The Effect of Car Sharing on Car Sales

Peter Schmidt

Bocconi University

February 2018

Abstract

Free-Floating Car Sharing is a potential substitute for privately owning a car. Using a new dataset and a difference-in-difference methodology, I examine new car sales in German cities before and after the introduction of Free-Floating Car Sharing. I find that one Free-Floating Car Sharing vehicle reduces annual new car sales by three cars, equivalent to an average decrease in sales of almost 8%. This result is driven by a reduction in sales of small cars.

The two dominant Free-Floating Car Sharing providers are owned by large car companies and the vehicles they provide for Free-Floating Car Sharing are models produced by their respective mother companies. Using a triple difference methodology, I examine the possibility that Free-Floating Car Sharing serves as advertising for the car models and brands made available to the car sharing customers. I find robust and economically important evidence for both.

1 Introduction

Car Sharing in Germany

Two types of car sharing are available to consumers in Germany. One, called “station based” car sharing, has been around for several decades. In the United States, a well-known provider of station based car sharing is *Zipcar*; big providers in Germany are *Flinkster* and *Stadtmobil*. Users of this version of car sharing choose from several cars available at fixed locations in a city. Cars can only be picked up from these fixed locations and have to be dropped off at the same at the end of the rental period. Users usually pay a fixed membership fee plus an hourly rental fee. There is no fundamental difference between station based car sharing and the classic car rental business model, except station based car sharing customers typically use a vehicle for several hours, while rental car customers typically keep vehicles for a couple of days at a time.

A second type of car sharing became available in Germany during the early 2010s. “Free-floating car sharing” (FFCS) vehicles are not located in specific places, but are scattered across the area of a city. Any vacant car may be rented by a customer. The car key is inside the vehicle, which is opened and locked using a smartphone app. Customers may drive to any destination within the FFCS operating area and park the vehicle in any available parking spot (public, residential, or paid). Customers usually pay by the minute, plus an initial, one-time registration fee. There is no substantial variation in the price paid by consumers for FFCS over time or across cities.

The value of free-floating car sharing to customers depends on the number of vehicles provided to them. Having more car sharing vehicles in a given operating area increases the chances of finding a car nearby when the customer needs one, increasing the usefulness of the service.

Growth in users of both types of car sharing and available car sharing vehicles has been steady until the early 2010s, as shown in Figure 1, which does not differentiate between station based and free-floating car sharing.

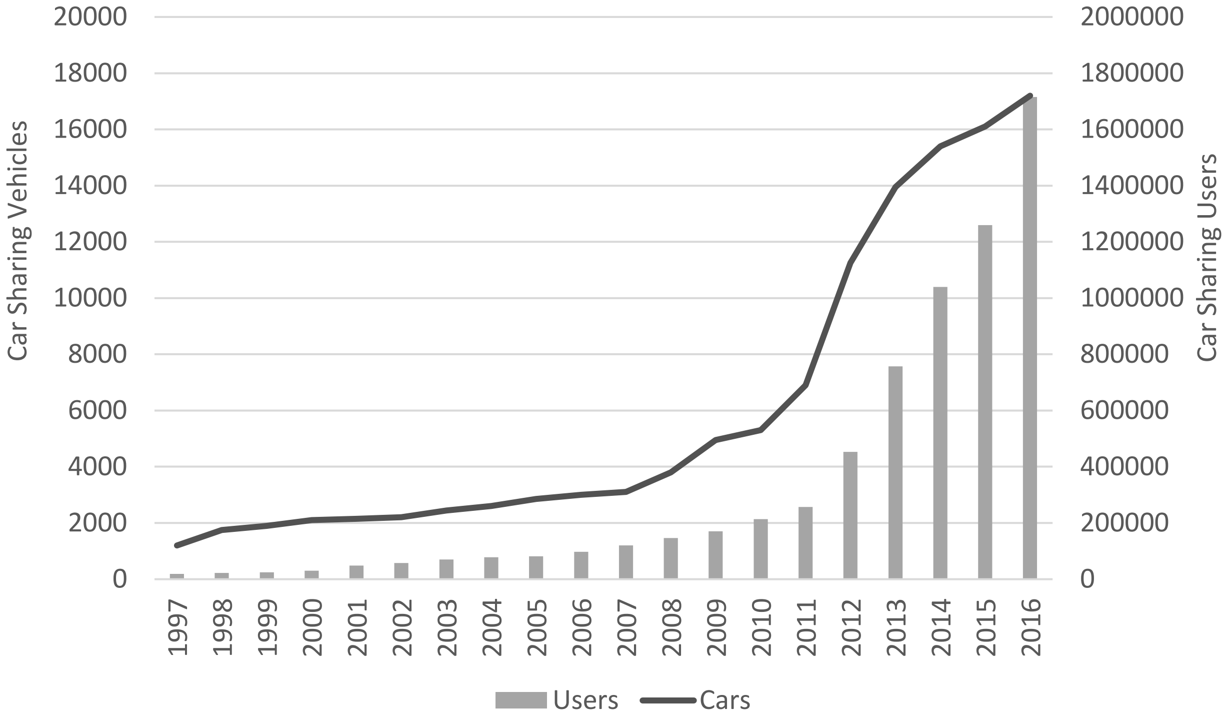

Figure 1: Development of Car Sharing in Germany 1997-2016. Source: Bundesverband Carsharing e.V.

Figure 2 splits the data by type of car sharing and provides visual evidence for the popularity of FFCS. The new technology has accounted for the explosive growth of car sharing since the early 2010s.

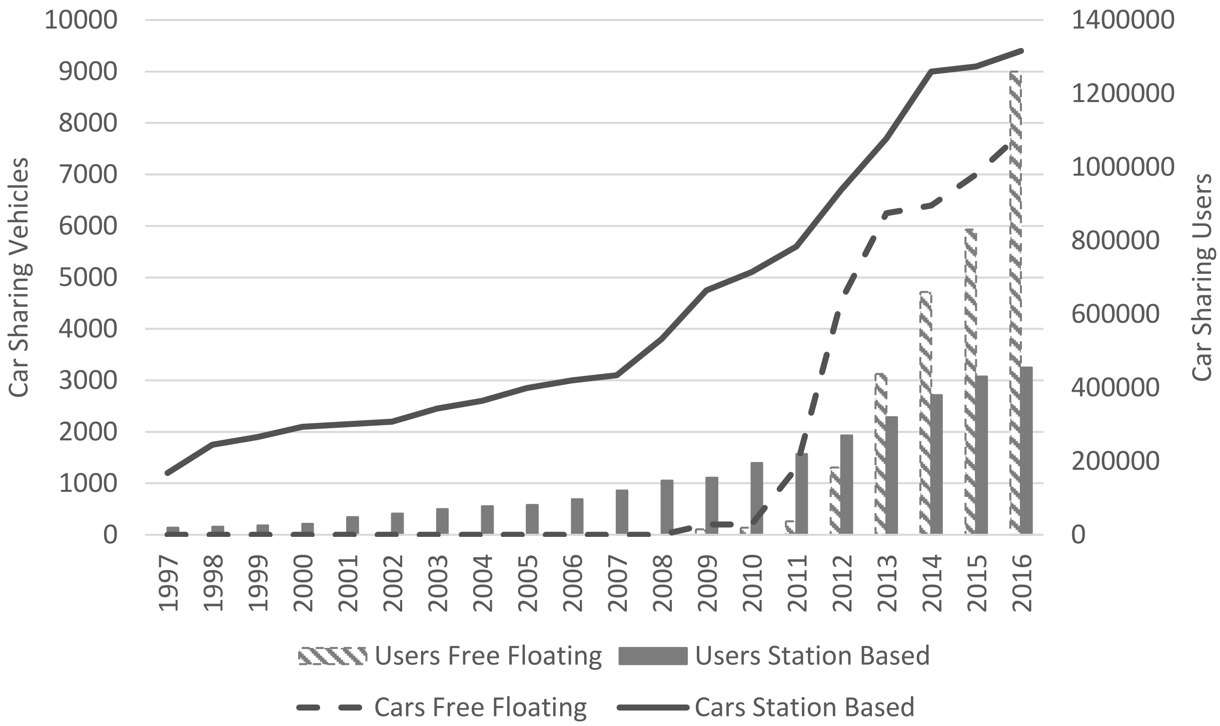

Figure 2: Car Sharing in Germany 1997-2016, split by type. Source: Bundesverband Carsharing e.V.

Figures 1 and 2 are the main motivation for conducting a study of the effects of FFCS in Germany. The technology has been available for several years now, adoption has reached significant levels and it looks like the business model is here to stay.

Free-Floating Car Sharing as a Potential Substitute to Privately Owning a Car

The main advantage of FFCS over other forms of car sharing lies in its convenience. A customer may use a free-floating car sharing vehicle to get from point A to point B and later back to point A. However, since she will do so in two separate trips, she will not be charged a rental fee for the duration of her stay at point B. Furthermore, she does not need to worry about the cost of parking during her stay at point B, since she may park the free-floating car-sharing vehicle in any parking spot at no cost to her. Especially in dense urban areas, the combination of these two characteristics makes free-floating car sharing a better alternative to privately owning a car than existing car sharing schemes. Of course, the convenience of FFCS hinges on the probability of being able to find an available vehicle within an acceptable distance.

Residential parking becomes scarcer as cities become denser. Residents of dense cities can therefore potentially save a lot of money by selling (or not buying) their own private car, but using free-floating car sharing instead. Other fixed costs of owning a car that would be saved include maintenance costs, insurance premia, gasoline costs and depreciation. Whether or not an individual would actually save money after substituting owning a car with using car sharing depends on how much that individual drives. Especially for people that drive less frequently, monetary savings could be substantial.

Monetary aspects are not the only determinants of private car ownership. For decades, cars have been important status symbols and a source of non-monetary benefits and joy. This will continue to play an important role in times to come. Nonetheless, the availability of free-floating car sharing should influence the decision over whether to privately own a car of a fraction of the population. This leads to the first research question of this project:

Research Question 1: *How does free-floating car sharing affect new car sales?*

To answer this question, I look at registrations of new cars in German cities before and after free-floating car sharing becomes available. This question is particularly important from a policy perspective. It may be socially desirable to have less privately owned vehicles in an urban area; free-floating car sharing is a potential means to that end.

Free-Floating Car Sharing Providers

There are two dominant providers of free-floating car sharing in Germany, *car2go* and *DriveNow*. In December 2016, together they provided 6 840 of the 7 800 available FFCS vehicles in Germany and accounted for 1 167 000 of the 1 260 000 users of the service. While both FFCS providers are registered companies, they are owned by large automobile manufacturers As of June 2016, *Daimler* owns *car2go* outright, while ownership of *DriveNow* is split between the *BMW Group* and *SIXT*, a car rental company, at 50% each. Given the potential substitutability between using car sharing and owning a car privately and the resulting potential drop in new car sales, as well as the fact that *car2go* and *DriveNow* were unprofitable for almost their entire company lives, *BMW* and *Daimler* must be pursuing goals other than immediate profit maximization.

A potential explanation is strategic behavior. Even though the car sharing services are not profitable yet, their parent companies may expect them to grow. It might have been strategically optimal then to enter before competitors do. If the car manufacturers do expect private car ownership to decline and consumers to shift towards demanding "mobility as a service", this behavior is comparable to a Monopolist's Dilemma, in the sense that some companies in an established industry temporarily forgo profits and innovate, in order to avoid becoming obsolete in the future.

Other potential incentives are data collection and the fulfillment of quotas; according to European Union rules, the average CO_2 emissions of the sold cars of a given manufacturer may not exceed a certain threshold. Since the vehicle models used by car sharing companies are very small and emit little CO_2, selling many of these vehicles to a car sharing company could lower the average emissions of a manufacturers' sold vehicles substantially.

While the incentives mentioned above mostly promise payoffs in the future, there is a potentially beneficial immediate effect of FFCS: advertising.

The car sharing vehicles provided by *car2go* (owned by *Daimler*) all belong to the *smart* brand[1] (also owned by *Daimler*), while *DriveNow* (partly owned by the *BMW Group*) offers small *BMW* and *MINI* models (the *BMW Group* owns both brands). Free-floating car sharing may provide advertising for the parent companies in two ways. First, since the car sharing vehicles provided are always new cars of the latest models[2], seeing them in the streets may enhance their visibility. More

[1] This is true for the vast majority of the sample period (2008-2016). In mid to late 2016, car2go started offering larger Mercedes-Benz models in some cities. Note that the Mercedes-Benz brand belongs to Daimler as well.
[2] The model that was mainly used throughout the sample period by car2go is the smart fortwo. DriveNow mostly used MINI Coopers and BMW 1 Series cars. A minority of the vehicles used are electric vehicles. Small numbers of other BMW and smart models were offered through FFCS, but they were not available for sale through the entire sample period and omitted from the analysis.

importantly however, for the customers of the car sharing services, each ride is comparable to a test drive. Car sharing customers learn about the characteristics and the quality of the model and may tell their friends about their experience or remember it themselves when they buy a new car. This leads to the second research question of this project:

Research Question 2: *Does free-floating car sharing have advertisement effects?*

The advertising effect may or may not turn out to be positive; it is also possible for consumers to learn about the model and decide that they don't like it. Alternatively, since the availability of a model in a city enables consumers to drive that model without having to buy it, they may like the car, yet be less likely to purchase it. The direction of the aggregate effect of a model being offered through FFCS on its sales is hence unclear. This paper provides evidence on which of the three mechanisms is dominant.

Research Question 2 is not only of interest from a marketing perspective, but also for policy makers and competition authorities. The car sharing providers pay the cities in which they operate a fixed amount of money per FFCS vehicle for the privilege of being allowed to park in any parking spot within city limits. Without taking the advertisement effects for the parent companies into account, cities may be undercharging the car sharing providers for parking. More generally, being able to quantify the advertisement effects is important for the correct calculation of company profits and hence welfare.

Preview of Results

I find strong and robust reduced-form evidence of a negative effect of the availability of FFCS on new car sales. An additional FFCS vehicle in a city is associated with a reduction in new car sales of three cars per year. This result is driven by a reduction of over 15% in sales of new cars that belong to the smallest car category.

Sales of the car models offered by *DriveNow* through FFCS (*MINI, BMW 1 Series*) increase by around 13% in the presence of FFCS. I take this as evidence for a strong positive advertising effect of FFCS. The associated profit increase partially compensates the parent company *BMW Group* for the loss incurred through their unprofitable FFCS subsidiary.

Connection to the Sharing Economy and Related Literature

"The sharing economy is the value in taking underutilized assets and making them accessible online to a community, leading to a reduced need for ownership of those assets." (Stephany (2015)).

Enabling access to assets or durable goods instead of transferring ownership of them is the main purpose of the sharing economy. The sharing economy consists of online platforms and services that seek to increase allocative efficiency by using technology to connect people that wish to use a good or need a service to those individuals or companies willing to rent out that good or perform that service. Examples include *Uber*, *Lyft* and *BlaBlaCar* for transportation, *eBay* and *Craigslist* for online marketplaces and *Airbnb* for housing. There are also popular car-sharing clubs like *getaround*, where members grant other members temporary access to their privately-owned cars.

Sharing economy business models can be divided into two categories: Peer-to-Peer (P2P) and Business-to-Consumer (B2C). While companies like *Uber* and *BlaBlaCar* provide P2P transportation solutions, *car2go* and *DriveNow* operate according to a B2C model.

There is an active literature in empirical industrial organization analyzing the impact of the new online platforms of the sharing economy on existing incumbent industries. Farronato & Fradkin (2017) look at the impact of *Airbnb* on hotel room occupancy. Cramer & Krueger (2016) analyze the effect of *Uber* availability on taxi usage in New York City. Seamans & Zhu (2014) quantify the effect of *Craigslist* on local newspaper ads. Fraiberger & Sundararajan (2016) examine the impact of P2P car sharing on car ownership. The last paper asks a very similar question as this project, but is concerned with P2P car sharing, while free-floating car sharing is a B2C business model.

FFCS is mostly used for short, within-city trips. *Uber* provides a very similar service. However, given that *Uber* never operated at large scale in Germany and has been illegal in many large cities, its simultaneous rise is unlikely to confound the results of this paper.

The question of how free-floating car sharing affects private car ownership has been addressed before, using survey methods. The most rigorous analysis was done by Martin & Shaheen (2016), but the car sharing providers themselves have also conducted surveys among their customers. These surveys all find very significant effects: an additional car sharing vehicle in a city reduces the amount of privately owned cars by between three and twenty. Furthermore, the survey results indicate that the main channel of reduction in private car ownership is suppression of new car purchases[3]. Survey results often overestimate the true effect and have limited out-of-sample validity. This is because those individuals likely to respond to a survey request are also more likely to be active users of the car sharing service. Furthermore, since the car sharing providers themselves administered some of the surveys and they have an interest in finding a large substitution effect[4],

[3] I take this as confirmation that new car registrations are the right measure to capture the effect of free-floating car sharing

[4] City councils are more likely take decisions favorable to the car sharing providers if they perceive them to do a public good, which in this case is presumably “taking cars off the streets”.

there is a need for more impartial empirical evidence from revealed preference as opposed to stated preference. This is one of the main objectives of this project and has, to the best of my knowledge, not been done before.

2 The Data

This project uses data in three categories: car sharing data, car sales data and demographic information.

Car Sharing Data

Launches and major fleet renewals of the car sharing providers are always accompanied by press releases and local newspaper articles. I pull this information off the websites of *car2go* and *DriveNow* in order to obtain fleet sizes (how many vehicles), fleet composition (which car models) and size of the operating area by month and by city for both providers for the sample period (January 2008 – December 2016). Since both companies have an incentive to make major changes to their fleet or operating area public, this data is granular and reliable. Table 1 shows the launch dates as well as fleet sizes at the end of the sample period for the two providers in the German cities.

	car2go	**DriveNow**
Berlin	**04/2012** (1100 cars, 160km^2)	**09/2011** (1200 cars, 161km^2)
Düsseldorf	**02/2012** (250 cars, 80km^2)	**01/2012** (210 cars, 55 km^2)
Frankfurt	**09/2014** (250 cars, 61 km^2)	X
Hamburg	**04/2011** (780 cars, 102 km^2)	**10/2013** (580 cars, 90 km^2)
Cologne	**02/2012** (350 cars, 130 km^2)	**09/2012** (400 cars, 90 km^2)
Munich	**06/2013** (480 cars, 125 km^2)	**06/2011** (700 cars, 85 km^2)
Stuttgart	**11/2012** (490 cars, 153 km^2)	X
Ulm	**10/2008 – 12/2014** (200 cars, 70 km^2)	X

Table 1: Launch Dates, Fleet Sizes and Operating Areas (as of December 2016) of Free-Floating Car Sharing Providers

The two providers launched their services in different cities at different times. There is substantial variation in fleet sizes and operating area, which together give the "treatment intensity" of free-floating car sharing. Typically, providers started in a given city with a smaller fleet and then increased the number of vehicles over time.

During the largest part of the sample period, the car sharing providers used three car models for their fleets: *car2go* used the micro car *smart* and *DriveNow* used the *MINI* and the slightly larger *BMW 1 Series.* While I do not see the exact fleet composition of *DriveNow* at all times, I take it from several snapshots of their fleets that both models were used in roughly equal proportion. Recall that *car2go* as well as the *smart* brand belong to *Daimler*, while *DriveNow*, the *MINI* brand and of course the *BMW* brand belong to the *BMW Group*. All of these models are small and easily maneuverable cars suited to driving in big cities.

Car Sales Data

As is common in the literature, I use registrations of new cars to proxy for sales. The dataset used in this project is new and original and was put together by the German Department of Motor Vehicles (*Kraftfahrtbundesamt*) for the purposes of this project. It contains monthly registrations of new cars (from now on referred to as car sales) by administrative district[5] and by car model from January 2008 until December 2016. Used car sales require a different administrative process (change of ownership) and don't feature in my data.

To give the reader a feel for the data, Figure 3 shows sales of *smart* cars in Berlin in 2011 and 2012.

[5] In rural areas, the administrative districts used by the authorities sometimes aggregate several smaller towns and villages. This is not a problem for this project, as I will only use large cities (to be defined in the next section) in the analysis. For large cities, administrative districts and city limits always coincide. I will therefore refer to the administrative districts as cities from now on.

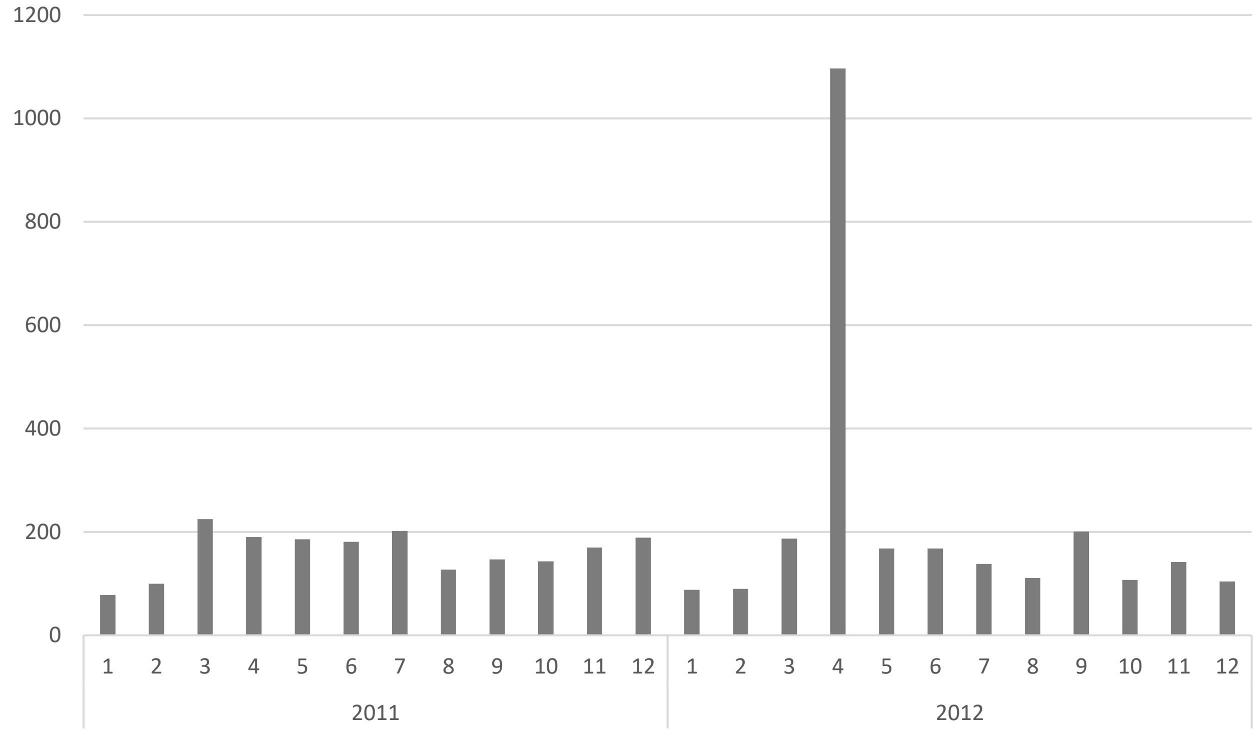

Figure 3: Sales of "smarts" in Berlin 2011 – 2012

There was a massive spike in sales in April 2012. Note from Table 1 that *car2go* launched its operation in Berlin using 1000 *smart* cars during that month. Launches and major fleet renewals of the two car sharing companies show up in the car sales data and since I know (from the company websites) how many cars of which model were added by the companies, I am able to subtract these cars from the car sales figures in order to obtain the "true" sales.

Demographic Information

The final source of data used in this project is demographic information. It is publicly available from the German Census. I use the following statistics that vary between cities and over time: Population, population per km^2, percentage of male population, mean age, mean income, mean disposable income, mean m^2 price of sold land.

Does Free-Floating Car Sharing Work Everywhere?

Free-floating car sharing allows its users to drive to any destination within the operating area. FFCS becomes more useful, if its operating area covers enough destinations and if there is a high probability that a user will find an available vehicle in her vicinity when she needs one. This implies that free-floating car sharing will only become a competitive transportation option, if there is a sufficient density of vehicles spread over an operating area that covers many desirable destinations. Therefore, the service will only work well in cities that are big and dense enough.

According to a DriveNow executive[6], “big cities” are cities with at least 500 000 inhabitants in a relatively confined metropolitan area. For this reason, I exclude all cities with less than 500 000 inhabitants from my analysis, as they are unlikely to be adequate controls. The only “treated” city with less than 500 000 inhabitants is Ulm (120 000 inhabitants as of 2016), where car2go was active between 2008 and 2014. The reason for this engagement by car2go is however likely to be organizational; Ulm is geographically close to the Mercedes-Benz headquarters and car2go was introduced there as a pilot project for Mercedes-Benz employees. car2go shut down operations in 2014 because the company saw no potential for future growth in Ulm[7].

The cities that have more than 500 000 inhabitants at least once during the sample period, but where free-floating car sharing was never offered are: Bremen, Dortmund, Dresden, Essen, Hannover, Leipzig, Nuremberg and Recklinghausen. The big cities where free-floating car sharing was offered at some point during the sample period are Berlin, Düsseldorf, Frankfurt, Hamburg, Cologne, Munich, and Stuttgart.

I also exclude all car models with cumulative sales over the sample period of less than 10 000 vehicles and car models that were not available for sale throughout the entire sample period 2008 – 2016, as well as the models offered through FFCS (*smartfortwo, MINI, BMW 1 Series).*

The unit of observation is a year-month-city-model combination. Summary statistics for the estimation sample are in Table 2:

[6] The interview can be found (in German) at http://www.carsharing-experten.de/drivenow-carsharing/drivenow-geschaeftsfueher-dr-andreas-schaaf-im-interview.html (last accessed 15/06/2017)
[7] The following link leads to a newspaper article (in German) describing car2go’s reasons to stop operating in Ulm http://www.swp.de/ulm/lokales/ulm_neu_ulm/car2go-macht-in-ulm-dicht-pilotstadt-war-zu-klein-und-zu-teuer-11136902.html (last accessed 15/06/2017)

	Treated (FFCS Offered at Some Point, 7 cities)		Untreated (FFCS Never Offered, 8 cities)	
	Mean (St. Dev.)	Median	Mean (SD)	Median
Mean FFCS Vehicles when FFCS Offered	778.3 (444.98)	600	-	-
Mean FFCS OP Area when FFCS Offered (in km^2)	145.1 (62.0)	136	-	-
Vehicle Sales (City-Month-Model Level)	15.3 (21.6)	5	6.8 (12.0)	2
Population	1 352 707 (939 382)	1 013 665	631 214 (194 951)	566 862
% Male Population	48.7% (0.005)	48.7%	48.8% (0.004)	48.7%
Population per km^2	3 196.6 (755.4)	2 951	1 727.0 (746.2)	1 709
Average Age	42.3 (0.667)	42.1	43.9 (0.482)	43.7
Income	28 620.7€ (4 381.0€)	28 943€	21 411€ (2 621.9€)	21 588€
Disposable Income	20 992.22€ (2 026.2€)	21 173€	20 303.3€ (1 833.6€)	20 427€
Price m^2 of Land	599.9€ (337.2€)	534.2€	173.1€ (86.0€)	152.1€
Observations	123 116		134 836	

Table 2: Summary Statistics for the Estimation Sample

3 Trends in New Car Sales

In order for the difference-in-difference estimator to produce valid results, the common trend assumption has to be satisfied. The outcome variables of interest of treated and untreated units must not necessarily be on equal levels, but their development must follow a common trend. It is conceivable that car ownership trends differ between big cities and rural areas. Reasons include faster improvements in public transportation in bigger cities, the availability of bike sharing and the addition of bike lanes in urban areas as well as cultural changes. Since urbanites are more likely to have higher education and cars are losing their decades-old role as a status symbol[8] among the more

[8] According to the CEO of a successful sharing economy business, Lynn Jurich, *“The new status symbol isn’t what you own – it’s what you’re smart enough not to own”.*

educated, car sales in large cities are potentially slowing down compared to rural areas. These are further reasons to limit the analysis to cities with 500 000 inhabitants or more.

Figure 4 shows trends in per capita new car sales in cities where free-floating car sharing was introduced at some point during the sample period (launch dates are indicated by vertical grey lines), and in "untreated" cities, where free-floating car sharing was never offered.

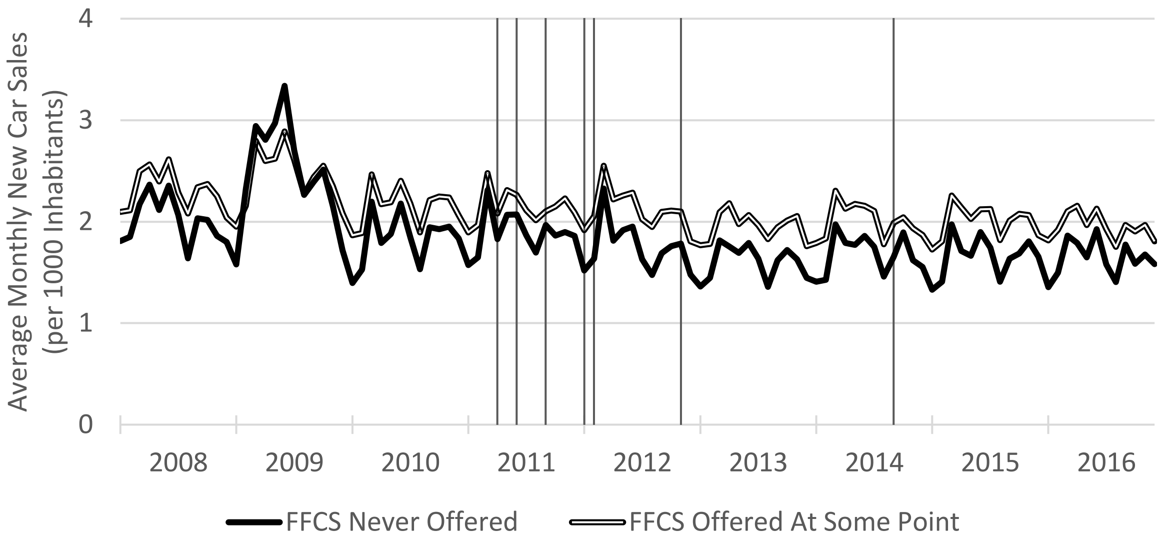

Figure 4: Trends in average monthly new car sales per 1 000 inhabitants. The solid line represents cities where free-floating car sharing was never introduced. The line without fill shows data for cities in which free-floating car sharing was launched at some point in the sample period. Vertical lines indicate free-floating car sharing launch dates. Models offered through FFCS were dropped from the sample.

There are no obvious differences in the trends between treated and untreated cities. The spike in sales in 2009 is the result of a scrapping subsidy offered by the German government. Owners of cars of age nine or older could claim a cash subsidy of 2 500€, if they scrapped their old vehicle and bought a new model which satisfied certain environmental standards.

4 Substitution Effect

The difference-in-difference estimation methodology employed here exploits the staggered launches across cities by the car sharing providers, as well as the fact that not all big German cities were "treated" with FFCS. Furthermore, there is substantial variation in the amount of available car sharing vehicles in a given city over time. Both providers eventually started operating in five out of the seven treated cities and increased their fleet sizes over time. This variation in "treatment intensity" will help identify parameters. For the difference-in-difference estimation, I run regressions of the following form:

$$y_{cts} = \alpha + \lambda_c + \lambda_t + \lambda_s + \delta \cdot D_{ct} + \beta \cdot X_{ct} + \varepsilon_{cts}, \qquad (1)$$

The unit of observation is at the city-time-model level; c denotes a city, t a year-month combination and s a car model. The outcome y variable is (log of) sales, α is a constant, λ are fixed effects, D denotes the treatment, X collects controls with associated parameters β and ε is the error term. The coefficient of interest is δ.

The treatment variable D_{ct} is specified as a measure of car sharing intensity. It is given by the combined number of vehicles offered for FFCS by *car2go* and *DriveNow* in city c in month t[9]. Free-floating car sharing is more useful to the consumer and hence the treatment of the population is more intense, when more cars are available in a city. Table 3 presents the regression results.

	(1) lg(sales)	(2) lg(sales)	(3) lg(sales)
Number of FFCS Vehicles	-9.97e-5*** (1.44e-5)	-7.46e-5*** (1.23e-5)	1.11e-4*** (2.91e-5)
Effect of Marginal FFCS Vehicle on Annual Sales	-3.0	-2.23	-3.3
Change in Sales for Average Number of FFCS Vehicles	-7.8%	-5.8%	-8.7%
City Specific Linear Trend	-	Yes	-
Controls	Yes	Yes	Yes
Fixed Effects	Time, City, Model	Time, City, Model	Time, City, Model
Sample	Full	Full	Only Treated Cities
R^2	55.8%	55.9%	56.0%
Observations	252 100	252 100	123 116

Table 3: Difference-in-Difference regression results. Standard Errors in parentheses. All coefficients are weighted by population. Standard Errors are clustered at the city level. All regressions include the following controls: Population, % male population, population density, average age, income, disposable income, price of land in €/m^2. The average number of FFCS vehicles in a treated city is 778. The average sales for on a city-month-model level in cities that offer FFCS at some point is 15.3. The total number of models in the sample is 163. Marginal effects and percentage changes in sales are annual and calculated at the mean levels of sales and number of FFCS vehicles. Models offered through FFCS were dropped from the sample.

The effect of free-floating car sharing on total new car sales is negative and strongly statistically significant. Column (1) shows that an additional free-floating car sharing vehicle is associated with a decrease of 3 new cars sold over the course of one year. For the average number of free-floating car sharing vehicles in a city, that corresponds to a drop in new car sales of almost 8%.

A potential concern is that the introduction of FFCS in the treated cities coincided with other trends in the treated cities, which negatively influence new car sales. In that case the regression

[9] The results are robust to different specifications of the treatment and the outcome variable. Robustness checks for the substitution effect can be found in Appendix A.1

coefficients would not pick up the effects of FFCS, but simply document pre-existing trends. Column (2) shows the results of a regression including city-specific linear trends. The estimated magnitude of the effect shrinks, but it remains statistically significant at the 1% level. In order to rule out other unobserved differences between treatment and control group that could potentially drive the results, column (3) presents regression estimates using only treated cities, relying only on the timing of the staggered launches (see Table 1) and the differences in treatment intensity (fleet sizes for identification). The results are similar in significance and magnitude.

The estimated annual reduction of new car sales by three for every FFCS vehicle in a city is not directly comparable to the survey results (e.g. Martin & Shaheen (2016)) mentioned in the introduction, because changes in used car sales are not taken into account here. Furthermore, in the survey results indicate permanent changes in car ownership, whereas the results of Table 3 show annual effects. For both of these reasons, the effects documented above should be interpreted as lower bounds on the true effect of FFCS on private car ownership.

Timing of the Effect of FFCS on New Car Sales

A way to get a better understanding of the timing of the effect and to test for potentially confounding pre-treatment trends is to include leads and lags of the treatment in the regression. Rewriting equation (1) to allow for *m* leads and *q* lags delivers:

$$y_{cts} = \alpha + \lambda_c + \lambda_t + \lambda_s + \sum_{j=-m}^{q} \delta_j \cdot D_{c,k+j} + \beta \cdot X_{ct} + \varepsilon_{cts} \qquad (2)$$

k_c denotes the true launch month of FFCS in city *c*. Figure 5 graphically shows the marginal effects of a FFCS vehicle on new car sales, as well as the 95% confidence intervals around them, including leads and lags of the treatment:

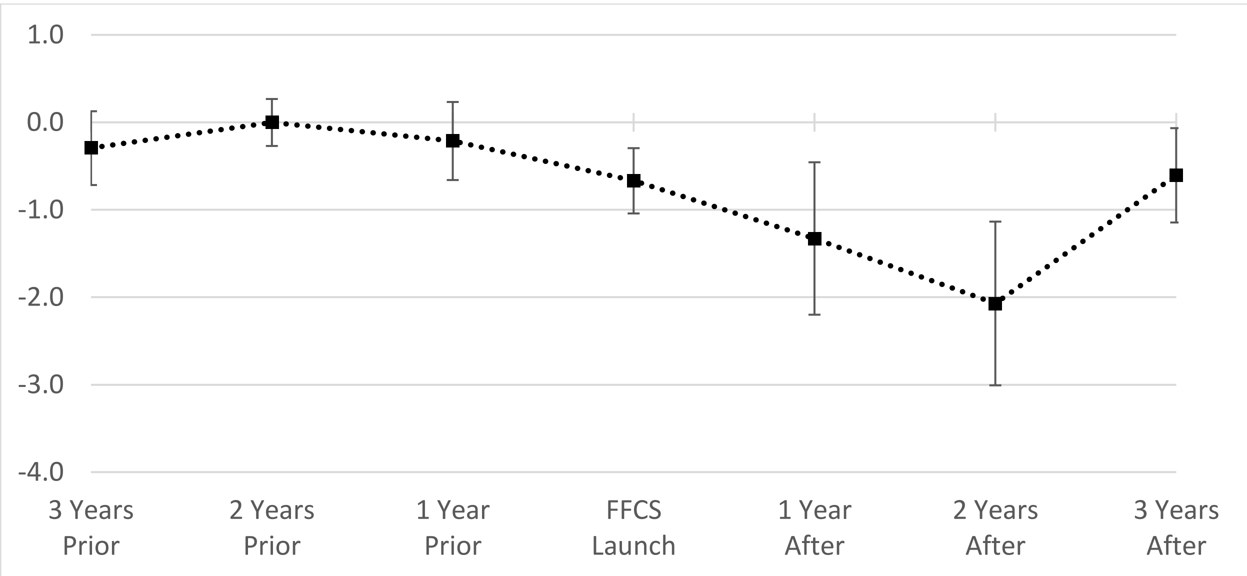

Figure 5: Marginal Effects of FFCS Vehicle on New Car Sales with Leads and Lags of Treatment. All coefficients are weighted by population. Standard Errors are clustered at the city level. All regressions include the following controls: Population, % male population, population density, average age, income, disposable income, price of land in €/m². The average number of FFCS vehicles in a treated city is 778. The average sales for on a city-month-model level in cities that offer FFCS at some point is 15.3. The total number of models in the sample is 163. Marginal effects are annual and calculated at the mean level of sales.

Reassuringly, there is no significant effect of the treatment before it was actually implemented. The effect of FFCS on new car sales gets stronger over time and is highest (in absolute terms) two years after the launch. This is intuitive since it likely takes time for consumers to learn about and adopt the new technology.

Differential Effects across Car Categories

An interesting question is what kinds of cars consumers substitute away from after the launch of FFCS. To answer this question, I run similar regressions as before separately on subsamples defined by different car categories[10]. The results are in Table 4:

	(1) lg(sales) Small	(2) lg(sales) Sub-Mid	(3) lg(sales) Mid	(4) lg(sales) Upper-Mid	(5) lg(sales) Upper	(6) lg(sales) Sports
Number of FFCS Vehicles	1.97e-4*** (2.11e-5)	5.43e-5** (1.86e-5)	9.29e-5*** (1.86e-5)	1.75e-5 (3.92e-5)	3.12e-6 (3.25e-5)	6.6e-5 (4.95e-5)
Effect of Marginal FFCS Vehicle on Annual Sales	-1.7	-0.6	-0.5	-	-	-
Change in Sales for Average Number of FFCS Vehicles	-15.1%	-4.2%	-7.1%	-	-	-

[10] The categories are determined by the largest German automobile club (ADAC) and categorize car models mostly according to size, price and purpose.

Controls	Yes	Yes	Yes	Yes	Yes	Yes
Fixed Effects	Time, City, Model	Time, City, Model	Time, City, Model	Time, City, Model	Time, City, Model	Time, City, Model
R^2	57.4%	58.5%	62.0%	53.2%	55.0%	50.4%
Observations	78 948	81 820	43 344	26 316	12 384	9 288
Nr of Models	51	53	28	17	8	6
Mean Sales	13.8	16.5	16.9	16.8	11.9	9.2

Table 4: Difference-in-Difference regression results for different car model categories. Standard Errors in parentheses. All coefficients are weighted by population. Standard Errors are clustered at the city level. All regressions include the following controls: Population, % male population, population density, average age, income, disposable income, price of land in €/m². The average number of FFCS vehicles in a treated city is 778. The average sales for on a city-month-model level in cities that offer FFCS at some point is 15.3. The total number of models in the sample is 163. Marginal effects and percentage changes in sales are annual and calculated at the mean levels of sales and number of FFCS vehicles. Models offered through FFCS were dropped from the sample.

Table 4 shows that the effect on total sales is driven by a large reduction in sales of the smallest car models. This is intuitive; the function of smaller cars is better substituted by free-floating car sharing than the function of larger cars, since small cars are often built for use in big cities. Their design emphasizes maneuverability and the possibility to find a parking spot. The models offered through FFCS are small and allowed to park in any free spot, so that free-floating car sharing is a closer substitute to the purposes of small cars than to those of larger ones.

The effect of FFCS declines for the larger car categories. It is insignificant for the expensive "upper-mid" and "upper" and "sports" categories. Models in these categories likely fulfill purposes beyond pure urban transportation needs and are hence more distant substitutes to free-floating car sharing.

Interestingly, these results fall in line with other studies of the effect of sharing economy business models on incumbent industries. For example, Zervas et al. (2014) find no effect of *Airbnb* on expensive hotels, but significant decreases in motel and cheap hotel room occupancy. Fraiberger & Sundararajan (2016) find that peer-to-peer car sharing mostly affected the used car market. Since small cars tend to be cheaper, the results discussed here suggest consumer welfare gains after the introduction of FFCS at the lower end of the income distribution.

Exogeneity of Treatment Assignment

A potential threat to identification comes from the fact that FFCS providers did not choose the cities in which they operate, nor the timing of their entry randomly. The concern is that treatment effects are overestimated, because FFCS providers entered cities (first), in which they saw large potential for FFCS.

Two observations alleviate this concern. First, FFCS companies started their operations close to their parent company headquarters. *car2go* launched its first FFCS operation in Ulm, which is the closest bigger city to the *smart* headquarter. Similarly, *DriveNow* started its first operation in Munich, where the *BMW Group* has its seat. I take this as evidence that the decision over which markets to enter first was driven to a large part by logistic and operational issues. Second, there is substantial anecdotal evidence[11] that FFCS providers were constrained in their decisions over when to enter and how many vehicles to provide by decisions and regulations of local governments.

5 Advertising Effect

The results presented in the previous section provide evidence on how the availability of free-floating car sharing leads to a sizable reduction in new car sales. The suggested mechanism is that individuals substitute away from owning a car towards using car sharing for their transportation needs. At first, it might therefore come as a surprise that two large automobile manufacturers own the two dominant FFCS providers in Germany, which are allegedly responsible for a decline in new car sales. There is, however, the possibility of differential effects of FFCS across car models; while the technology provides a substitute for all car models, it potentially serves as advertising for the specific car models used by the car sharing companies. Daimler owns the brands of *car2go* as well as of *smart*, the cars of which are offered by *car2go*. DriveNow uses the *MINI* and *BMW 1 Series* models; the *BMW group* owns half of *DriveNow* as well as the *MINI* and *BMW* brands in whole.

FFCS could potentially as advertising according to the following logic: By using FFCS and driving the provided models, FFCS users learn about the characteristics and quality of the models offered by the providers. These users may then be more likely to choose one of these models they've become acquainted with through FFCS, when they buy a new car. The effect may work in the other direction as well. A consumer may learn that she does not like the models offered to her through FFCS and become less likely to buy one of these models. Finally, a consumer may not buy a one of the models offered through FFCS, but another one, because the introduction of FFCS made it possible to drive that model without having to own it.

The results of this subsection provide evidence towards which of the effects described above is dominant across the population. However, it may also be the case that one of the mechanisms is

[11] A representative example of how the Munich city council allowed *DriveNow* to increase its fleet size is described in this (German) news paper article: https://www.merkur.de/lokales/muenchen/stadt-muenchen/immer-mehr-carsharing-in-muenchen-6846279.html (last accessed (27.10.2017)

dominant for one of the models offered through FFCS, while another drives the sales of a second of the three models. Therefore, I also provide evidence for each of the models separately.

Registrations by *car2go* and *DriveNow*

The data used in this project does not differentiate between corporate and private registrations of new cars. As illustrated by Figure 3, it is mostly possible to match FFCS launch dates and major fleet renewals (both of which are observed from company press releases) to spikes in the registration data. However, depending on company policy, not every registration of a new FFCS vehicle is accompanied by a press release. In particular, replacements of broken-down vehicles as well as rolling replacements of parts of the fleet may not be publicly announced. The frequency of these replacements is unknown, but could potentially be substantial, as the FFCS companies seek to provide their customers with relatively new vehicles. Not accounting for these replacement registrations would lead me to wildly overestimate the advertising effect, as I would not be picking up private purchases of consumers persuaded by the FFCS experience to buy a *smart*, *MINI* or *BMW 1 Series* car, but simply FFCS company replacement registrations.

Nonetheless, it is possible to estimate the advertising effect of two of the three FFCS models. *DriveNow* registers the all FFCS vehicles used in German cities in Munich. I can therefore exclude all confounding company registrations by *DriveNow* by dropping all observations from Munich from the sample and estimate the advertising effect of FFCS on the two models used by *DriveNow*, the *MINI* and the *BMW 1 Series*. Unfortunately, *car2go* registers its FFCS vehicles in the cities where they are offered, so that it is not possible to disentangle FFCS company registrations from private vehicle purchases.

Advertising Effect Triple Difference Regressions

To examine a potential advertising effect, I use a triple difference regression setup. The differences are over time (before vs. after *DriveNow* launch), between cities (*DriveNow* active vs. not active) and across car models (*MINI* or *BMW 1 Series* vs. other models). The treatment variable is a dummy variable that switches on for observations of sales of *MINI*s or *BMW 1 Series* in cities and at times when *DriveNow* is active.

$$D_{cts} = \mathbf{1}\{DriveNow\ was\ ever\ active\ in\ c\} \times \mathbf{1}\{t > k_c\} \times \mathbf{1}\{s\ is\ MINI\ or\ BMW\ 1\ Series\},$$

As before, c denotes cities, t time, s car models and k_c denotes the *DriveNow* launch date in c. To document the advertising effect, I run the following regressions:

$$y_{cts} = \alpha + \lambda_{ct} + \lambda_{cs} + \lambda_{ts} + \delta \cdot D_{cts} + \varepsilon_{cts}, \qquad (3)$$

where λ_{ct}, λ_{cs} and λ_{ts} are city-time, city-model and time-model fixed effects, respectively. The treatment D_{cts} is defined as above, α is a constant and ε_{cts} the error term[12]. Regression results are in Table 5.

	(1) lg(sales)	(2) lg(sales)	(3) lg(sales)
DriveNow	0.133** (0.040)	-	-
MINI	-	0.108* (0.061)	-
BMW 1 Series	-	-	0.159*** (0.037)
Fixed Effects	City-Time, City-Model, Time-Model	City-Time, City-Model, Time-Model	City-Time, City-Model, Time-Model
Sample	Small and Sub-Mid models, excl. Munich	Small models, excl. Munich	Sub-Mid models, excl. Munich
R^2	87.73%	86.1%	89.5%
Observations	156 232	76 752	79 480

Table 5: Difference-in-Difference-in-Differnce regression results. Standard errors in parentheses. All coefficients are weighted by population. Standard Errors are clustered at the city level. Average monthly sales in cities where DriveNow became active, but before the launch date for the MINI and BMW 1 Series are, respectively, 51 and 55.5.

The triple-difference regression result in column (1) suggests an increase in sales of the models used by *DriveNow* of 13.3%[13]. Columns (2) and (3) show the effects for the two used models separately. The coefficients indicate significant effects for both models. The advertising effect for the *BMW 1 Series* model is more significant and larger at almost 16%, than the estimated effect for the *MINI* at around 10%.

The economic significance of these estimate can be demonstrated with a quick back-of-the-envelope calculation. Average monthly sales in cities where DriveNow became active, but before the launch date for the MINI and BMW 1 Series are, respectively, 51 and 55.5. Assuming a per-car sales profit of 10% of the list price[14], the *BMW Group* makes a profit of 2 500€ and 2 700€ per sold *MINI* and *BMW 1* Series vehicle. Taking into account that *DriveNow* operates in five cities, combining these numbers with the advertising effect estimates from Table 5 leads to an estimated annual profit increase of around 2.3M € for the *BMW Group*. According to the *BMW Group Annual*

[12] It would be possible to construct a variable trying to measure the "advertisement intensity", similar to the "car sharing intensity" used in the previous subsection. I use the dummy variable specification here, since, for the purposes of advertising, the fact that a model is available to customers is more important than the number of identical models in a city.
[13] Robustness checks and placebo tests for the advertising effect are in Appendix A.2.
[14] A per-car profit of 10% was suggested by a quick online search as well as the results of Cosar et al. (2015). 25 000€ and 27 000€ are conservative estimates for average list prices of a new *MINI* and *BMW 1 Series* vehicle, respectively.

Report 2015[15], the financial result of *DriveNow* in 2015 was a loss of 6M €[16]. There is hence evidence that the profits from additional *MINI and BMW 1 Series* sales due to the advertising effect of FFCS compensated the *BMW Group* for a substantial part of the losses of the partial subsidiary *DriveNow*.

Several caveats apply: I did not account for the substitution/advertising effects of FFCS on the other models offered by *BMW*. FFCS launches may be accompanied by city-specific increases (decreases) in other local advertisement expenditure (e.g. billboards, local newspapers, local TV/radio) which I don't observe. This change in advertising could then lead me to overestimate (underestimate) the advertising effects of FFCS. Furthermore, the true average per car sales profit may be lower or higher than the numbers assumed in the calculations above. Nonetheless, even if the total estimated advertising effect is only on the correct order of magnitude, its existence may be of interest to FFCS stakeholders. For example, city councils may want to take it into account when determining how much to charge the FFCS providers for the privilege of letting their customers use public parking spaces.

6 Discussion: Ambiguous Effects of Free-Floating Car Sharing on Cities

In the introduction I mentioned that reducing the amount of privately owned cars may be beneficial in dense urban areas from a policy planner's perspective. This project provides evidence that free-floating car sharing is indeed effective towards that end, in that it induces some parts of the population to substitute from owning a car towards using a car sharing service for transportation. The effects of this transition on a city however deserve a closer look.

A potential challenge for city planners in coping with rising population densities is how to provide enough parking spaces[17]. If the availability of the marginal free-floating car sharing vehicle does indeed induce individuals to reduce the number of privately held cars by more than one, parking space as measured at the city level should free up. However, this is not necessarily true for every neighborhood, since the inhabitants of a city tend to pursue similar activities at roughly the same time. For example, a large group of people would like to park in the city center close to their

---

[15] https://www.bmwgroup.com/content/dam/bmw-group-websites/bmwgroup_com/ir/downloads/en/2016/hv/Annual_Report_2015.pdf last accessed 16.11.2017

[16] There is even evidence that *DriveNow* managed to earn a profit in 2017: http://www.autonews.com/article/20161003/GLOBAL/310039970/bmws-drivenow-is-profitable-now last accessed 16.11.2017

[17] For a discussion, see *The Economist* (April 6th 2017) – "The perilous politics of parking"

workplaces in the morning, but the same group commutes back to the outskirts in the evening, so that parking space may not necessarily free up where it is needed most.

It is also not clear a priori whether FFCS alleviates congestion in city streets. Some people may substitute away from walking, biking or using public transportation towards using the car sharing service, thereby actually making traffic worse.

FFCS users are more likely to be inexperienced drivers, or at least unfamiliar with the model offered through FFCS. This may increase the likelihood of accidents. Furthermore, since FFCS customers pay by the minute, not distance, they have an incentive to get to their destination quickly. This may encourage reckless driving and further increase the probability of an accident.

Another aspect of city life that is likely to deteriorate as cities become denser and more populated is air quality. As described above, the availability of FFCS may induce people to drive more, not less. However, FFCS customers are more likely to be inexperienced drivers, at least with the unfamiliar FFCS model, resulting in suboptimal gear shifting and high engine revs, resulting in high exhaustion of pollutants. Many FFCS trips are short and hence driven with a cold engine. Driving with a cold engine significantly increases pollutant exhaustion as compared to driving with a warm engine. On the other hand, vehicles offered through car sharing typically emit less harmful substances than the average car, since they are smaller. The direction of the effect of FFCS on air quality is therefore not clear a priori, but an interesting topic for future research.

7 Conclusion

Using a new and original dataset I examine the effects of free-floating car sharing (FFCS) on sales of new cars. I find strong and robust evidence for a large-scale substitution effect away from privately owning a car towards using car sharing. I also find evidence for a positive advertisement effect for the specific models that are used by one of the car sharing providers. These advertising effects benefit the large automobile company that owns the car sharing providers and compensates it to a significant degree for the losses incurred from the FFCS subsidiary.

Car sharing and the sharing economy in general show great promise to improve the provision of fundamental services like transportation. A car sharing vehicle is used more than three times as much on average compared to a privately-owned vehicle, which constitutes a significant improvement in efficiency. That number is bound to rise, as more consumers start to use free-floating car sharing. In order to correctly regulate this up-and-coming industry, as well as properly understand its impact on cities and existing industries, all of its effects need to be taken into account.

References

Bert, Julien, Brian Collie, Marco Gerrits & Gang Xu - What's Ahead for Car Sharing? - The New Mobility and Its Impact on Vehicle Sales, *Boston Consulting Group Study, February 23 2016*

Cosar, A. Kerem, Paul LE Grieco, Shengyu Li, and Felix Tintelnot - What drives home market advantage?. *No. w21583. National Bureau of Economic Research, 2015*.

Cramer, Judd & Alan B. Krueger - Disruptive Change in the Taxi Business: The Case of Uber, *AMERICAN ECONOMIC REVIEW VOL. 106, NO. 5, MAY 2016*

Farronato, Chiara & Andrey Fradkin – Market Structure with the Entry of Peer-to-Peer Platforms: The Case of Hotels and Airbnb, *Working Paper, January 2017*

Fraiberger, Samuel & Arun Sundararajan - Peer-to-Peer Rental Markets in the Sharing Economy*, Working Paper, 2016*

Martin, Elliott & Susan Shaheen – Impacts of car2go on Vehicle Ownership, Modal Shift, Vehicle Miles Travelled, and Greenhouse Gas Emissions, *Working Paper, July 2016*

Seamans, Robert & Feng Zhu - Responses to entry in multi-sided markets: The impact of Craigslist on local newspapers, *Management Science 60.2 (2013): 476-493.*

Stephany, Alex. The business of sharing: Making it in the new sharing economy. *Springer, 2015.*

Zervas, Georgios, Davide Proserpio, & John W. Byers"The rise of the sharing economy: Estimating the impact of Airbnb on the hotel industry *Journal of Marketing Research (2014)*

Appendix

A.1 Substitution Effect Robustness Checks

	(1) Sales	(2) Sales	(3) Sales	(4) Sales	(5) lg(Sales)	(6) Sales	(7) lg(Sales)
$FFCS\ Vehicles_{ct}$	-1.24e-3*** (3.35e-4)	-2.31e-4 (1.74e-4)	-2.04e-3** (8.01e-4)	-	-	-	-
$\frac{FFCS\ Vehicles_{ct}}{FFCS\ OP\ Area_{ct}}$	-	-	-	-0.169*** (0.053)	-0.012*** (0.003)	-	-
$FFCS\ Vehicles_{ct}$ $* pop\_density_{ct}$	-	-	-	-	-	2.64e-7** (1.06e-7)	2.27e-8*** (5.19e-9)
Effect of Marginal FFCS Vehicle on Annual Sales	-2.4	-0.45	-4.0	-2.3	-2.4	-1.7	-2.2
Change in Sales for Average Number of FFCS Vehicles	-6.3%	-1.1%	-10.4%	-5.9%	-6.2%	-4.3%	-5.6%
City-Specific Linear Trend	-	Yes	-	-	-	-	-
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed Effects	Time, City, Model	Time, City, Model	Time, City, Model	Time, City, Model	Time, City, Model	Time, City, Model	Time, City, Model
Sample	Full	Full	Only Treated Cities	Full	Full	Full	Full
R^2	54.6%	54.7%	56.38%	54.59%	55.83%	54.6%	55.9%
Observations	252 100	252 100	123 116	252 100	252 100	252 100	252 100

Table 6: Difference-in-Difference regression results for different car model categories. Standard Errors in parentheses. All coefficients are weighted by population. Standard Errors are clustered at the city level. All regressions include the following controls: Population, % male population, population density, average age, income, disposable income, price of land in €/m². The average number of FFCS vehicles in a treated city is 778. The average sales for on a city-month-model level in cities that offer FFCS at some point is 15.3. The total number of models in the sample is 163. Marginal effects and percentage changes in sales are annual and calculated at the mean levels of sales and number of FFCS vehicles. Models offered through FFCS were dropped from the sample.

A. 2 Advertising Effect Robustness Checks

	(1) Sales	(2) Sales	(3) Sales	(4) lg(Sales)	(5) lg(Sales)	(6) lg(Sales)
DriveNow	2.558*** (0.852)	-	-	-	-	-
MINI	-	1.867 (1.109)	-	-	-	-
BMW 1 Series	-	-	3.305*** (0.945)	-	-	-
Fiat 500	-	-	-	0.227 (0.135)	-	-
Audi A3	-	-	-	-	-0.414*** (0.116)	-
Mercedes A-Class	-	-	-	-	-	0.045 (0.119)
Fixed Effects	City-Time, City-Model, Time-Model	City-Time, City-Model, Time-Model	City-Time, City-Model, Time-Model	City-Time, City-Model, Time-Model	City-Time, City-Model, Time-Model	City-Time, City-Model, Time-Model
R^2	84.1%	87.7%	86.1%	86.1%	89.5%	89.5%
Observations	156 232	76 752	79 480	76 752	79 840	79 840
Sample	Small and Sub-Mid models, excl. Munich	Small models, excl. Munich	Sub-Mid models, excl. Munich	Small models, excl. Munich	Sub-Mid models, excl. Munich	Sub-Mid models, excl. Munich

Table 7: Difference-in-Difference-in-Differnce regression results. Standard errors in parentheses. All coefficients are weighted by population. Standard Errors are clustered at the city level. Average monthly sales in cities where DriveNow became active, but before the launch date for the MINI and BMW 1 Series are, respectively, 51 and 55.5.