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# Explaining carsharing supply across Western European cities

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**ABSTRACT**
Carsharing can partially replace private ownership of vehicles with a service that allows the use of a car temporarily on an on-demand basis. In this study, we analyze the supply of shared cars across 177 cities in five Western European countries (Belgium, France, Germany, The Netherlands, United Kingdom), while distinguishing between the traditional business-to-consumer (B2C) business model and the more recent peer-to-peer (P2P) business model. The data on carsharing supply is individually collected of all operators in the respective cities, while data of city characteristics is drawn from international or national statistical databases. We explain carsharing supply using comparable data of 14 explanatory variables. The results indicate that carsharing is popular in cities with a high educational level or university presence and, in the B2C case, with many green party votes. Furthermore, carsharing is less popular in cities with many car commuters. Particularly striking are the differences between countries, with peer-to-peer carsharing being especially popular in French cities and business-to-consumer carsharing in Germany. We reflect on the findings in the light of (sustainable) mobility policy options.

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Business-to-consumer; carsharing; peer-to-peer; policy; sharing economy

## 1. Introduction

Carsharing is a key example of what is called the "sharing economy," which consists of new business models exploiting underutilized assets by replacing ownership by access (Botsman & Rogers, 2010; Rifkin, 2000). Just as other forms of shared mobility such as bikesharing and ridesharing, carsharing is growing rapidly in many places around the world (Bundesverband CarSharing (bcs), 2018; Steer Davies Gleave, 2017a, 2017b, 2018; Peng, Yan, & Bai, 2017; Shaheen, Cohen, & Jaffee, 2018). Studies show that carsharing has the potential to satisfy individualized transportation demands in a more sustainable way, by foregoing car purchases and driven kilometers, decreasing the demand for cars and parking and decreasing emissions as shown by Shaheen and Cohen (2013) and Chen and Kockelman (2016) in a summary of studies. Emissions are lowered because carsharing adopters use the multimodal mobility system and drive less car kilometers (Chen & Kockelman, 2016; Sioui, Morency, & Trépanier, 2013) and because carsharing fleets contain more efficient vehicles than the average car (Martin, Shaheen, & Lidicker, 2010). Next to environmental impact, proponents of collaborative consumption claim positive social impacts through more community interactions and sharing resources (Botsman & Rogers, 2010; McLaren & Agyeman, 2015). It has to be noted that although these studies advance positive overall impacts of carsharing on environmental and social sustainability, more recent studies predict smaller emission decreases and draw the attention to differentiating between different business models as well as noting rebound effects. Becker, Ciari, and Axhausen (2017), for example, find varied impacts on car purchase avoidance and substitution between transport modes for different carsharing business models (free-floating vs. station based).

The promises of carsharing has attracted research interests. So far, most publications on carsharing have focused on the question which consumers opt for carsharing and why they do so (Burkhardt & Millard-Ball, 2006; Juschten, Ohnmacht, Thao, Gerike, & Hössinger, 2017; Lindloff, Pieper, Bandelow, & Woisetschläger, 2014; Martin et al., 2010; Schaefers, 2013; Sioui et al., 2013). And, in transportation research more specifically, there is also work on on-demand modeling and the logistic optimization of carsharing systems [for reviews, see Ciari, Balac, & Axhausen (2016) and Vosooghi, Puchinger, Jankovic, & Sirin (2018)]. Finally, more recently, management research on sharing-based business models and firm strategies has gained momentum (Clark, Gifford, & LeVine, 2014; Cohen & Kietzmann, 2014; Firnkorn & Müller, 2012; Münzel, Boon, Frenken, & Vaskelainen, 2018).

Much less emphasis has been on the question why carsharing supply differs between cities and countries. Earlier

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Supplemental data for this article can be accessed here.

studies analyzing urban factors affecting the size of the carsharing market focus on the analysis of specific cities instead of studying a larger dataset of cities across different countries (Braun, Koch, & Hochschild, 2016; Stillwater, Mokhtarian, & Shaheen, 2009). City size and population density are often mentioned as the main factors explaining why carsharing diffuses per capita more in larger cities than in smaller cities as sharing systems require a critical mass of local users to be profitable (Hampshire & Gaites, 2011; Millard-Ball, Murray, Schure, Fox, & Burkhardt, 2005). However, apart from size and density, other city characteristics have not been studied so far in the context of an intercity comparison. It is, therefore, interesting to analyze what factors drive the popularity of carsharing in cities and whether certain urban environments act as niches for the carsharing innovation as it is often the case in early transitions processes (Truffer & Coenen, 2012). Analyzing which city characteristics matter next to city size and density, helps to understand differences in supply and to identify favorable policy conditions or current barriers to success.

In this study, we analyze the supply of shared cars in all cities with more than 150,000 inhabitants in Belgium, France, Germany, The Netherlands and United Kingdom (177 cities in total). As explanatory factors, we include several city-level variables, as well as country dummies. In our analyses, we will distinguish between the two main carsharing business models currently on the market: the business-to-consumer (B2C) model in which an organization owns a fleet of cars which are rented out to users, and the peer-to-peer (P2P) business models where consumers rent out their own cars to other consumers on a two-sided platform operated by a coordinating carsharing organization. The business model types have important differences in organization, use and impact and may well prosper in different city environments. The setup of our database makes the findings, thus, unique through simultaneously analyzing 177 cities in five countries with comparable city characteristics, while at the same time including not only B2C but also the more recently diffusing P2P cars.

We will proceed as follows. In the next section, a more extensive literature review is given on carsharing. In Section 3, we go into the possible factors affecting carsharing supply at the city level as well as at the national levels of the five countries included in our study. Section 4 presents the methodology and Section 5 the results. We end with some concluding remarks.

## 2. Carsharing background and relevant studies

Carsharing can be defined as a system that allows people to use locally available cars at any time and for any duration (Frenken, 2015). It differs from taxis in the way that a shared car is driven by the renter and it also differs from car rental since cars are available locally and at any time and duration. Within carsharing, various business models have been distinguished (Cohen & Kietzmann, 2014; Remane, Nickerson, Hanelt, Tesch, & Kolbe, 2016). Figure 1 summarizes the different forms of carsharing business models. Shaheen, Cohen, and Zohdy (2016) explain distinctions between further shared mobility forms such as ridesharing and ridesourcing which we are not including in this study.

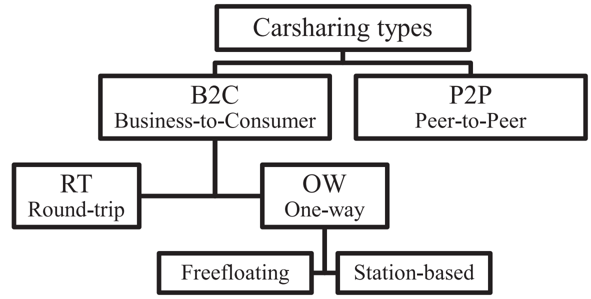


**Figure 1.** Types of carsharing business models.

The first viable carsharing initiatives started in the late 1980s in Switzerland and Germany with small projects run by environment-minded groups (Shaheen, Sperling, & Wagner, 1998; Truffer, 2003). These early organizations were arranged in a business-to-consumer (B2C) fashion, in which the carsharing organization (be it for-profit or not-for-profit) owns a fleet of cars that it rents out to its customers. Initially, the B2C business models were fairly similar and based on a Round-Trip (RT) system where the cars have to be returned to the same parking spot at the end of the trip as where they were rented from. Often, specific parking spots were made available to carsharing organizations by local governments as a way to promote sustainable mobility. A new type of B2C carsharing business model emerged around 2009 when some organizations developed a One-Way (OW) system (Car2Go being the most well-known worldwide). In a One-Way system, the cars do not have to be returned to the spot where the trip was started but can be dropped off either anywhere in a designated city area (free-floating) or at a different station of the provider (station based).

Around 2011, a new business model was introduced with the introduction of online peer-to-peer (P2P) platforms on which car owners can rent out their own car to fellow consumers ("peers"). The platform takes a fee for matching supply and demand and usually offers additional services like insurances (Shaheen, Mallery, & Kingsley, 2012). P2P carsharing is only operated in a Round-trip manner as the car is picked up from and returned to the car owner. Current market leader in Europe is Drivy, which operates in France, Germany, and three other countries.

Important to note is that P2P cars are used much less frequently than B2C cars. This difference can be explained by the zero marginal costs of supplying a P2P car, as these cars are privately owned and used, and only made available for sharing when they are idle. As a consequence, many car owners offer their car online even if the car is rented out only rarely. By contrast, a B2C shared car is only offered if there is sufficient local demand to cover the investment made by the carsharing operator. Hence, the supply of a B2C car gives a rather reliable indication that the car is actually rented out often. It should although also be considered that not all operators are profitable, since some receive

Table 1. Studies on carsharing supply and use.

| | Koch (2002) | Stillwater et al. (2009) | Coll et al. (2014) | Kortum (2014) | Schmöller et al. (2015) | Braun et al. (2016) | Müller et al. (2017) |
|---|---|---|---|---|---|---|---|
| Coverage | Bremen, single operator | US, single operator | Québec City, single operator | Austin, single operator | Munich and Berlin, 2 operators | Tübingen, single operator | Berlin, single operator |
| Unit of analysis | | Neighborhood | | | | | |
| Dependent variable | Data on car location | Data on booking location | Data on member location | Data on trip location | Data on booking location | Data on usage location | Data on booking location |
| **Structural variables of the neighborhood** | | | | | | | |
| Population density | + | 0 | 0 | + | | + | – |
| Rate of residentially used area | | | + | | | | |
| Age of housing units | | 0 | | | | | |
| Quality and proximity of public transit | | + (light rail)<br>– (regional rail) | + | | | 0 | |
| Pedestrian-, bike-, and car-friendliness | | + (pedestrian) | | | | 0 | |
| Parking quality | | 0 | | | | | + |
| Centrality in city | + | | | | | + | + |
| Job opportunities in area | + (large diversity in job opportunities) | | + | | + | | |
| Availability of services | | | | | + (medium level of services) | | + (bars and companies) |
| **Socio-demographic variables of neighborhood** | | | | | | | |
| Age | | 0 | + (middle-aged) | | + (middle-aged) | + (middle-aged) | |
| Gender | | | 0 | | | | |
| Household type and composition | | 0 | + (families) | – (household size) | – (families) | + (families) | – (young families)<br>+ (families with older children)<br>+ (1 or 2 person household) |
| Nationality or race | | 0 | | | | – (foreigners) | – (foreigners) |
| Income | | 0 | – | – | | | + |
| Education | | 0 | + | | | | |
| Personal attitudes | | | | | | + (environmentally minded) | – (conservative milieu)<br>+ (Green party voters) |
| Mode of transport for commute | | – (commute by car) | | | | | |
| Car ownership | (–) | –<br>(+ in case of 1–vehicle households) | – | | | 0 | – |

+ positive influence – negative influence 0 no influence.

investments from investors or mother companies that are putting faith in the growth and success of the market in the future or experiment to gather knowledge and explore.

Research on spatial factors affecting the supply or use of carsharing is limited. Table 1 summarizes studies that use statistical analyses to identify factors that influence supply and use of carsharing in cities. The table indicates which variables were considered in these studies and show either no or a significant influence on the extent of carsharing. All studies are either focusing on one city or on one operator, and analyze neighborhood differences rather than city-level differences. Our research, in contrast, aims to compare carsharing supply at the city-level and country-level. Inspired by the studies included in Table 1, we extend the range of factors that may affect carsharing supply (Braun et al., 2016; Coll, Vandersmissen, & Thériault, 2014; Knie et al., 2016; Koch, 2002; Stillwater et al., 2009).

## 3. Factors affecting the supply of carsharing

Carsharing is a multifaceted innovation and its popularity is affected by a multitude of factors ranging from individual preferences, city characteristics, and country institutions. To identify these factors, we apply a range of theories from innovation studies, transportation studies, and urban geography. We use six categories to group these variables.

*First*, Rogers' (2003) theory on the diffusion of innovation details how individual adoption is aggregated into diffusion patterns of innovations. Commonly, early adopters of new technologies or system innovations are characterized by age (younger age groups), education (higher education), and income (higher income). Earlier studies on carsharing users identified these factors as well (Burkhardt & Millard-Ball, 2006; Lane, 2005; Loose, 2010; Prettenthaler & Steininger, 1999). Schmöller, Weikl, Müller, and Bogenberger (2015) Knie et al. (2016), Braun et al. (2016), and Coll et al. (2014) further identify the share of middle-aged groups to have an influence on carsharing market size.

*Second*, innovation theories stress the role of niches in which innovations get the chance to nurture without pressure from incumbent rules and competitors (Geels, 2012; Hoogma, Kemp, Schot, & Truffer, 2002). Specific user groups have preferences in common that render them willing to pay for a particular innovation and more eager to participate in niche experimentation. Typical user groups around which niches in the context of carsharing are formed were identified by, for example, Shaheen, Cohen, and Roberts (2006), Stocker, Lazarus, Becker, and Shaheen (2016), and Truffer (2003). Shaheen et al. pointed out the early adoption by students or on college campuses and Stocker et al. study the effects carsharing has on college communities. Students have fewer resources to own a car, use different transportation modes and are more open to innovations. Both studies analyzed carsharing in an North American context, where public transport options are more limited than in the European context studied by Truffer. Moreover, college campuses are often less integrated in a city infrastructure but form their own campus towns. Truffer identified members of environmental groups or others with a strong ideological background as early adopters. People with strong environmental ideologies identify carsharing as a more sustainable transportation mode and act on these benefits. This effect has indeed been empirically supported in the study by Meelen, Hobrink, and Frenken (2015) on carsharing supply in Dutch neighborhoods. Another user group providing a possible niche for carsharing use are families, which often are dependent on access to two cars. Instead of owning two cars, carsharing allows them to economize by substituting the second car by temporary access to a shared car. Schmöller et al. (2015) Knie et al. (2016), Coll et al. (2014), and Braun et al. (2016) found that a higher presence of families in neighborhoods increased carsharing. Müller, Correia, de, and Bogenberger (2017) found this to be true for families with older children, while families with young children decrease carsharing demand. Similarly, one can argue that one-person households are more eager to adopt carsharing, as the fixed costs of owning a car is twice the cost for a one-person household compared to a two-person household. Meelen et al. (2015) and Müller et al. (2017) found such an effect in their study.

*Third*, a city's legacy of spatial planning and in particularly the notion of *urban form* is relevant to understand the diffusion of mobility innovations like carsharing. Cohen and Shaheen (2016) describe in detail how shared mobility is shaping and has been shaped by urban policies and planning and discuss possible impacts. The relevance of the built environment on mobility behavior has also been highlighted by Maat and Arentze (2012) and the studies included in Table 1. Urban form is defined as the building structure and density as well as all other structural elements that physically define a city like natural features or transportation corridors (Stead & Marshall, 2001). The size and shape of a city influences transportation and the diffusion of transport innovations within. Also, dense historic cities, where car use and parking may be difficult, draw people to different mobility modes than in large outspread modern-times cities, where distances are longer and car use is more feasible. The density of a city is furthermore important for an efficient operation of carsharing for most firms. In dense cities it is likely that a shared car is in easy reach and the shared cars are used more frequently.

*Fourth*, the availability and use of different transportation modes could also be influential. If there is a strong public transit system present in the city, it is easier to live without a car or multimodal travel including carsharing might be easier. Opposing to this, carsharing could also be useful in cities with a weaker public transit system, since a car is needed more frequently to get to locations. Equally interesting is the share of private car travel in the commuting modal split. Car commuters will be unlikely clients for carsharing as they depend on car use on a daily basis. Stillwater et al. (2009) also analyzed the influence of travel modes used for the commute on carsharing (Table 1).

*Fifth*, national contexts are of importance as well given the large differences in the popularity of carsharing across countries (Shaheen & Cohen, 2013). The mobility system is greatly influenced by its infrastructure as well as institutions such as regulations, tax regimes, and support policies. For the five countries in our study specifically (Belgium, France, Germany, The Netherlands, United Kingdom), substantial differences have already been highlighted by Loose (2010) and Le Vine, Zolfaghari, and Polak (2014) and include the historical development, governmental support, and institutions. In Belgium carsharing started in 2002 with strong support of regional governments and through partnerships with local transit operators. In France, carsharing exists since 1999 and is especially popular in Paris with strong municipal support. It is also the home base of Drivy, which is currently the largest peer-to-peer provider in Europe. In Germany, carsharing already started in 1988 and is characterized by a few large companies and many small organization which enjoy variable municipal support. In The Netherlands, carsharing started in 1994 and had known supportive policies both at local and national levels. Finally, carsharing in the United Kingdom is relatively recent with fragmented government policies. A specific hurdle for peer-to-peer carsharing has been insurance policies that hinder car owners to rent out their own car (Wosskow, 2014).

*Sixth*, the popularity of carsharing can be influenced by the presence of other sharing systems. In particular, bikesharing systems can benefit carsharing in two ways. First, people can get aware and familiar with the notion of shared use of transportation modes. This effect is known as a spillover effect among innovations (Jaffe, Trajtenberg, & Fogarty, 2000). Second, people get less dependent on owning a car if both bike- and different carsharing systems are in place. In this respect, the use of carsharing and bikesharing systems is complementary. In addition, a large supply of B2C carsharing cars may affect the popularity of P2P carsharing and the other way around. On the one hand, a negative effect can be hypothesized as the two business models compete for users. On the other hand, in a city with another carsharing system present, many inhabitants are already familiar with carsharing which may lower the barriers to offer and use shared cars through the other platform as well.

## 4. Research design

We measure the supply of shared cars, as the dependent variable, by counting the number of shared B2C and P2P cars on offer in each city and dividing it by the population size. This measure reflects the extent to which carsharing has diffused at the time of data collection. The numbers of shared cars in each city are taken from the carsharing suppliers' websites during weekdays between November 2015 and April 2016. In rare cases that data on supply were not publicly available, firms were contacted by phone or email. The firms are identified by an extensive internet search with relevant names and translations of 'carsharing' in combination with the included cities[1] and through membership registers of umbrella organizations,[2] and are categorized by their business model (P2P, B2C).[3] Given that carsharing is mostly a city-phenomenon (Shaheen & Cohen, 2007), we selected all cities with more than 150,000 inhabitants. This resulted in a dataset covering carsharing supply in 177 cities in five European countries: Belgium, France, Germany, The Netherlands, and the United Kingdom.

Other possibilities to measure the city-level popularity of carsharing would have been possible. Shaheen and Cohen (2016) for example refer to number of members in their overview of the carsharing market. Moreover, the number of bookings could give the most precise measure of carsharing adoption, because it would correct for members who are not using the service regularly (both in B2C and P2P systems) and for cars not being used regularly (especially in the P2P system). Unfortunately, a complete database with active member numbers or bookings for each carsharing provider is not publicly available.

Following the factors affecting carsharing supply derived from theory in the preceding section, we constructed 14 independent variables. Table 2 presents the variables and how these have been collected and measured. The independent variables were primarily drawn from the European Eurostat database and national statistics databases. Note that we did not include the share of single-households in a city as independent variable, because this variable showed signs of multicollinearity and was, therefore, excluded from the analysis.

To test which factors affect carsharing supply, several OLS regression analyses are carried out. We analyze the two business models separately since the number of cars for each business model is not comparable directly. As stressed in the theory section, P2P cars are used rather infrequently, while B2C cars are used frequently. At first a linear regression model including all 14 independent variables is carried out. In a second step only the variables showing a significant influence on the number of cars are included and the regression model is re-run. For the dependent variable, the number of cars is divided by the population in 100,000 and then log-transformed before entering it in the model. This transformation is needed to correct the distribution, which otherwise has a long-tail. As some cities have zero shared cars, one count of one car is added to all cases before the log transformation.

Because the dependent variable can also be seen as a count when considering the absolute numbers of cars, we also considered a negative binomial regression (NegBin), which can more accurately model the distribution and correct for overdispersion. In the B2C case there are a number of zeros (cities with no B2C cars on offer) and a zero-inflated negative binomial regression (ZINB) can be used to account for this. The results of the NegBin regression for P2P cars and the ZINB regression can be found in Supporting Information Appendix 2. The first part of the B2C model explaining the zeros shows the high influence of city size also observed in the linear regression and following

[1]"Carsharing + city name"; "autodelen + city name"; "car clubs + city name"; "autopartage + city name"; "voiture en libre service + city name"
[2]Germany: Bundesverband Carsharing; Belgium: Autodelen.net

[3]Few firms offer both B2C and P2P carsharing. The respective cars were then counted separately an allocated to in the appropriate category accordingly.

**Table 2.** Variables included in model to explain carsharing supply.

| | Theory | Variable | Indicators | Data source |
|---|---|---|---|---|
| 1 | Innovation adoption | Young age | Percentage of inhabitants aged 20–34 years | Eurostat |
| | | Middle age | Percentage of inhabitants aged 35–49 years | Eurostat |
| | | Higher education | Percentage of inhabitants (aged 25–64) with high level of education (ISCED 5 or 6[a]) | Eurostat |
| 2 | Innovation niches | University presence | Binary (1 = university is present) | CWTS Leiden Ranking |
| | | Green party votes[b] | Percentage of votes for green party | Official national election statistics; municipal election statistics for Belgium |
| | | Families | Percentage of households with children | Eurostat |
| 3 | Urban form | City size | Number of inhabitants | Eurostat |
| | | Population density | Number of inhabitants per km$^2$ | Statistics Belgium, Belgium; Insee, France; DEStatis, Germany; CBS, The Netherlands; ONS, UK; |
| | | Historic city (larger than 10,000 inhabitants before 1800) | Binary (1 = historic city) | De Vries (1984) |
| 4 | Modal split | Car use | Percentage of commute trips done by car | Eurostat, CBS for The Netherlands |
| | | Public transit use | Percentage of commute trips done by public transit | Eurostat, CBS for The Netherlands |
| 5 | Institution | Country | Country dummies | |
| 6 | Spillover effects | Bikesharing presence | Binary (1 = bikesharing present) | Google search, Bikeshare.com |
| | | Supply of other carsharing type | Number of P2P or B2C cars per capita | Own database |

[a]International Standard Classification of Education (ISCED) 5&6 equals a bachelor's degree or similar.
[b]A similar operationalization of attitude toward the environment is followed by Braun et al. (2016).

the argumentation that to start a B2C carsharing operation a critical mass of users is needed to cover the fixed costs of operations. The second part of the model, the NegBin regression, shows the influence of the independent variables on the number of cars and results mostly resemble the results of the linear regression and resemble for the largest part results of the linear regression. Also the NegBin results of the P2P model resemble the linear regression model results. We thus conclude that out results are robust with regard to the chosen regression method (OLS, NegBin, or ZINB).

Additionally, to be able to analyze the overall *use* of shared cars next to the supply, we added up the number of B2C and P2P cars for each city. We applied different weighting schemes such that B2C cars are weighted more than P2P cars, because P2P cars are used much less frequently than B2C cars (as explained, this is due to the zero marginal costs of supplying a P2P car[4]). This additional analysis, reported in Supporting Information Appendix 3, can be considered as an extra robustness check. The results support the OLS regression results based on the supply of shared cars.

[4]A Dutch P2P platform owner reported during a public carsharing event in Utrecht (3 June 2015) that the cars are rented out only seven times a year on average, while a study of B2C Round-trip providers in Berlin shows use patterns for the cars of 0.71 to 0.81 bookings per day (Lawinczak & Heinrichs, 2008), while another study finds for Munich and Berlin that B2C Round-trip cars are in use 31%–35% of a day and cars of a One-Way provider at 12%–21% of a day (Knie et al., 2016). Though the figures are imprecise, it is clear that P2P cars are indeed rented out less frequently than B2C cars.

## 5. Results

### 5.1 Descriptive statistics

Table 3 provides the descriptive statistics of dependent and independent variables. The mean number of shared cars in cities is 135, and 17.8 per 100,000 inhabitants, for B2C cars. For P2P cars the mean is at 187 cars, and 34.8 per 100,000 inhabitants. Many cities feature rather small numbers of shared cars, with 74 cities who have fewer than 50 shared cars available. P2P cars are present in all but two of the 177 cities, whereas there are no B2C cars available in 33 out of the 177 cities. Figure 2 further shows the large differences between countries. In France, we see the largest numbers of shared cars in cities due to an exceptionally high number of P2P cars. This stands in contrast to the situation in Germany where most cars are operated in a B2C model. In the other three countries, the number of shared cars are more equally divided between P2P and B2C models. Overall, the United Kingdom lags behind in the number of shared cars. Table 4 lists the cities where carsharing supply is largest. The large supply of B2C cars in Germany and P2P cars in France can also be observed here. The largest total amounts of shared cars can be found in the capital cities, whereas the leading cities in ratio of cars per capita are other, smaller cities.

Before including the variables in the model, correlations, and multicollinearity between the independent variables were checked. Some variables correlate significantly, but multicollinearity shows no signs of these variables significantly influencing the precision of the model with all VIF

Table 3. Descriptive statistics of number of shared cars and city characteristics.

| | *N* | Min. | Max. | Mean | Std. Dev. |
|---|---|---|---|---|---|
| **Number of B2C cars** | 177 | 0 | 3,961 | 134.7 | 441.6 |
| **Number of B2C cars per 100,000 inhabitants** | 177 | 0 | 223 | 17.8 | 31.7 |
| Dependent variable | | | | | |
| **Number of P2P cars** | 177 | 0 | 7,516 | 187.3 | 619.2 |
| **Number of P2P cars per 100,000 inhabitants** | 177 | 0 | 202 | 34.8 | 47.4 |
| Dependent variable | | | | | |
| **Young age** | 177 | 15.8 | 35.4 | 21.9 | 3.6 |
| % of people between 20- and 34-year old | | | | | |
| **Middle age** | 177 | 22.6 | 32.2 | 27.4 | 1.9 |
| % of people between 35- and 49-year old | | | | | |
| **Higher education** | 166 | 13.1 | 60.3 | 33.3 | 9.1 |
| % of working age population qualified at level 5 or 6 ISCED | | | | | |
| **University presence** | 177 | 0 | 1 | 0.5 | |
| Dummy variable if university is present (1) or not (0) | | | | | |
| **Green party votes** | 177 | 0 | 19.8 | 6.5 | 4.5 |
| % of votes in last election for Green party | | | | | |
| **Families** | 163 | 12.4 | 40.0 | 24.2 | 5.7 |
| % of households with children | | | | | |
| **City size** | 177 | 1.5 | 83.6 | 4.7 | 8.7 |
| City population in 100,000 | | | | | |
| **Population density** | 176 | 0.3 | 8.8 | 1.8 | 1.3 |
| Population density in 1,000 people/km$^2$ | | | | | |
| **Historical city** | 177 | 0 | 1 | 0.6 | |
| Dummy variable for cities that had over 10,000 inhabitants before 1800 (1) or not (0) | | | | | |
| **Commute by car** | 175 | 12.9 | 86.1 | 61.3 | 13.3 |
| % of journeys to work by car | | | | | |
| **Commute by public transport** | 175 | 4.2 | 69.4 | 18.5 | 9.7 |
| % of journeys to work by public transport | | | | | |
| **Bikesharing present** | 177 | 0 | 1 | 0.5 | |
| Dummy variable if bikesharing is present (1) or not (0) | | | | | |
| **Country Dummy Belgium** | 177 | 0 | 1 | 0.03 | |
| **Country Dummy Germany** | 177 | 0 | 1 | 0.30 | |
| **Country Dummy France** | 177 | 0 | 1 | 0.26 | |
| **Country Dummy The Netherlands** | 177 | 0 | 1 | 0.07 | |
| **Country Dummy United Kingdom** | 177 | 0 | 1 | 0.34 | |
| Valid N | 155 | | | | |

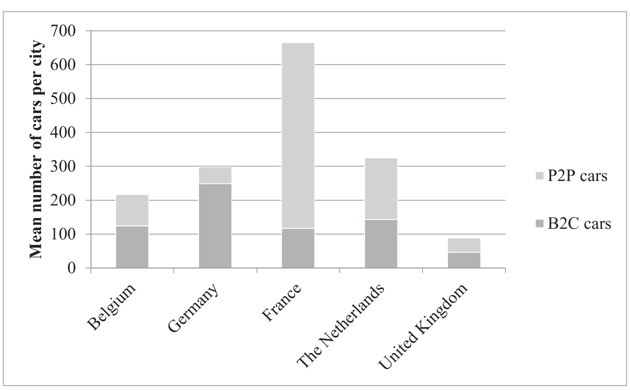


Figure 2. Country differences in numbers of shared cars.

scores lower than 5 (Rogerson, 2010). The correlation matrix is provided in Supporting Information Appendix 1. When analyzing the data for outliers using the Cook's distance[5] no case was identified as having a too large effect on the results, with all Cook's measures well below 1.

### 5.2. Regression results on the number of shared cars per capita

In the regression results, we report the regression coefficients (*B*) to indicate the effect and its direction (positive or negative). Model 1 in Table 5 shows the regression results for the number of B2C cars in cities. Two submodels (1.1–1.2) were run, with Model 1.1 including all theoretically derived independent variables and Model 1.2 only including variables which showed a significant effect in Model 1.1. Model 2 repeats the regression analysis for the number of P2P cars, using the same submodels as Model 1.

For B2C car sharing, we observe a significant effect of university presence on supply. Cities with a university have higher numbers of shared cars per capita. Furthermore, we see an effect of green party voters. This effect is in line with the common understanding of carsharing as a sustainable mobility service. For a rise of the share of green party voting by 1, the model expects 9% more B2C cars per capita.[6] Both car commuting and public transit commuting negatively affects carsharing. A large supply of P2P carsharing cars positively influence the supply of B2C cars. Finally, the country dummies indicate strong differences between countries. The coefficients show that B2C carsharing is much less popular in French and Dutch cities compared to the reference group of the United Kingdom cities. The $R^2$ of 0.75 of Model 1.2 shows that the included variables explain a large part of the variance. The results are mainly reproduced when using a zero-inflated negative binomial regression analysis (Supporting Information Appendix 2).

[5]The Cook's distance measures the influence of a single observation on the overall model (Cook & Weisberg, 1982).

[6]This is calculated through: exp(B)-1

**Table 4.** Top 5 carsharing cities.

| | Shared Cars per 100,000 inhabitants | | | Shared Cars | | |
|---|---|---|---|---|---|---|
| | total | B2C | P2P | total | B2C | P2P |
| 1 | Karlsruhe *Germany* (237) | Karlsruhe *Germany* (223) | Montpellier *France* (202) | Paris *France* (11,477) | Paris *France* (3,961) | Paris *France* (7,516) |
| 2 | Utrecht *The Netherlands* (214) | Stuttgart *Germany* (152) | Bordeaux *France* (177) | London *UK* (3,390) | Berlin *Germany* (2,676) | Lyon *France* (1,453) |
| 3 | Montpellier *France* (211) | Amsterdam *The Netherlands* (125) | Versailles *France* (175) | Berlin *Germany* (3,221) | London *UK* (1,955) | London *UK* (1,435) |
| 4 | Amsterdam *The Netherlands* (210) | Köln *Germany* (119) | Toulouse *France* (171) | Amsterdam *The Netherlands* (2,172) | München *Germany* (1,589) | Lille *France* (1,386) |
| 5 | Bordeaux *France* (204) | Heidelberg *Germany* (116) | Nantes *France* (1.62) | München *Germany* (1,806) | Hamburg *Germany* (1,449) | Bordeaux *France* (1,295) |

The result for P2P carsharing are slightly different. While the education level in this case has a significant positive effect on shared P2P cars, university presence has an (unexpected) negative effect. Furthermore, different from B2C carsharing, green party votes do not increase P2P carsharing in a city. Density has a small negative effect on P2P car sharing. Possibly, there are fewer car owners and with that fewer P2P carsharing suppliers in densely populated cities in the first place, given higher costs of parking. In contrast to B2C carsharing, the share of car commuting has no effect on P2P carsharing, while public transit commuting again positively affects carsharing supply. As in the B2C case, a large supply of shared cars of the other carsharing type positively influences the supply of P2P carsharing cars. Finally, we see again strong country differences. Especially French cities outperform other European cities. The model fit is good with an $R^2$ of 0.887 for Model 2.2. Finally, the negative binomial regressions for P2P carsharing (Supporting Information Appendix 2) are robust with regard to the OLS regression results reported in Table 5.

## 6. Concluding remarks

In this research, a unique dataset was constructed showing the urban supply of peer-to-peer (P2P) and business-to-consumer (B2C) carsharing in 177 cities in Western Europe. Our study is the first to provide quantitative insights on city-level factors that affect the supply of these two types of carsharing business models, covering a wide range of cities and variables. We found that carsharing is popular in cities with many highly educated inhabitants or cities with a university. B2C carsharing is further supported by green party voters, as well as weak car and public transit and strong pedestrian and bike commuting regimes.

Population density is most often mentioned as one of the most important factors for a carsharing system to function. We, therefore, expected that population density would support carsharing in cities. Nevertheless, population density shows no significant positive effect on the number of B2C shared cars per capita and even a small negative effect on the number of shared P2P cars per capita. One explanation for this finding could be that the dataset covers only cities with more than 150,000 inhabitants where a certain density threshold might already be reached. Another point to consider is the influence of measuring population density between neighborhoods instead of at a city level. The studies by Braun et al. (2016), Müller et al. (2017) and Koch (2002) did find significant influence of population density on the diffusion of B2C carsharing when analyzing differences between neighborhoods of one city. Thus, density may well be important at the neighborhood level (which is a car's service area), but not necessarily at the city level.

Finally, the effects of country dummies suggest that the national context plays a key role. This finding supports qualitative reports on the state of carsharing in different European countries by Loose (2010) and Le Vine, Zolfaghari, and Polak (2014). Differences across countries can be observed in the history of the market, the background of operators and their networks, the operation area of provider (local vs. national providers), insurance markets, and public policies. A further finding holds that countries also differ in the specific type of business model that is most popular. Notably, P2P sharing is especially booming in French cities, while German and Belgian cities are leading in B2C carsharing. German cities are especially leading in the One-Way carsharing type, which is associated with operators who are backed by German car manufacturers and are present with large fleets in several cities. The low number of shared P2P cars in the United Kingdom suggest that the strict insurance regulations in the United Kingdom for renting out one's own car indeed hamper P2P sharing (Wosskow, 2014) and the United Kingdom's strong culture and tradition of private vehicle ownership can also be regarded as a hurdle for B2C carsharing (Reuters, 2014). The striking differences suggest that there is ample room for policies to support carsharing diffusion, both at the municipality level and at the national level.

Several ideas for future research can be proposed. First, carsharing is a relatively recent phenomenon in mobility systems with most of its growth occurring in the last decade. Developments may take different paths depending on future policies, technological innovations and business strategies. Prospective diffusion analysis would, therefore, complement our analysis of supply. Second, our analysis can be extended

**Table 5.** Linear regression models for P2P and B2C carsharing.

| | Model 1.1 | | Model 1.2 | | Model 2.1 | | Model 2.2 | |
|---|---|---|---|---|---|---|---|---|
| Dependent variable | ln(number of B2C cars per 100,000 inhabitants) | | ln(number of B2C cars per 100,000 inhabitants) | | ln(number of P2P cars per 100,000 inhabitants) | | ln(number of P2P cars per 100,000 inhabitants) | |
| N | 154 | | 174 | | 154 | | 162 | |
| $R^2$ | 0.782 | | 0.750 | | 0.894 | | 0.887 | |
| | B | t | B | t | B | t | B | t |
| Young age | −0.02 | −0.46 | | | 0.03 | 1.44 | | |
| Middle age | 0.08 | 1.13 | | | −0.01 | −0.30 | | |
| Higher education | 0.02 | 1.32 | | | 0.02** | 2.25 | 0.02*** | 3.71 |
| University presence | 0.66*** | 3.44 | 0.57*** | 3.96 | −0.44*** | −3.59 | −0.32*** | −3.19 |
| Green party votes | 0.07*** | 3.06 | 0.09*** | 5.34 | −0.02 | −1.38 | | |
| Families | 0.02 | 0.60 | | | −0.02 | −1.19 | | |
| Population density | 0.05 | 0.67 | | | −0.10** | −2.15 | −0.09** | −2.16 |
| Historic city | 0.13 | 0.73 | | | 0.06 | 0.55 | | |
| Commute by car | −0.04** | −2.56 | −0.04*** | −3.45 | 0.00 | −0.19 | | |
| Commute by public transit | −0.03* | −1.87 | −0.01 | −0.51 | 0.02* | 1.82 | 0.02*** | 2.86 |
| Bikesharing presence | 0.25 | 1.45 | | | −0.02 | −0.14 | | |
| LN(number of B2C or P2P cars (resp.) per 100,000 inhabitants) | 0.58*** | 4.63 | 0.61*** | 5.91 | 0.23*** | 4.63 | 0.27*** | 7.23 |
| Belgium | 0.35 | 0.77 | | | 0.97*** | 3.53 | 0.81*** | 3.59 |
| Germany | 0.64 | 1.50 | | | 0.13 | 0.47 | | |
| France | −1.88*** | −4.47 | −2.25*** | −7.12 | 2.82*** | 17.85 | 2.77*** | 27.16 |
| The Netherlands | −1.48*** | −2.65 | −1.21*** | −2.83 | 1.62*** | 4.78 | 1.66*** | 9.97 |
| United Kingdom (reference) | 0 | | | | 0 | | | |

*Significance at the 0.1 level.
**Significance at the 0.05 level.
***Significance at the 0.01 level.

to include other countries across the globe. Future research depends heavily on the quality of data. We already highlighted the limitations inherent to the use of the number of shared cars as a proxy for diffusion. Especially in the P2P case, the supply of cars can be highly different from the actual use. Ideally, real usage data is required from carsharing providers or through large-scale surveys, as to understand the different appeal to users in different spatial contexts, and for different carsharing business models. Third, future analysis could focus especially on smaller towns and rural regions, where carsharing is often community-based and driven by personal involvement and ideological motives (Millard-Ball et al., 2005; Münzel et al., 2018; Nobis, 2006; Truffer, 2003). Fourth, our analysis could be extended by differentiating between carsharing types in more detail. Especially free-floating and station-based carsharing services seem to be used differently and can, thus, have divergent impacts (Ciari, Bock, & Balmer, 2014; Heilig, Mallig, Schröder, Kagerbauer, & Vortisch, 2018). Fifth, in our present study, the political and institutional variables were broad-brushed (as captured by green party votes at the urban level and country dummies), and should be made more granular in future studies. This necessitates systematic data collection on city-specific tax, parking, and carsharing policies as well as national differences in taxes and regulations regarding insurance and shared use.

All in all, the results make clear that carsharing supply differs substantially between cities and between countries, and between the older B2C variant and the more recent P2P variant. To understand the future potential of carsharing as an environmental innovation that supports the transition toward a sustainable mobility system, one thus needs to understand the transition process geographically and at different spatial (neighborhood, city, country) levels (Truffer & Coenen, 2012). Our study made clear that besides physical and socio-demographic factors, political orientations and institutions greatly influence the popularity of carsharing.

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