The impact of curbside parking regulations on car ownership

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ABSTRACT

Car ownership is a major driver of household travel behavior, and has implications on transport demand, energy consumption, emission levels and land use. However, how curbside parking regulations (i.e. paid parking) affect car ownership remains unclear. Here, we employ a two-way fixed effect model using panel data and difference-in-differences estimations to determine the causal impact of changes in parking regulations and the impact of an extension of a city-wide parking policy in Barcelona. Our results show that the introduction of paid curbside parking to reduce non-resident/visitor demand had a positive impact on resident car ownership levels (who enjoy parking permits for free or at a very low cost – 1€/week). Our calculation of the net social cost of reallocating curbside parking to residents indicates that the costs derived from the residents' parking subsidy and their likely increase in car usage can easily offset the benefits derived from visitor-trip deterrence, showing the relevance of the tradeoff between efficiency and acceptability.

Keywords: parking regulations, car ownership, policy evaluation, difference-in-differences.

JEL Codes: H42; L91; L98; R41; R42; R48

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1 Introduction

Expansion of cars during the 20th century has shaped cities and urban environments, giving rise to economic relevant problems (like congestion and pollution). This has motivated cities to move on from car-dependent planning towards travel demand management (TDM), implementing different policies trying to mitigate car related externalities and reclaim public space (i.e.: road pricing, parking management or even banning cars). The relevance of car ownership as a key element of household travel behavior has a direct impact on transport demand (congestion), energy consumption, emission levels and land use (including urban sprawl, space occupation, and housing affordability). Thus, the impact of TDM measures on car ownership levels is of crucial relevance for cities aiming to address these problems.

Recent research suggests that parking policy is another dimension that needs to be considered, as it affects both ownership and car use (Chatman, 2013; Guo, 2013a; Weinberger, 2012; Christiansen et al., 2017a and b).[1] If a parking spot is difficult to find or it is costly, then owning a car becomes less attractive as both its usage and storage costs rise. However, the causal effect between car ownership and parking regulations is still under-researched, despite the wide scale adoption of such policy tools to rationalize the use of cars and their externalities in urban areas. A few empirical studies have, however, sought to assess this impact and conclude that it is relevant. More specifically, drawing on data for non-densely populated areas in New York, it has been suggested that parking supply variables can have more than twice the impact of income on car ownership, depending on the household ownership level (Guo, 2013b). Additionally, this same author also provides suggestive evidence that free and uncrowded curbside parking increase ownership even for households owning off-street parking (Guo, 2013c). This might suggest that curbside parking has both a supply effect (making it easier for a household to own more cars) and an amenity effect (being more convenient to use than the off-street alternative).

In a similar vein, waiting lists for parking permits in Amsterdam are found to reduce the car ownership of residents in districts where they operate (de Groote et al., 2016); while data from the US suggests that 'hiding' the cost of off-street parking in housing prices/rents reduces

[1] Research has long focused on the determinants of car ownership, including, among others, household composition, life cycle, income, employment status, car fixed costs, population density, public transport provision, job and amenities accessibility (See Dargay, 2000; de Jong, 2004; Giuliano and Dargay, 2006; Dargay and Hanly, 2007; Matas and Raymond, 2008; Potoglou and Kanaroglou, 2008; Nolan, 2010; Mulalic et al., 2016).

the odds of people being car-free compared to situations where this cost is not bundled (Manville, 2017).

To demonstrate the validity of their causal impact estimates, the above studies apply a different identification strategy to deal with the possibility that households might not be randomly assigned to locations but sorted in accordance with their car ownership preferences. This suggests a potential self-selection bias, as residents may well take parking availability into consideration when deciding where to locate or work, so people with low parking needs will tend to opt for areas with less parking availability.

All studies exploring the causal impact of parking on car ownership to date have used cross-sectional data (or repeated cross-sections) and have sought to account for time-invariant unobservable factors. Guo (2013b) uses a contemporaneous, within-group comparison separating households with a car from those without that enjoy similar parking types, assuming that sub-groups share similar unobservable attributes related to car ownership preferences. In addition, he uses an instrumental variable estimation as a robustness check for his main findings. De Groote et al. (2016) propose an alternative approach using repeated cross-sectional data and a boundary-discontinuity design. Their key identifying assumption is that unobserved characteristics vary continuously over space and that parking policy is district specific, generating a sharp regulatory boundary along which they assume sorting to be continuous. Manville (2017) uses the American Housing Survey, addressing self-selection by instrumental variables, and takes advantage of different natural experiments that arise within subsamples (using recent movers, those that report their home as being the only one available and rent-regulated units).

This body research does not address the impact of curbside parking regulations (i.e. paid parking) on car ownership. As such, we have no insights into fairly common situations where non-resident parking is subsidized (with curbside charges being lower than garage fees) and all car-owning residents are granted a parking permit (with no waiting list), and where both parties compete for part of the available curbside parking supply but enjoy different levels of priority. Such regulatory schemes arise from the need to avoid what is often fierce opposition on the part of residents (that are also voters) to curbside pricing, and to give them preferential parking treatment (subsidy). This implies a potential welfare transfer between visitors and residents, which impact on parking policy efficiency in not well understood. Additionally, this use of cross-sectional data does not allow the temporal dimension of policy intervention to be analyzed, with previous studies measuring a 'contemporaneous impact' despite the fact that car ownership is a medium-term household choice (as a durable good).

In this paper, we take advantage of the introduction of a city-wide parking regulation policy in Barcelona (known as ÀREA) and use a panel dataset covering the period 2006-2014 to identify the causal effect of changes in parking policy variables on changes in car ownership within neighborhoods. We exploit the within-group variation in the number of registered cars per neighborhood (neighborhood fixed-effects), ruling out any bias induced by unobserved time-invariant factors. Additionally, we also take advantage of a policy expansion to identify the causal impact of the specific transformation of free parking spots into regulated spaces (providing preferential parking treatment to residents) on car ownership comparing the outcomes of newly treated neighborhoods with the never treated ones as counterfactual for what would have happened to the treated group if the policy had not been implemented. In both cases, to further test the robustness of our estimates, we control for average household characteristics at the neighborhood level (economic, sociodemographic and mobility related variables) to account for potential sorting of households among neighborhoods according to their car-related preferences; and for time-specific effects to account for time trends and specific shocks. As such, our paper is – as far as we know – the first to assess the causal impact of curbside parking regulations on car ownership.

Our findings indicate that increasing the number of regulated parking spaces increased neighborhood car-ownership levels, even when not specifically offering residents preferential treatment (impact differentiated by type of dedicated space). Moreover, our analysis of the introduction of ÀREA suggests that the implementation of parking regulations in treated neighborhoods increased average car ownership at rates that were 2.9% above those experienced in control areas. Furthermore, our calculation of the net social cost of reallocating curbside parking to residents suggests that the costs of granting them parking permits can even offset the gains from 'chasing out' visitor parking.

The rest of this paper is organized as follows. Section 2 describes the parking policy intervention implemented in Barcelona. Section 3 describes our empirical strategy for estimating the causal impact of parking regulations on car ownership levels. Section 4 describes our data. Section 5 presents our main results and discusses their implications and Section 6 concludes.

2 Parking policy intervention in Barcelona

The city of Barcelona is one of Europe's most densely populated cities (UN, 2015), characterized by inevitable traffic-related problems and very high competition for public space. Barcelona first introduced parking regulations in the early 1980s, when commercial curbside parking spaces (blue zones) were implemented. Tariffs and limited parking durations were set to deter long-stay parking and to increase turnover in high-demand downtown commercial areas. These regulations were successively expanded to other specifically targeted downtown areas and commercial streets in the city's outer neighborhoods, increasing from about 650 regulated spaces in 1984 to around 7,000 in 2005. These regulations were implemented at the request of business owners and users, following the technical assessment of the local authority.

Concern over increasing traffic congestion – with predictions of total gridlock by 2010 – led the City Council to explore measures to reduce the number of private vehicle trips to the downtown area. The result of their study was the ÀREA regulations that rather than a congestion charge implemented a paid parking scheme for all curbside spaces.

The scheme's first wave, implemented in 2005-06, targeted the Central Business District (CBD) and 28 neighborhoods inside the city's inner ring road. The primary purpose was to reduce the number of car trips into the city center. The scheme's second wave (2009) saw regulations expanded within the already treated neighborhoods, extended to the area in the immediate vicinity of the CBD, and introduced in a further 13 new neighborhoods. The third wave (2010-2011) involved its extension into five neighborhoods of the city's outskirts. The implementation of ÀREA meant converting free parking spaces into regulated spaces (c. 28,500 in the first wave, 15,500 in the second and 250 in the third). Today, the overall parking supply in Barcelona is calculated at around 140,000 spaces (DB Aj.BCN, 2015), more than 50,000 of which are regulated by the ÀREA scheme.

The regulated parking spaces are assigned different dedicated uses: commercial activities (blue zones), where all users are considered visitors; mixed-use (green zones), where both residents and visitors can park, and resident-exclusive spaces ('green exclusive'). The City Council established spaces for commercial activities to encourage a high turnover in commercial areas and in the proximity of community services (hospitals, schools, etc.). The stated aim for mixed-use spaces is to prioritize residential parking over that of visitors in areas where the sum of all parking needs exceed supply. Finally, resident-exclusive spaces aim at easing what the City Council considers severe supply shortages, which in their view justifies the allocation of all curbside spaces to residents (their use being prohibited to visitors).

Commercial space regulations apply from 09:00 to 14:00 and from 16:00 to 20:00 Monday to Friday, being extended in the city center to include Saturdays and in the city's beach areas to include Sundays and holidays also. Mixed-use space regulations operate from 08:00 to 20:00 Monday to Friday, including Saturdays in the city center. Resident-exclusive spaces tend to operate 24/7 throughout the year, though some adhere to the same operation times as commercial spaces. Regulated spaces are distributed across twenty-two zones. Commercial spaces apply four fee/hour bands (€1.08 to €2.50) with associated maximum stays (from 1 to 4 hours), mixed-use spaces apply just two fee/hour bands (€2.75 to €3.00) and allow users to stay for maximum periods of either 1 or 2 hours.[2] Residents are allowed to park in both mixed-use and resident-exclusive spaces at a reduced rate of €0.20/day during operating hours with no maximum stay restriction, as long as they hold a valid parking permit for that zone. Resident parking permits are granted upon request to any resident paying motor vehicle tax for a car registered in the zone, there being no total number limitation and no waiting list in operation. This means parking regulation targets visitors by chasing out free parking for them; while residents receive a resident permit at a price lower than marginal provision cost (subsidy). This was used as the main instrument to overcome opposition to the policy implementation.

ÀREA is characterized by a predominance of mixed-use spaces that give residents such preferential treatment. The scheme's first wave turned some 21,700 free curbside spots into mixed-use spaces (a further 14,4000 being created in the second wave) and an additional 4,500 into resident-exclusive spaces. In the case of commercial parking spaces 2,200 free spots were converted in the first wave and 1,100 in the second. The third wave also saw an increase in the number of mixed-use spaces but the total net curbside parking supply fell, with curbside space being allocated to other transport modes.[3]

A comparison of mixed-use and commercial parking spaces shows that the former are more restrictive in terms of their use by visitors; however, a previous study suggests that this

[2] Figures correspond to prices and limits established for 2016.
[3] In our sample, we assume that any fall in the number of regulated parking spaces means the space was eliminated and used for new bus or bike lanes, bike-sharing stations or the expansion of pedestrian walkways.

difference might not be substantial.[4] The inverse does not necessarily hold for residents, as we must consider the total parking cost, which here includes cruising. Mixed-use spaces are preferentially allocated to residents who tend to park their vehicle over consecutive days, while residents and visitors are left to compete for the few available spots given the low turnover. In contrast, commercial spaces offer higher rates of turnover by limiting residential parking during operating hours, providing a greater chance of finding a spot especially at the end of the regulated period. It is not unusual for residents to selectively patronize streets with commercial spaces to increase their chances of finding a vacant spot, especially if they plan to use their car the next day.

Additionally, it is relevant to stress that some other mobility-related policies were implemented during the period of analysis by the City Council, linked to the development of the Sustainable Urban Mobility Plan (SUMP). This included the extension of bike and bus lanes, and pedestrianizations small-scale and scattered interventions all over the central city areas. Thus, we take this into account in our empirical strategy, so we address the potential biases this might introduce.

3 Empirical strategy

In this paper, we seek to estimate the causal impact of curbside parking regulations on car ownership using a panel of 72 neighborhoods in the city of Barcelona for the period 2007-2014. We take advantage of both the cross-sectional and longitudinal variation in our data to estimate different models in our efforts to address potential econometric issues.

Our first approach involves analyzing the effect of changes in regulations at the neighborhood level over time. To do so, we specify the following general model:

$$Y_{it} = \alpha Z_{it} + \beta X_{it} + v_t + u_{it}. \tag{1}$$

where Y_{it} is the number of cars owned per 1000 inhabitants in each neighborhood i and period t, and Z_{it} are the parking spaces variables (regulated parking spaces, fee and maximum length

[4] Gragera and Albalate (2016) show that mixed-use spaces can shift occasional parkers' demand towards garages, having controlled for parking fees.

of stay). To account for the fact that systematic differences may arise between neighborhoods due to households sorting according to their preferences and car needs, X_{it} is the vector of time-varying control covariates that account for average household characteristics at the neighborhood level (economic, sociodemographic and mobility related variables). This does also allow us to control for potential changes in accessibility introduced by other mobility-related policies that might bias our estimates. Additionally, we also include v_t time-specific effects to account for time trends and specific shocks (such as the economic crisis). Parameters α and β will be estimated, while u_{it} is the idiosyncratic error term, which follows a normal distribution and has mean 0. Equation (1) describes a pooled OLS model (POLS).

However, this model fails to take into account the possibility that we might not be able to control for all potential factors determining car-related neighborhood characteristics and those affecting a household's location decision. Were this to be the case, any latent heterogeneity in (1) would be averaged out and might bias our estimates. In order to account for unobserved heterogeneity, in equation (2) we include neighborhood-specific fixed effects (w_i) and so specify a two-way fixed effects model (FE). This allows us to identify the causal impact by analyzing the effect of changes in parking policy variables on changes in car ownership within neighborhoods. It exploits the within-group variation in our sample, ruling out any bias induced by unobserved time-invariant factors.

$$Y_{it} = \alpha Z_{it} + \beta X_{it} + w_i + v_t + \varepsilon_{it}. \tag{2}$$

To gain insights into the specific impact of policy implementation, our second approach involves an analysis of the causal impact of the specific transformation of free parking spots into regulated spaces by taking advantage of the quasi-experimental design derived from the extension of ÀREA in the second and third waves of its implementation (2009 and onwards), as shown in Figure 1. This allows us to conduct a difference-in-differences estimation by substituting the number of regulated parking spaces with a policy dummy (T_{it}), which takes value $T_{it} = 1$ when parking regulation extension was active in neighborhood i in period t, and zero for control neighborhoods that did not undergo any changes in their parking regulations. In this model parking fee and maximum stay limit are kept as controls to account for potential differences in visitor demand levels (Z'_{it}). This allows us to estimate the difference-in-differences model (DID) specified in (3).[5]

$$Y_{it} = \delta T_{it} + \alpha' Z'_{it} + \beta X_{it} + w_i + v_t + \varepsilon_{it}. \tag{3}$$

In this case, the causal impact of 'chasing out' free parking is given by the parameter δ, which measures the difference between the average change in car ownership levels in the treated neighborhoods (those to which, at some point in time, parking regulations are extended) and the average change in car ownership levels in the control group (neighborhoods in which parking regulations have never been implemented). This is formally shown in (4), where Y_B and Y_A are the car ownership levels before and after implementation, respectively, and $T = 1$ and $T = 0$ refer to the treatment and control groups, respectively.

$$\delta = [E(Y_A|T = 1) - E(Y_B|T = 1)] - [E(Y_A|T = 0) - E(Y_B|T = 0)]. \tag{4}$$

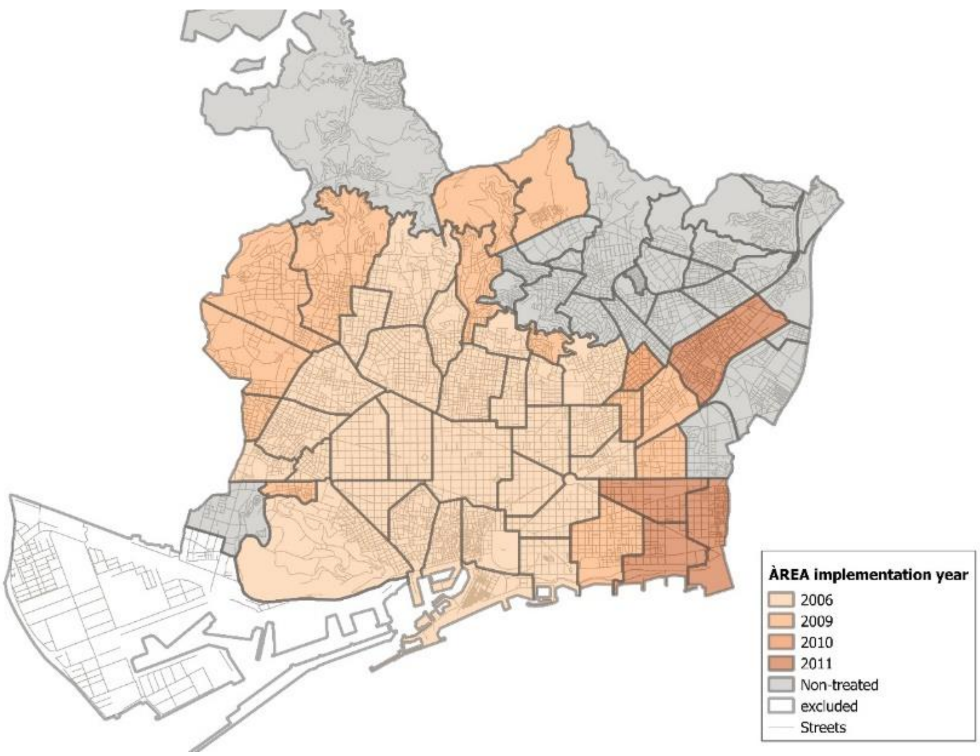
The key identifying assumption in (4) is the **parallel trends assumption**, which means that average changes in car ownership need to be equal for both treated and control groups in the absence of the policy in order to obtain unbiased estimates of δ, as the control group is a good counterfactual for what would have happened to the treated group if the policy had not been implemented. Because the identification strategy is grounded on the assumption of time-invariant heterogeneity – and the main threat would be the presence of time-variant unobserved heterogeneity- we follow Galiani et al. (2005) to test this assumption by using observations for the treatment and control groups during pre-treatment period. Thus, we modify (3) by substituting the policy treatment variable with separate year dummies for each group and checking whether we can reject the null hypothesis of equality between the group dummies for each year. As a further robustness check of this hypothesis, we also conduct a placebo test by randomly assigning the treatment to the population of neighborhoods during the pre-treatment period. Results of these tests are reported in Appendix 1.

Up to this point, we have considered pre-treatment changes in the outcome variables for the treated neighborhoods to be exogenous to the policy, but this assumption will be violated if

[5] In line with Bertrand et al. (2004) taking into account not only heteroscedasticity but also serial correlation within neighborhoods, while allowing for an arbitrary variance-covariance matrix with cluster-robust standard errors.

households changed their car ownership levels in anticipation of changes in parking costs derived from future policy expansion or simply by demand spillover resulting from first wave implementation. Thus, we analyze the time pattern of the policy effects with respect to the year of policy implementation. We test for the validity of the previous assumption by substituting the policy dummy in (3) and introducing policy leads and lags, as a set of dummy variables that are equal to 1 for the number of years elapsed prior to or following policy implementation. The previous assumption holds whenever we are unable to reject the fact that leads are not statistically different from zero, thus rejecting potential anticipatory or spillover effects of the policy. Additionally, lags give us additional information on the effectiveness of the timing of the policy, which does necessarily only have to be contemporaneous.

Figure 1. Curbside parking regulation (ÀREA) implementation per neighborhood in Barcelona



4 Data

We employ a dataset with information on car ownership levels for 72 neighborhoods in Barcelona during the period 2007-2014. It also includes information on neighborhood characteristics and mobility-related indicators made publicly available by the City Council's Statistics Department (CCSD). Parking policy characteristics are computed at the neighborhood level using GIS software, based on the BSM parking regulation data maps as used in Gragera & Albalate (2016). Table 1 provides a description of the variables used in our models and its corresponding source. Table 2 provides descriptive statistics.

Our dependent variable is the car ownership ratio, measured by the number of cars per thousand inhabitants in each neighborhood and year. In order to estimate the effect of transforming free parking spots into regulated spaces, we introduce a set of parking policy variables. Our main variable of interest is the ratio of parking spaces per thousand inhabitants, which we introduce in different estimations of the model in aggregate and disaggregate terms to account for the differentiated impact of dedicated spaces (commercial, mixed-use and resident-exclusive). In this case, we aim to test whether different preferential allocations of spaces have a different impact on car ownership by restricting which demand segments compete for the same spaces. We also include the average weighted curbside parking fee and maximum stay time limit (in hours) as a way to control for potential differences in visitor demand levels.

Table 1. Description of variables included in our model and information source

Dependent variable		**Source**
Car ownership	Number of cars owned per 1000 inhabitants	CCSD
Covariates		
Parking policy		
Regulated spaces	Parking spaces per 1000 inhabitant (commercial, mixed-use, resident-exclusive)	BSM
Parking fee	Average weighted curbside parking fee	"
Maximum time limit	Average weighted maximum parking stay limit in hours	"
Neighborhood characteristics		
Economic		
Income	Gross neighborhood income (millions euros)	CCSD
Population density	Number of inhabitants per 1000 m^2	"
Sociodemographic		
Age	Average age of household members (years)	CCSD
Gender share	Share of women	"
Household size	Average household size (number of members)	"
Mobility		"
Share of local trips	Ratio of resident trips within district to the total number of resident trips	ATM
Share trips walking	Share of trips with the district as destination made on foot	"
Share trips private veh.	Share of trips with the district as destination made by private vehicle	"

We also include a set of variables that describe household characteristics so as to account for neighborhood differences that might arise from household sorting in terms of preferences and car needs. We control for income and population density, since richer neighborhoods can be expected to enjoy higher levels of car ownership while densely populated neighborhoods might be discouraged from owning a vehicle. Specifically, we use a neighborhood's gross average income (millions of euros) and the number of inhabitants per hectare.[6] We also include several sociodemographic characteristics that have been shown to be related to car preferences: namely, average age, share of women and the number of household members, on the grounds that younger populations, with fewer females and with larger families might rely more heavily on the car as a means of transport. Likewise, we take into account changes in neighborhood mobility characteristics. Here, we use the share of local trips, measured as the ratio of resident trips undertaken within the district compared to all the trips residents undertake. We also include the share of trips undertaken on foot or using private vehicle with the district as destination, as we expect lower share of local trips to be indicative of a lower degree of dependence on the car given they can satisfy their needs using amenities in close proximity, while a low share of walking trips and a high share of private vehicle trips indicate that residents might face greater competition for parking spaces from visitors.

Table 2. Descriptive statistics

		Std. Dev.		
Variables	**Mean**	**overall**	**between**	**within**
Car ownership	362.84	81.28	77.24	26.69
Regulated spaces	27.13	35.66	31.35	17.34
Mixed use	19.90	30.46	26.04	16.04
Commercial	4.81	6.88	6.64	1.91
Resident-exclusive	2.39	10.65	10.70	0.64
Parking fee	1.69	1.15	1.04	0.49
Maximum time limit	1.65	1.18	1.12	0.39
Income	28,763.21	12,157.68	12,022.2	2,243.94
Population density	25.34	15.24	15.31	0.74
Age	43.12	2.29	2.15	0.84
Gender share	0.52	0.02	0.02	0.00
Household size	2.52	0.19	0.18	0.07
Share of local trips	43.33	5.86	4.43	3.86
Share trips walking	53.03	6.59	5.47	3.73
Share trips private veh.	17.38	4.29	3.53	2.47

Note: The sample includes 576 observations (72 neighborhoods and 8 years)

[6] Alternative measures of income and density are also analyzed, but the estimated coefficients of the main variables remain the same.

5 Results

5.1 Effect of changes in regulations

We report our results for the impact of changes in parking regulations on car ownership in Table 3. Column (1) to (4) report our estimation results based on Eq. (2), all reporting cluster-robust standard errors. Columns (1-2) show the estimates with an aggregate measure for regulated parking spaces, while (3-4) show the effect for each type of dedicated space. Columns (1) and (3) include just parking related controls, while (2) and (4) add neighborhood characteristics. A comparison between models suggests that our estimates are robust to not including neighborhood characteristics as controls.

These results show that regulated parking spaces are positively related to car ownership. On average, an increase of one space per 1000 inhabitants results in a 0.26-increase in the number of cars registered per 1000 inhabitants, with a relatively differentiated impact according to the type of dedicated space implemented. Thus, resident-exclusive (3.59) and commercial spaces (1.46) have a higher impact than mixed-use spaces (0.12).[7] Based on this, average elasticity of car ownership to regulated parking spaces is 0.019 (ranging from 0.006 to 0.024 depending on the type of space). Resident-exclusive spaces offer easier parking for residents as their use is forbidden to visitors. Commercial spaces yield a higher positive impact on car ownership than mixed-use spaces, even that the latter would appear to be more restrictive for resident parking than the former. On the one hand, mixed-use spaces allow the two demand segments to compete for vacant spots, where residents tend to crowd these spaces during long parking stays. On the other hand, commercial spaces, while preventing residents from parking there during operating hours offer higher turnover rates, especially at the end of regulation periods. This tends to make it easier to find a parking place in commercial spaces than in mixed-use zones.

Our results also show that the parking fee and maximum stay time limits do not have a statistically significant impact on car ownership, additional that is to who has the right to park in a given spot (dedicated spaces). However, the main drivers of car ownership are found to be neighborhood income level and population density. Thus, increases in income levels increase car

[7] A Wald test show we can reject the hypothesis that the coefficient for mixed-use spaces are equal to those for commercial or resident-exclusive spots, but that we cannot reject the possibility that commercial and resident-exclusive spaces have the same impact. The low variation in resident-exclusive spaces yields an estimated coefficient with higher standard errors, although the estimate points in the direction of a greater impact.

ownership, while population density presents a negative relationship that decreases as density increases (positive quadratic term). The estimated elasticities at sample mean values show that car ownership income elasticity is about 0.19 and that the elasticity to population density is -1.11.

5.2 Impact of policy implementation

To analyze the specific impact of the implementation of the parking regulations on car ownership, we exploit the quasi-experimental design derived from the extension of ÀREA in its second and third waves (2009 and onwards), which transformed free-parking into paid-parking spaces. In this case, we report the estimation results shown in columns (5-6)from Table 3, models based in Eq. (3) . Figure 2 gives a graphical description of the evolution of mean car ownership levels during pre and post intervention for treated and non-treated groups, and its comparison with assumed counterfactual. Figure 3 shows the effects of policy leads and lags, rejecting a potential anticipatory effect (or spillover), and point to policy effect building up over time. Further robustness check of the validity of our identification strategy is provided by a test of equality of separate year-treatment dummies for treated and control groups and a placebo test, both reported in Appendix 1.[8]

Our results show that the second and third waves of the implementation of ÀREA increased car ownership levels in the treated neighborhoods by an average 11 cars per 1000 inhabitants during the treatment period compared to their counterfactual. This is equivalent to a 2.9% increase with respect to the treated neighborhoods' mean values. This is in line with the results reported in the previous section and highlights an unintended effect of the parking policy implemented in Barcelona. Paid parking was introduced to 'chase out' visitor parking, while acceptance of the policy measure relied on residents being granted preferential parking treatment, which appears to have offered them incentives to increase their car ownership levels. As reported in in Table 4, the introduction of policy lags suggests that the contemporaneous (short term) impact of the policy is statistically significant just at a 10% level, yet it builds up over time reaching standard statistically significant impacts 4-5 years after the implementation. The long term impact after such period is that treated neighborhoods increase in about 52 cars per 1000 inhabitants, equivalent to a 14.6% increase with respect to mean motorization levels. We believe that this is consistent with the fact that cars are a durable good, being replaced every

[8] In this test, even with a restricted sample to the pre-treatment period that leaves us with 132 observations, standard errors are low.

few years. So in the short run the policy should be expected to trigger less car ownership changes than in the long run.

As we discuss below, increasing residents' welfare would seem to make parking regulations politically feasible, but the increase in car ownership might also bring welfare losses in the form of increased car journeys and the increase in their associated externalities, outcomes that need careful consideration.

Table 3. Car ownership

	FE				DiD	
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Regulated parking spaces (Treatment)	0.280***	0.262***			11.81*	10.98**
	(0.0605)	(0.0402)			(5.925)	(4.226)
Mixed-use			0.135**	0.119*		
			(0.0530)	(0.0637)		
Commercial			1.498**	1.456**		
			(0.662)	(0.718)		
Resident-exclusive			3.579***	3.594**		
			(1.117)	(1.396)		
Parking fee	-3.970	-3.287	-1.735	-1.168	-0.236	-3.577
	(4.084)	(2.216)	(4.840)	(2.854)	(6.537)	(3.103)
Maximum time limit	-1.432	-0.912	-2.793	-2.194	-4.379	-0.506
	(5.413)	(2.757)	(6.016)	(3.250)	(7.609)	(2.852)
Income		0.00238**		0.00244**		0.00366**
		(0.00119)		(0.00115)		(0.00152)
Population density		-15.86**		-15.92**		-22.25**
		(6.712)		(6.611)		(10.37)
(Population density)^2		0.201**		0.199**		0.257**
		(0.0765)		(0.0771)		(0.126)
Sociodemographic	NO	YES	NO	YES	NO	YES
Mobility	NO	YES	NO	YES	NO	YES
Number of neighborhoods	72	72	72	72	44	44
Observations	576	576	576	576	352	352
R^2	0.139	0.238	0.151	0.250	0.159	0.248

*Note: Dependent variable is the number of registered cars (veh*1000inhab.) in each neighborhood. All models include year (8) and neighborhood fixed effects. Robust standard errors in parentheses.*

***** p<0.01, ** p<0.05, * p<0.1**

Figure 2. Mean car ownership levels during pre and post intervention for treated and non-treated groups, and comparison with assumed counterfactual

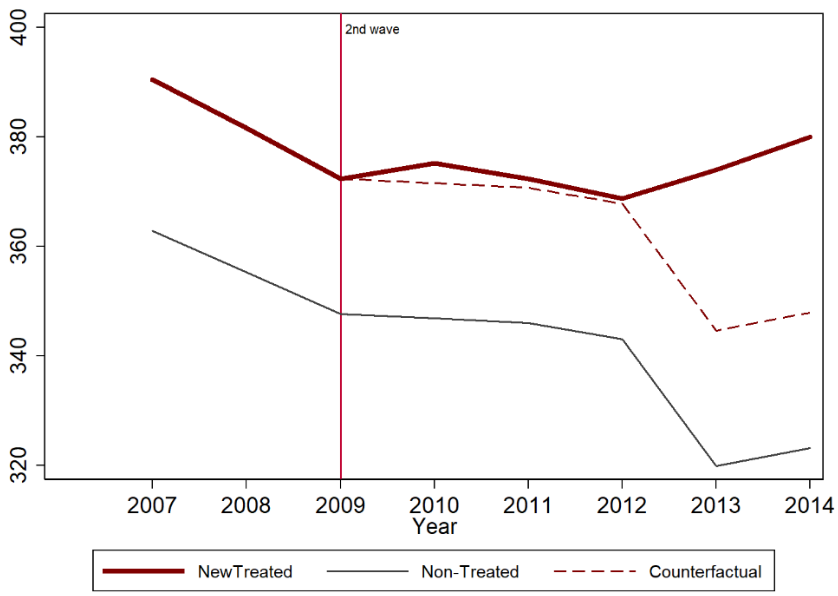


Figure 3. Leads and lags for policy implementation impact on car ownership levels in treated neighborhoods

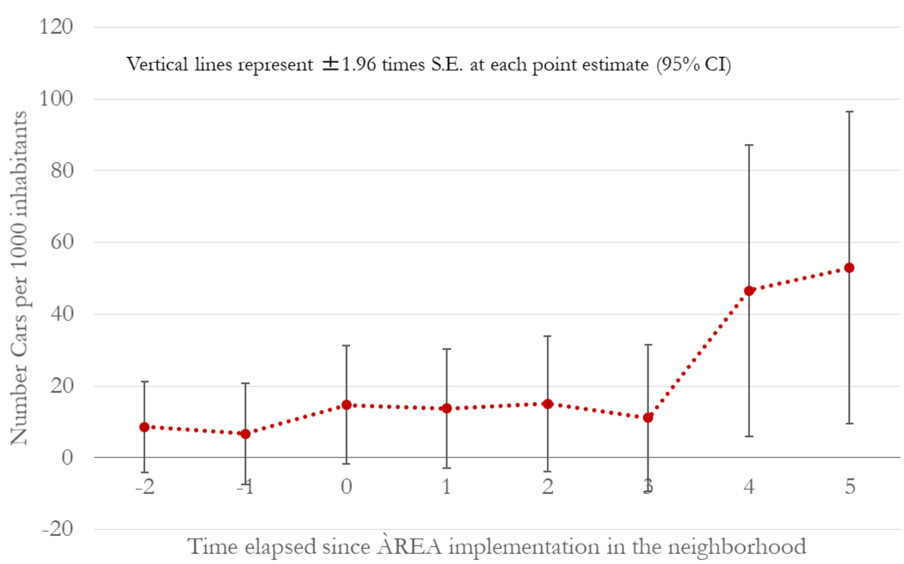


Table 4. Leads and lags for policy implementation estimated impact on car ownership levels

	Time elapsed since ÀREA implementation (years)							
	-2	-1	0	1	2	3	4	5
Treatment	8.645	6.723	14.76*	13.73	15.1	11.09	46.57**	52.98**
	(6.451)	(7.21)	(8.392)	(8.444)	(9.613)	(10.45)	(20.7)	(22.19)

*Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1*

5.3 The social cost of reallocating parking spaces using residential permits

To ensure the validity of the parking policy recommendations that arise from this study, we seek to analyze the welfare implications of our findings. We analyze the social benefits and costs derived from the introduction of parking regulation (ÀREA expansion) that chased out visitors free parking and reallocated parking spaces to residents (by granting them with residential parking permits) and its impact on residents' car ownership levels.[9] With this, we aim to highlight the tradeoff between efficiency and its acceptability that arise when parking permits are implemented and the raise in car ownership forces the reallocation of curbside spaces to residents.

This policy can have a wide set of effects and responses with welfare implications, as listed below:

- A subsidy to residents owning a car via parking permits, that keep parking price below its marginal provision cost.
- An increase in parking costs for visitors competing with residents for the same spots derived from the reallocation of curbside spots to the later.
- Changes in visitors' travel behavior (i.e.: trip deterrence, modal change, trip timing, parking choice) and residents' car usage levels due to changes in parking costs.
- Changes in transport-related externalities derived from the new allocation of curbside spaces and travel behavioral changes.
- Changes in the prices of other goods derived from parking cost changes, as an intermediate good.
- Changes in residential location and housing prices derived from increased availability of parking for residents as an amenity.

[9] We follow De Groote et al. (2016) and van Ommeren et al. (2014), but we also account for the interaction between residents and visitors competing for parking spots.

- Changes in wages and labor supply due to visitors free parking elimination, if no employer-paid parking is provided.

In our opinion, the most relevant policy effects are those restricted to the transport market. The most direct benefit in the list is the potential external cost reduction due to visitors' trip deterrence, which was the intended impact of the policy. The most direct costs in this list are the parking subsidy to residents and the increase in parking costs experienced by visitors due to curbside spaces reallocation. Below, we provide an attempt to measure and compare the effect of these factors on welfare via a partial equilibrium analysis using a back-of-the-envelope calculation. In any case, our net social costs need to be considered in reference to other perceived benefits of the program not included in our analysis.

The deadweight loss associated to the subsidy and the associated reallocation of curbside spaces is computed by comparing residents inverse demand function and the parking supply opportunity cost for blocking a parking spot by residents (equal to visitors' inverse demand function) when deviating from the social optimum (where the price for both demand segments is equated). The reduction in externalities is computed by comparing the net external costs associated with allocating a parking space to a resident due to parking permits (increased travel due to higher car ownership) and the savings derived from visitors' trip deterrence. The welfare deviation due to the unintended impact of the policy (efficiency loss) is measured by confronting the net social cost in the scenario with increased car ownership with respect to the intended welfare gain (external cost reduction).

We ignore in our analysis how policy effects transfer to other markets (general equilibrium effects), due to the lack of conclusive evidence on the magnitude of such second-order effects and detailed enough data to properly address them. We believe this is unlikely to modify the broad conclusion we draw from the analysis. Furthermore, we rely on the following simplifying but plausible general assumptions. We try to keep them to a minimum, and set them to obtain the most conservative estimates of the efficiency loss derived from reallocating parking spaces to residents:

- We assume that travel behavior, besides trip deterrence, is unaffected by the policy. Modal choice is assumed unaffected given the low cross-elasticity of transit demand to car costs (Asensio, 2002), and the fact that disruptive transport network companies (like Uber or Lyft) have a very limited presence in Barcelona due to strict regulations.

- Trip timing is not expected to change, given that all parking fees are flat rate (both for curbside and garage options), just varying with parking duration (garages).
- We assume that residents do not change their cars usage besides the potential incentives introduced by the policy, as no travel diary data is available for a before-after comparison.
- We assume that both residents and visitors' parking choice is unaffected by the effects of the policy. Parking permits do just improve the situation for those already parking on-street by granting them with unreserved parking spaces, as those enjoyed by garage subscription holders. Visitors are not expected to change much their parking choice, as their trip is somewhat linked to a given destination and their knowledge about garage parking alternatives or prices is found to be very low (Albalate and Gragera, 2018).
- We assume that cruising levels and parking prices do not change with the increase in the number of cars caused by the policy (parking on-street). We hold this constant as it gives us a more conservative estimate of the difference between benefits and costs of the policy, that we cannot precise further due to the lack of data on the changes in cruising costs and garage price.
- Furthermore, we assume no policy impact spatial or temporal heterogeneity. We disregard spatial differentiation of the effects on car ownership levels, as individual analysis at a neighborhood level is not precise enough, and most key figures in our analysis are provided at aggregate level with no temporal differentiation. We also disregard any heterogeneous response by residents or visitors on their travel behavior or car usage, also due to lack of disaggregated data.

Further detailed assumptions are made to provide specific figures used in the computation, that are specified in the following subsections.

5.3.1 Parking subsidy and curbside allocation to residents

The provision of curbside parking permits to residents implies a welfare loss if the price is kept below its marginal provision cost. Additionally, taking into account that both residents and visitors compete for the same parking spaces, a lower parking cost for residents will allocate a higher proportion of spots to them and reduce its availability for visitors. In order to clear the market, the parking costs for visitors will increase with higher search cost and some of them will give up trips. This does also imply a welfare loss derived from the interaction between both demand segments.

Thus, the welfare change induced by the policy intervention depends on the following factors: First, the number of curbside parking spaces (N), is assumed to be equal to 52,000.[10] Second, the price of parking at the curb after the introduction of parking permits (P_r), is considered equal to 52€/year. Third, as we know that there are 138,654 vehicles registered in the ÀREA expansion neighborhoods (30% of which park in the curb on a regular basis) and that an extra 4,039 vehicles will park on the curb due to the estimated unintended impact of the policy; we can assume that the number of parking spaces available for residents (Q_r) would be equal to 45,635, leaving $N - Q_r$ just equal to 6,365 spaces available for visitors (Q_v). We further assume that parking spots allocated to residents are only used by one car per day. Fourth, the price for visitors (P_v) is computed as their annual willingness-to-pay (WTP) per parking space using the total number of visitors per spot and their hourly WTP. Using travel survey data for Barcelona, we can infer that 47,300 visitors park their car in the curb, based on the number of trips and how many of them park on street (EMEF, 2013).[11] Dividing this figure by Q_v and keeping previous assumptions, we estimate that each curbside space turnover is about 7 visitors per day.[12] Additionally, we further assume that visitors' WTP is equal to the public garage parking fee plus the average fee differential with respect to the private operators (3.81€/hour) and that they park on average just for 1 hour each during 280 labor days a year (the figure typically employed by Barcelona's transport authorities).[13] This means that P_v is 7,468€/year, a figure that accounts both for what visitors pay in parking fees but also search time they experience, as in equilibrium the total cost of parking in a garage equates the total cost of parking in the curb.

[10] This is an estimate given the total number of curbside parking spaces reported by the City Council (about 147,600) and that the already treated neighborhoods deploy for certain 38,200 of them, as no free parking space is available. The remaining parking supply is split proportionally to the surface devoted to roads in each neighborhood, eliminating the logistics activity area associated to Barcelona's Port.

[11] EMEF (2013) shows that the city receives 1.4M visitor trips and about 50% of them have destination to the newly treated neighborhoods, where 15.3% of them are done by car and around 40% of them end up parking on the curb. Note that our definition of visitors does only include residents of the Metropolitan Area that travel to a zone where they do not reside in.

[12] This figure means an average stay length of 1.4 hours per visitor if all operating hours (10 hours per day) are fully occupied. This figure is consistent with previous data gathered in Albalate and Gragera (2018) survey to garage parkers, where those that previously searched for a curbside spot park on average for slightly more than 1.5 hours. However, we will consider that they just park on average 1 hour, as BSM data seems to point to lower parking stays for those parking on the curb.

[13] These figures are the ones typically employed by the Metropolitan Transport Authority (ATM), see *Observatori de la Mobilitat* (https://doc.atm.cat/ca/_dir_pdm/Observatori_Mobilitat/files/assets/basic-html/page-1.html)

For sake of convenience, we assume that both residents and visitors face constant-elasticity inverse demand functions given by $D_r(Q) = P_r(Q/Q_r)^{\frac{1}{\varepsilon r}}$ for residents, and $D_v(Q) = P_v((N - Q)/(N - Q_r))^{\frac{1}{\varepsilon v}}$ for visitors; where Q is the number of parking spaces allocated to residents and the reciprocal $N - Q$ the one allocated to visitors, ε_r is residents' price elasticity of demand for cars and ε_v is visitors' price elasticity of demand for parking. Regarding residents, we can use previous estimates to infer price-demand elasticity from the percentage change in their number of cars and the change in price induced by the policy intervention. Change in the number of cars with respect to decentralized equilibrium can be computed from the data showed in previous sections. To compute price change we follow a similar approach to that suggested by Shoup (2005), assuming that in pre-intervention equilibrium on-street and off-street parking are equally valued. So we can infer curbside parking price using public garage subscription costs (1,368€/year). This takes into account the *occupied* parking cost (capital and operating costs) and the land opportunity cost (most of them being underground facilities that are rarely used for anything other than storage).[14] Thus, each resident permit implies an annual subsidy of 1,316€.[15] This translates into a demand price elasticity equal to -0.03 for residents. Regarding visitors, we assume a demand price-elasticity of -0.30, in line with van Ommeren et al. (2014) and consistent with recent meta-regression evidence reported in Lehner & Peer (2019).

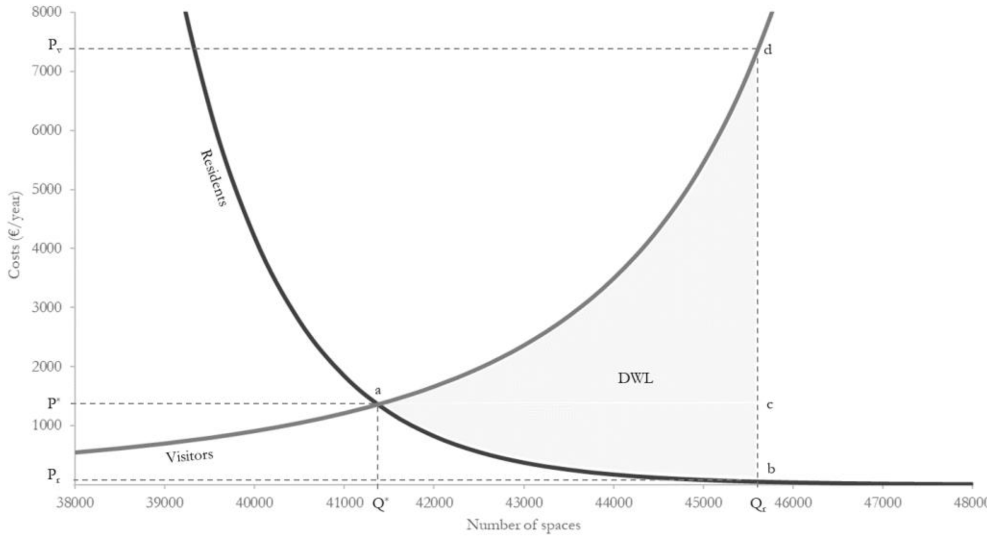
By combining both in a single diagram, we can estimate the welfare effects of the parking subsidy and reallocation of spaces due to the ÀREA expansion, as shown in Figure 4. The equilibrium in such a setting is attained when the allocation between residents and visitors is such that the price for both is equated, as denoted by P^*.[16] The introduction of parking permits subsidizes residential parking increasing the number of spaces blocked by newly owned cars. Thus, visitors face a tighter supply level and higher parking cost to clear the market. Thus, we can write the deadweight loss induced by parking policy (residents' permits) ΔW as the integrated difference between inverse demand functions between Q^* and Q_r.

$$\Delta W = \int_{Q^*}^{Q_r} D_r(Q) - D_v(Q)\, dQ \tag{5}$$

[14] In this case, we implicitly assume that a public garage operator charges subscription prices at marginal provision costs.
[15] This figure provides a cost estimate that is almost the same as that reported by Shoup (2005): \$127/month equivalent to 1,311€/year. Changes in that figure affecting assumed demand price-elasticity are taken into account in the Appendix 3.
[16] Note that in such setting we can interpret visitors' inverse demand function as the parking supply opportunity cost for blocking a parking spot by residents.

This ΔW does simultaneously take into account the welfare change associated to the parking permits subsidy given by setting prices below provision cost (the area enclosed by abc), and the change derived from visitors' consumer surplus reduction due to supply constraint (the area within acd), as described in Figure 4. Given previous figures we can compute the ΔW using equation (5), which yields a welfare loss of 12.5M€ per year.[17] Sensitivity analysis for previous figures is reported in Appendix 3.

Figure 4. Welfare loss due to parking subsidy and curbside allocation to residents



5.3.2 Externalities

We believe we cannot assume that external costs are internalized through optimal parking prices (De Groote et al., 2016), as in previous studies we find evidence of relevant pricing distortion in Barcelona that points to the existence of cruising externalities and non-optimal car usage levels (Gragera and Albalate, 2016; Albalate and Gragera, 2017). In this subsection, we take into account that the increase in residents' car ownership levels translates into an increase in vehicle use, which imposes an external cost on the rest of society, while, in contrast, increased travel costs for visitors cause them to make fewer trips and reduces the externalities they cause.

In this case, we compute the net external costs associated with allocating a parking space to a resident due to parking permits (and the increased car ownership). We do that by computing the

[17] It is important to state that in this section, for sake of simplicity, we implicitly assumed that the reduction in visitors' parking demand is due to them giving up their trips, so no transfer to garage parking occurs. Note that assuming that such transfer occurs will yield both lower welfare loss due to visitors' consumer surplus reduction and lower welfare gains due external cost reduction of allocating spaces to residents in the curb.

external costs of congestion, accidents, air pollution, noise, climate change, infrastructure wear and tear, and up-stream processes (pre-combustion and vehicle production) due to an increased car travel based on the marginal external cost figures provided in Table A2. We assume that after policy intervention residents' cars are used on average in the same way as they are used before, that is, the average annual distance traveled will be about 13,000 km/year in major urban areas (INE, 2008). This gives us an external cost of 722€/year for each newly owned car that we assume will block a curbside parking space. Moreover, we do also assume that residents owning these extra cars will face the same cruising levels as previous ones (assuming cruising levels are not affected by the policy to produce more conservative estimates), which can be inferred by the difference between public garage subscription costs and private garage subscription prices, which in our case is 264€/year. Here, we assume that only private operators take advantage of their localized market power to set their prices equal to total parking costs in equilibrium, also that the public operator sets subscription costs equal to the marginal provision costs, and that cruising levels or parking prices do not change with the increase in the number of owned cars.[18] Thus, the total external cost of allocating a curbside space to a resident is 986€/year.

Additionally, each parking space allocated to visitors has also an external cost associated with the car usage they make. As in the previous paragraphs, assuming that each visitor trip is 18 km long (that needs to be multiplied by 2 to make it back and forth), previously stated visitors turnover per space (see subsection 5.3.1.), and using marginal external cost figures in Table A2, we get that each space yields an external cost of 3,900€/year. The differential of external costs between residents and visitors means that there is a net benefit in terms of externalities into allocating curbside spaces to residents (2,914€/year-space). This, given previous subsection figures, implies that the reduction in visitors' trips saves society from bearing an external cost of 16.6M€/year. It is important to highlight that this is the intended impact of the policy, as this was the policymakers' goal to implement it in the first place (or at least part of it). Additionally, the increase in car ownership (and its use) increases external costs in 4.2M€/year and leaves the external costs net effect of allocating parking spaces to residents in a gain of 12.4M€/year.[19]

[18] This is unlikely to be the case, but it gives us a simpler and more conservative estimate of the welfare change.
[19] Note that this welfare change is referred to the equilibrium in section 5.3.1 and not the social optimum, as externalities are not internalized for neither residents nor visitors.

5.3.3 Net social cost

Summing up previous subsection results, we can compute that the baseline net social cost of reallocating curbside parking spaces to residents a loss that is equivalent to 0.1M€/year. This means that the ÀREA expansion could have been globally welfare improving or detrimental depending on the specific figures of the inputs used in our analysis (Appendix 3 reports a sensitivity analysis for the main parameters). However, what is relevant is to compare the change in economic efficiency induced by the impact of parking regulations on car ownership. Previous sections show that parking policy did help to lower transport externalities due to excessive traffic yielding relevant welfare gains, but most (if not all) is wasted due to the unintended policy impacts.

To show this we compute a relative efficiency deviation measure (eff). We use this measure to give a more straightforward idea of how much real policy implementation welfare change deviates from the policy intended one. In this case, we assume as our benchmark the welfare change induced by the reduction in the number of visitors' trips (the policy's main goal) as if the policy had no impact on the residents' car ownership levels (ΔW_o).[20] We measure the welfare deviation due to the policy having an impact on car ownership (ΔW_p) with respect to the benchmark level as $eff = (\Delta W_p - \Delta W_o)/|\Delta W_o|$. In our baseline calculation, the efficiency deviation is equal to -1.01, meaning that the policy impact on car ownership levels eats up all the gains the policymaker initially intended to get. In this regard, we can isolate the impact on the efficiency of each of the previously computed effects. The efficiency loss due to parking permits subsidy is 0.25, consumers' surplus reduction accounts for 0.51, and externalities for the remaining 0.25. In this sense, we should also stress that our baseline calculation only takes into account the average treatment on the treated (an 11-car increase per thousand inhabitants) as the policy impact on car ownership, yet the earlier analysis also shows that the impact on car ownership seems to build up over time following policy implementation. Which makes us believe that the impact can potentially be worse than what we report here.

These results suggest that the tradeoff between acceptability and efficiency are relevant when the unintended impact of parking policy that translates into an increase residents' car ownership is taken into account. Granting resident permits might help overcome political opposition to paid

[20] This is mainly the welfare gain derived from the reduction in external costs due to fewer visitors traveling by car.

parking implementation, but it can also make the whole policy package welfare detrimental. Policymakers should no longer ignore this tradeoff.

6 Concluding remarks

In this paper our aim has been to gain insights into the specific impact of parking regulations on car ownership, focusing on the introduction of paid parking in a major European urban area, namely that of Barcelona, which introduced a city-wide parking regulation policy (known as ÀREA) aimed at curbing traffic congestion. We have used a panel dataset covering 72 neighborhoods for the period 2007-2014 to estimate the causal effect of changes in parking regulations on the number of cars owned and to evaluate the causal impact of the gradual extension of the ÀREA scheme. Based on these estimates, we have also computed the net social cost of paid parking introduction for visitors and the reallocation of parking spaces to residents using a partial equilibrium welfare analysis approach.

Our empirical results demonstrate that an increase in the density of regulated parking spaces increases car ownership at the neighborhood level by 0.26 cars per 1,000 inhabitants, which is equivalent to an elasticity in the sample mean values of 0.019. We find that the different types of dedicated space (i.e. mixed-use, resident-exclusive and commercial) have different impacts on car ownership, due to the way in which the allocation of parking rights facilitates competition between demand segments for the same parking spaces. Moreover, we find that the introduction of ÀREA had an average treatment effect on the treated neighborhoods of an increase of 11 cars per 1,000 inhabitants per year (an average increase of 2.9% at the sample mean values). This can be interpreted as evidence of an unintended rebound on the level of car ownership attributable to the specific parking policy introduced. This effect, moreover, appears to accumulate over time, its impact multiplying more than fourfold five years after its initial implementation. Our computation of the net social cost of reallocating curbside parking spaces to residents suggests that the policy implementation has, under our assumptions, been welfare detrimental with respect to the intended policy impact. The welfare losses associated with granting residents with parking permits can offset the gains from chasing out visitors' parking. This result seems quite robust in the light of a sensitivity analysis.

These figures clearly reflect the relevance of an unintentional policy effect and stress the need for it to be taken into account when designing paid parking schemes in cities. From a political economy perspective, it might make sense for policymakers to give residents preferential treatment so as to maximize their welfare (as voters) at the expense of visitors who, after all, are responsible for congestion problems. By so doing, administrators might be able to circumvent opposition to parking regulations and make their introduction politically feasible, but our results highlight the need for them to be aware of the tradeoff between economic efficiency and acceptability. Parking permits and regulatory measures that ease parking conditions for residents are a subsidy that effectively lowers parking costs and increases residents' car ownership, which in turn leads to more car use and greater externalities. Our estimates suggest that the net social cost of the implementation of such policies may have completely undermined the intended welfare gains in Barcelona.

In the light of our results, we advocate the elimination of parking subsidies in the form of resident permits. Residents should bear the full cost of owning a vehicle, including those of parking, given its status as a scarce resource. Moving in this direction might be politically challenging, but municipalities can readily change both the supply of parking and associated pricing schemes and they can impose stricter conditions on the awarding of permits, by means of quotas or rationing via waiting lists (which at least, temporarily, means users have to face market costs). We believe that the introduction of so-called 'parking benefit districts' might prove to be a sounder political strategy as it should serve to overcome resident (and retailer) opposition through the smart use of the revenues raised, allowing residents to enjoy the benefits of paid parking implementation while avoiding the distortionary effects described above.

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APPENDIX 1.

STATA output for the parallel trend assumption test

. test ntreated2007 - ncontrol2007 = 0 : F(1, 43) = 1.47 ; Prob > F = 0.2319

. test ntreated2008 - ncontrol2008 = 0 : F(1, 43) = 2.54 ; Prob > F = 0.1183

Table A1. Placebo tests

VARIABLES	(1) PLACEBO	(2) PLACEBOall
placebo	-1.817	-4.201
	(2.727)	(3.802)
Maximum time limit	0.366	-1.603
	(1.825)	(2.204)
Fee	-2.366	0.642
	(2.871)	(3.294)
Income	0.000152	0.00151
	(0.000829)	(0.00173)
Population density	-28.28***	-21.42***
	(8.656)	(6.470)
(Population density)^2	0.239***	0.188***
	(0.0768)	(0.0653)
Gender share	549.0	113.0
	(456.8)	(352.4)
Age	1.888	1.602
	(3.940)	(4.383)
Household size	24.50	2.825
	(51.67)	(30.40)
Share of local trips	-0.249	-0.323
	(0.238)	(0.287)
Share trips private veh.	-0.313	-0.877
	(0.483)	(0.719)
Share trips walking	-0.326	-1.130
	(0.526)	(0.957)
2008.Year	-5.374**	-8.432*
	(2.007)	(5.058)
2009.Year	-7.241***	-13.97**
	(2.351)	(6.017)
Constant	415.8	667.8**
	(357.9)	(286.7)
Observations	132	216
R-squared	0.622	0.408
Number of C_Barri	44	72

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

APPENDIX 2

Table A2. Marginal external costs derived from the use of private vehicle in urban areas (€/vkm)

Marginal external costs (€/vkm)	
Congestion	0.009
Accidents	0.001
Air pollution	0.0189
Noise	0.0088
Climate change	0.0104
Infrastructure cost	0.006
Pre-combustion	0.0012
Vehicle production	3.852

Source: DGMOVE (2014) and SAIT (2015)

APPENDIX 3.

In order to test the robustness of our baseline welfare analysis we conduct a sensitivity analysis of our results by introducing changes in the main inputs: visitors' parking turnover, their willingness-to-pay (WTP), visitors' trip distance and demand price elasticity, and residents' travel distance. We recalculate the baseline welfare by separately multiplying each one of these inputs by a deviation factor ranging from 0 (eliminating the effect of this input) and 2 (multiplying its baseline value by 2). The outcomes of this analysis, in terms of efficiency deviation measures is summarized in Figure A3.1, which suggests that the unintended effects of the policy eat up most of the intended gains. Note that even with extreme values it is not possible to recover intended impact of the policy.

Figure A3.1. Sensitivity analysis of efficiency deviation measure (eff)