305	211	33.509
2006	657	13,207	18,654	219	32,737
2007	632	16,627	19,902	314	37,475
2008	707	24,030	23,397	323	48,457
2009	675	29,199	26,356	440	56,670

Source: Spanish Directorate General for Traffic (2009).

Table 6: Country weights for Synthetic Spain: Placebo Test

	Donor Pool	
Country	All countries	No PPS (or adopted before 1996)
Austria	0	-
Belgium	0.193	0.051
Denmark	0	-
Finland	0.073	0.047
France	0	0.323
Germany	0	0.260
Greece	0.157	0.319
Ireland	0.009	-
Italy	0.197	-
Luxembourg	0	-
Netherlands	0	-
Portugal	0.282	0
Sweden	0	0
United Kingdom	0.089	0

Note: this table reports the weights assigned to each country using the synthetic control method explained in section 3. In this case, we conduct a placebo test on which we move the policy to year 2000. By construction, the weights are nonnegative and must add up to one. In the first column, the pool of donors contains all EU-15 countries excluding Spain. In the second column, the pool of donors contains the subset of countries that have never adopted a penalty points system (PPS) or adopted it before the year 1996.