Explaining the differential growth of peer-to-peer car-sharing in European cities

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Master's Thesis

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Abstract

While car-sharing has proven quite successful in some cities, in other cities the phenomenon of car-sharing is less developed. This study aims to explain these spatial differences in the growth of peer-to-peer (P2P) car-sharing in cities. Firstly, this study shows the current state of P2P car-sharing in cities within the countries United Kingdom, The Netherlands, France, Germany, and Belgium. P2P car-sharing shows to be more successful in France and The Netherlands, and less successful in Germany and the United Kingdom when compared to Belgium.

Secondly, from a Multi-level perspective (MLP), niche and regime factors were operationalized which can differ on the city level to explain the spatial differences in niche developments and regime interactions. A quantitative research method was applied, using a negative binomial regression model, to test the influence of these city level variables on the number of shared cars.

Cities where the regime of personal car ownership and use is less established, indicated by a larger share of trips taken by public transport and a historic city center less suitable for car use shows to lead to more shared P2P cars. User innovativeness, indicated by younger age (24-35yrs) and a higher level of education showed to be beneficial for the growth of the niche of P2P car-sharing. A higher percentage of one-person households also leads to more shared P2P cars. Also the presence of a lot of platform actors within a city showed to be associated with a high number of shared P2P cars.

This study also showed that population density did not significantly influences the number of shared cars, indicating that P2P car-sharing might be a more feasible alternative to "traditional" Business-to-consumer car-sharing in less densely populated places. Also, this study showed that protected niche markets. Indicated by a university city or international city are less important to P2P car-sharing, indicating that the supply of P2P cars is less demand driven. It is suggested that the supply of P2P car-sharing is more focused around a personal decision to share a car on a P2P platform. Further research could identify the reasoning behind this personal decision.

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1 Introduction

The last decade, traffic in urban areas is recognized as increasingly causing problems of road congestion and local air pollution (Schrank, 2008; Shefer, 1994). Road congestion in Europe is estimated to cost the European economy nearly 100 billion Euros (1% of EU GDP) annually (European Commision, 2011). Besides economic costs, urban traffic is also found to cause health related issues. Traffic related air pollution is found to be associated with respiratory symptoms among other health issues (J. J. Kim et al., 2004). It is also suggested that Land traffic emissions are responsible for about one-fifth of premature mortality linked to outdoor air pollution in Germany, The UK and the USA (Lelieveld, Evans, Fnais, Giannadaki, & Pozzer, 2015). With the expectation that 85% of the projected world population in 2100 will live in urban areas (OECD, 2015) and with the US and EU populations already reaching these percentages of urbanization (Banister, 2011; OECD, 2015) there is a strong need for a more sustainable form of transport in urban areas.

Private car ownership is found to be the main contributor of CO2 emissions of transport in metropolitan areas (Brown, Southworth, & Sarzynski, 2009; Sovacool & Brown, 2010). Reducing private car use thus holds the promise of reducing Green House Gas (GHG) emissions while also contributing to less traffic congestion. Over the last years several alternatives to private car ownership have emerged (Botsman & Rogers, 2010). One of these alternatives is car-sharing.

Car-sharing, defined as a system that allows people to rent locally available cars at any time and for any duration (Frenken, 2014), holds the promise to reduce the number of vehicles on the road. Studies show ranges of seven to thirteen cars either disposed or not purchased per added shared vehicle (Loose, 2010; E. Martin, Shaheen, & Lidicker, 2010). The average amount of vehicle kilometers travelled was also found to decline by 27% in North America (E. Martin & Shaheen, 2011).

With the first car-sharing initiative emerging in Switzerland in 1948, the number of shared cars is increasing globally throughout the years (Shaheen, Sperling, & Wagner, 1998). Already in 2007 car-sharing platforms were operating in over 600 cities worldwide, with an estimated amount of 11,700 shared cars of which more than 60% were stationed in Europe (Shaheen & Cohen, 2008). However car-sharing has proven quite successful in some places, in other places it has stagnated and the car-sharing operators (CSO) were closed down (Celsor & Millard-Ball, 2007; Shaheen & Cohen, 2008). While car-sharing succeeds in for example Switzerland, other attempts failed to succeed which raises the question of which factors lead to the success of car-sharing initiatives.

Not only differences are seen between the growth of car-sharing between places, but also in business models. Although other delineations can be made, for the purpose of this paper a division is made between the Business-to-consumer (B2C) model and the Peer-to-peer (P2P) model. Even though it does not guarantee success, Business to consumer platforms often use thresholds of indicators like population density before expanding to a particular city (Celsor & Millard-Ball, 2007). A B2C CSO, which owns its own fleet of cars, has to reach a certain level of demand to cover the costs of fleet maintenance and to be profitable in a certain city. This indicates that in the B2C business model, the offer of shared cars in a city is mostly demand driven.

However, P2P car-sharing, which are individual car owners who rent out their own car supported by an internet service (Frenken, 2014), is less straightforward. In this case it is the individual car owner which makes the decision to offer the car on a car-sharing platform. This decision might be besides being based on monetary reasons, also be influenced by other factors like the willingness to share underused assets or environmental values (Ballús-Armet, Shaheen, Clonts, & Weinzimmer, 2014).

With P2P car-sharing in the Netherlands being the fastest growing in number of shared cars and accounting for about half of all cars used for car-sharing (KvPP, 2013), it has a significant share in the overall growth of car-sharing. It is however unknown which factors explain this growth of P2P car-sharing. This leads us to the following research question:

What explains the differential growth of peer-to-peer car-sharing in cities?

Surveys and interviews with users of car-sharing platforms tried to identify characteristics of participants on car-sharing platforms. Participants tend to be younger and more highly educated (Loose, 2010; Prettenthaler & Steininger, 1999; Shaheen et al., 1998). Mixed results are found on the influence of level of income and amount of persons per household (Coll, Vandersmissen, & Thériault, 2014; Prettenthaler & Steininger, 1999; Shaheen et al., 1998). Other studies suggests that factors like population density, parking availability, or the presence of a university play a significant role in the success of car-sharing (Celsor & Millard-Ball, 2007; Enoch & Taylor, 2006; Shaheen & Cohen, 2013). However, most of these studies deal with the "traditional" B2C model and the research efforts on P2P car-sharing tend to be rather limited. Also there are no studies that gathered city level statistical evidence on both the socio-demographic and city characteristics to explain the spatially differential growth of car-sharing.

The aim of this study is twofold. First of all, an overview will be given on the state of P2P car-sharing on the city level in the countries United Kingdom, France, The Netherlands, Germany, and Belgium showing the differential growth in P2P car-sharing between cities. Second of all, using a multilevel perspective, this study aims to show spatial differences in car-sharing niche interactions with the regime of personal car ownership and use. Using a negative binomial regression model this study shows which city level characteristics influence the differential growth of P2P car-sharing.

With the potential of reducing the amount of vehicles on the road and the amount of kilometers driven (Loose, 2010; E. Martin et al., 2010), car-sharing could be a more sustainable alternative for urban transport. Understanding what explains the success of car-sharing helps local government in decision-making when they aim to stimulate P2P car-sharing. For the facilitating P2P CSOs, this research could help in consumer understanding and finding new successful target markets.

From a theoretical perspective, this study demonstrates empirically the usefulness and importance of a better defined spatial perspective in the Multi-level perspective (MLP) literature building on previous critique that the MLP literature is spatially naïve (Smith, Voß, & Grin, 2010). By taking a stronger spatial perspective, this study demonstrates the spatial differences in the growth of the car-sharing niche in cities confirming the importance of a spatial perspective in niche developments (Sengers & Raven, 2015), and improves our understanding of P2P car-sharing by showing which city level factors influence the growth.

First of all, the theoretical background will be discussed and applied to the case of P2P car-sharing. Then the discussed concepts are operationalized after which the methodology of data collection and modelling will be explained. Finally, the results of the negative binomial regression model will be presented followed by a critical discussion of the results and implications of this study. Finally, the conclusions will be summarized.

2 Theoretical background

One of the central themes in innovation literature is that innovation is not a linear process as once thought, but that it is an uncertain process in a wider complex social and institutional structure (Dosi, Freeman, Nelson, Silverberg, & Soete, 1988; Nelson & Winter, 1977). That not only technology, but also economics, politics and general culture explain the occurrence of innovation has led to a more systemic view on innovation (Freeman, 1995).

From an evolutionary perspective, Nelson & Winter (1977) argue that innovation follows natural trajectories based on previous knowledge while then the fate of an innovation is determined by a 'selection environment' consisting not only of users and markets but where policies and institutions also play a role. Variations in these 'selection environments', can affect the speed and extend of the spread of an innovation (Nelson & Winter, 1977)

In light of technological transitions, the concept of 'socio-technical configurations' builds on this notion of a 'selection environment'. An alignment of linked heterogeneous elements that fulfill a certain function make up a socio-technical configuration that forms a stable environment. New technologies or practices often face a mismatch with such a configuration which could hamper it from further spreading (Geels, 2002).

The Multi-Level Perspective (MLP) offers a view on technological transitions in which a radical innovation is protected from the 'normal market' and selection environment in a niche on the micro-level. Existing technologies, markets, user practices, sectoral policy, techno-scientific knowledge, industrial network/strategy, culture, symbolic meaning and infrastructure make up the current regime at the meso level. The macro-level accounts for external landscape pressures. The micro- and macro-level both interact with the meso-level and can change the stability and its practices. As demonstrated in Figure 1 tensions in the regime and landscape shifts can make an innovation break out of a niche and transition into the new dominant practice (Geels, 2002).

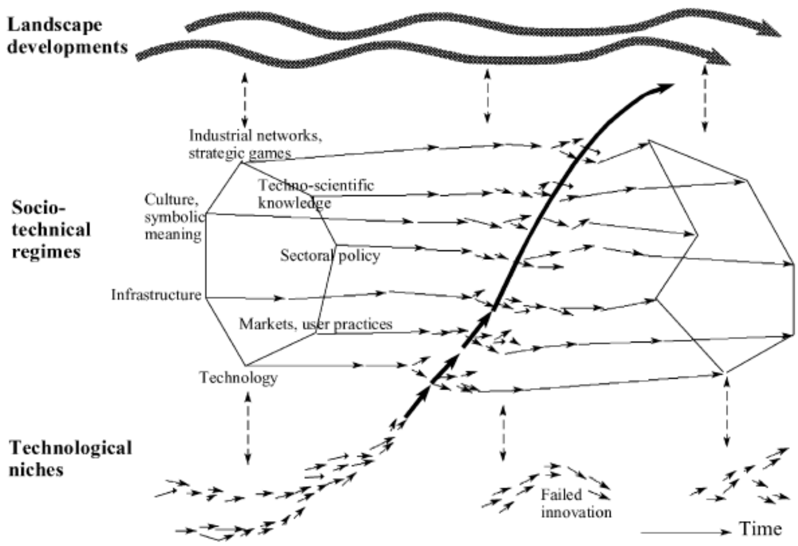

Figure 1: Dynamic Multi-Level Perspective (Source: Geels, 2002)

The MLP literature offers a straightforward framework for arranging and contextualizing transition processes but has been criticized to be oversimplifying and lacking an explicit geographical indication (Smith et al., 2010). Without a more spatially sensitive perspective on transitions there is a risk of failing to recognize why transformative instances of institutional, entrepreneurial and innovative interactions occur at a certain location while not at others (Coenen & Truffer, 2012). Other studies also recognize this issue and stress the importance of local activities in regional transitions

(Späth & Rohracher, 2010) and more explicitly how transitions occur in urban context (Hodson & Marvin, 2010).

Drawing on economic geography literature, Coenen et al., (2012) work towards a more explicit spatial perspective in transition literature. The territorial embeddedness of institutional arrangements in cities or regions could explain regional differences in niche developments. These different geographical scales are again interrelated through actor's relationships and connections within networks across these scales. They thus conceptualize transitions as interdependent processes between territorialized, local and trans-local networks within the context of multi-scalar institutional structures (Coenen, Benneworth, & Truffer, 2012).

Sengers & Raven (2015) also respond to the critique that transition studies are spatially naïve by introducing a complementary spatial perspective on niche development stressing the importance of the spatiality of the production and transfer of knowledge, the geographies of actor networks involved, and the dynamics of embeddedness by which global networks are entangled with place-specific institutions and infrastructures (Sengers & Raven, 2015).

How the niche interacts with the regime could thus differ spatially, explaining the differential spreading or adoption of innovation. By getting insight in the socio-technical configuration on the city level this study reveals the differential growth of car-sharing between cities. The next paragraph discusses car-sharing developed as a niche within the context of the current sociotechnical configuration of private car ownership and use, while taking spatial differences on city and national level into account.

2.1 Transition of car-sharing

Although car-sharing is a growing phenomenon, it is still in its early phases of development and not even close of being a dominant practice of mobility. Private car ownership and use can be seen as the current regime with which car-sharing competes. However, the extent to which car-sharing actually competes to the current regime should be nuanced. Car-sharing, either B2C or P2P, builds on the same infrastructure as the regime of personal car ownership and use. Infrastructure like good roads which favor car ownership might also be beneficial for car-sharing (Frenken, 2014). Car-sharing providers can be classified in a number of service types and business models (Barth & Shaheen, 2002). For the purpose of this paper, and to better understand the transition towards car-sharing, a delineation will be made between the two main types of car-sharing.

The most familiar form of car-sharing, and the form which has had most attention in the literature is the business to consumer (B2C) model, also called "traditional" car-sharing. It is defined as a for-profit or nonprofit car-sharing organization (CSO) that provides vehicle access on an hourly or daily basis to its members (Ballús-Armet et al., 2014). In this case it is a firm owning a fleet of cars that are spread out throughout a certain area, which are available at all times, depending on availability, for their members. Although variants on this business model exist, B2C cars are typically located on dedicated parking spots in a city. Whether or not a firm decides to place a car on a certain location will mostly be based on the level of demand the firm expects based on certain criteria. (Celsor & Millard-Ball, 2007).

The P2P car-sharing model differs in many respects to the "traditional" B2C CSO's. P2P car-sharing are individual car owners who rent out their own car supported by an internet service (Frenken, 2014). In this case it is the private vehicle owner who decides to offer the car on a certain location. The P2P CSO does not own the vehicle, but typically facilitates the rental by providing insurance and connecting the vehicle owner with renters, in exchange for a portion of the usage fee (Ballús-Armet et al., 2014). P2P car-sharing is therefore part of a larger phenomenon, which is called the sharing economy. The sharing economy can be defined as "consumers or firms granting each other temporary access to their underutilized physical assets (idle capacity), possibly for money" (Meelen & Frenken, 2015). The B2C car-sharing providers do not necessarily fit this definition since they own a fleet of cars with the main purpose of renting them out to consumers. In this sense, these cars are thus not "underutilized" since during times that they are not rented out, they are there to provide a service of having enough availability of cars for the consumers. Privately owned cars, when not used for personal transportation, can be defined as "underutilized". When shared on a P2P platform, these cars become available to other members, reducing their underutilization.

Having a clearer definition of the main types of car-sharing, the transition towards P2P car-sharing, which is the focus of this research, can be better assessed. With P2P car-sharing, there might be a strong link to the current regime of private car ownership and use. Personal car ownership is namely a requisite to choose to share a car on a car-sharing platform. This suggests that P2P car-sharing is more complementary to the current regime of private car ownership and use than for example B2C models. Building on the large amount of already privately owned vehicles might make P2P car-sharing also more scalable to remote places and smaller cities where a B2C platform cannot reach a sufficient level of utilization of their car fleet. However, P2P car-sharing might also have some disadvantages. When sharing a car, you lose the comfort of having a car at your disposal at all times. Also, a car seen as a status symbol or a reflection of ones identity (Belk, 1988) might make people reluctant to share their own car.

The MLP literature suggests that when pressure occurs on the regime, this might form opportunities for the regime to be overthrown by a niche-practice or to reconfigure the regime and steer it in a different direction (Geels & Schot, 2007; Geels, 2002). The similarities between the niche practices and regime practices described above, suggest that it is unlikely that there is a need for the niche of P2P car-sharing to overthrow the regime. It is more likely that the regime will undergo a transformation pathway in which the viability of car-sharing proven in a niche will change the perception of regime insiders leading to a reorientation of their activities (Geels & Schot, 2007). While a large part of the socio-technical configuration of personal car ownership and use can stay intact, the empowerment of the niche of P2P car-sharing can result in a process of where car-sharing practices will be become institutionalized as new norms and routines in a stretched and transformed regime (Smith & Raven, 2012).

2.2 Measuring the transition:

To measure the described transition process to P2P car-sharing practices, the number of shared cars can be identified to assess the state of car-sharing within a certain area. However, as argued above, people offering cars and people renting out cars is less closely linked than in the case of "traditional" B2C car-sharing. The offer of shared cars is thus expected to be less demand driven. Also, the average number of times a P2P shared car is actually rented out remains uncertain. In the Netherlands the CSO "Wego" reports that a vehicle shared on their site is on average rented out 3.5 times a month (Glimmerveen, 2015). There is however no peer-reviewed research backing up this number, and if other platforms have a sort like usage rate remains unclear.

The number of shared P2P cars thus does not reflect the use of car-sharing in a city. It does however reflect the number of people within a city who are willing to share their private car on a P2P car-sharing platform, and thus can be used as a measure for the number of people who are willing to move away from the regime of private car use by sharing their personal vehicle with others.

As argued, how well the niche is developed can differ spatially leading to a difference in the number of shared P2P cars. Also the pressure on the regime can differ spatially depending on how well the regime is established. Landscape pressures and the regime of car ownership are discussed below, followed by niche developments of P2P car-sharing.

2.2.1 Landscape pressures

The recent economic crisis has directly affected a lot of people worldwide. In need of reevaluating their budget, they might seek for an alternative for car ownership, or a way to make owning a car less costly. Either way, it creates pressure on the regime of private car ownership and use. The economic crisis is however not the only landscape pressure. Within the context of human induced climate change, pressure is set on finding more sustainable alternatives for the way we produce and use resources. With personal transportation being a large contributor of emissions

(Brown et al., 2009; Sovacool & Brown, 2010) there is a strong need for alternatives putting a pressure on the current regime of car ownership and use in cities in general. These Landscape pressures, seen as an external structure or context (Geels, 2002) are assumed to be felt evenly across geographical boundaries.

2.2.2 Regime pressures

How well the regime of personal transportation functions can differ spatially. The socio-technical regime functions as a selection and retention mechanism (Geels, 2002). How well the regime is established and how much pressure there is on the regime could influence the stability of the regime. If the regime is unstable, this can open up "windows of opportunity" for a niche to break through (see Figure 1) (Geels & Schot, 2007; Geels, 2002). How the regime is established and how well it fits with the niche developments could explain the ease of the transition. Below, the relevant concepts that can differ spatially are discussed related to the regime of personal transportation and car ownership on the national level and city level.

Costs of car ownership and car use:

One of the factors that can put pressure on the regime of personal transportation and car ownership is the costs of owning and using a car. When costs are high, people might be more eager to find alternatives for the car, like public transport, walking/cycling, or car-sharing. Costs of car ownership are often regulated on the national level. Taxes on buying a car for example differ mostly per country (Zahedi & Oliver, 2012). The costs of car ownership could thus differ spatially indicating differences in pressure on the regime.

When the costs of car ownership are high, people might look for an alternative which could increase the demand for car-sharing which is seen as a cheaper alternative (Duncan, 2011). For car owners, the high costs of ownership might be an incentive for looking for a way to make owning a car more affordable. Renting out a car on a P2P platform might be a way of doing just that. It is therefore expected that when the costs of car ownership are high, cities will have more P2P shared cars.

A similar relationship is expected for car use. The tax on fuel for example differs per country, resulting in varying costs per travelled kilometer. High taxes suggest pressure on the regime by governments wanting to reduce car use. When car use is expensive people might look for an alternative for the gross of their trips, making their car underutilization even bigger. High parking costs increasing the costs of car use in for example city centers might also lead to a switch to alternative means of transportation. People who still choose to own a car for occasional trips might be more willing to share their car if they do not use it daily. It is therefore expected that if the costs of car use are high, cities will have more P2P shared cars.

Car Ownership:

Costs of a car are not the only factor influencing car ownership. It goes beyond the scope of this study to explain motives for car ownership, but the amount of owned cars could however be an indicator of how well the regime of personal car use is established. When less cars are owned, the weaker the regime of car ownership, which might be beneficial for car-sharing in general. A study on car-sharing, analyzing geographical market segments in urban areas agrees with this expectation. Celsor & Millard-Ball (2007) showed that low vehicle ownership has the strongest and most consistent correlation to the number of car-sharing services in a neighborhood (Celsor & Millard-Ball, 2007). Also, car-sharing participants in Europe tend to own fewer cars than the population average (Loose, 2010; Prettenthaler & Steininger, 1999). Ciari, Balmer & Axhausen (2009) suggests that changes in car ownership are not simply related to participation on a car-sharing platform, but are often triggered by a personal event like divorce, moving, or changes of employment (Ciari, Balmer, & Axhausen, 2009).

The relationship between car ownership and the number of shared cars is thus questionable. In the case of P2P car-sharing this relationship is even less clear since vehicle ownership is a necessity to have a shared P2P car. If more people own a car in a specific city, purely by chance, it is expected that more people participate on a P2P car-sharing platform. But, if more people own a car, this also indicates a high presence of the regime of car ownership and it lowers the demand for shared cars, since people own one themselves.

However, when car ownership is low, this indicates a weak presence of the regime and might increase the demand for shared cars since most people do not have one, making the people that do own a car more willing to participate since they can generate more income if demand is higher. It is therefore expected that when car ownership is relatively low, more P2P shared cars are found due to the higher demand, although this relationship might be less visible.

Public transport / model split:

Another factor indicating the strength of the regime of personal car use might be that of the availability of public transport (PT). It is suggested that if an automobile is absolutely necessary for either work or non-work trips, then the household is likely to own a vehicle (E. Martin et al., 2010). When for example public transport is not easily accessible, people are more dependent on other ways of mobility like a private car and the regime will be strongly established. When people only need their car for some occasional trips, there is a lot of idle capacity for the cars, which might lead to people sharing their cars on P2P platforms. If within a city, more trips are taken by public transport compared to private cars, indicating a weak presence of the regime, it is expected that more cars will be shared in a city.

Population Density:

In a study on adoption intention of portable internet services, Kim & Jee (2006) showed that living in a metropolitan area positively influences adoption. This suggests that in the general adoption of innovation, population density could play a role. Also in the case of car-sharing, one third of customers tend to live in the city center, and half in densely build neighborhoods while only 5% of customers come from peripheral neighborhoods (Loose, 2010). Also, it is found that in cities with higher density, less kilometers are travelled by car (van de Coevering & Schwanen, 2006). This could be explained by lesser dependence on a personal car, since in densely build environments, all the necessities are closer by which makes a car necessary only occasionally. It is therefore argued that cities with higher population density will have a higher amount of P2P shared cars.

Historical city:

It is suggested that the characters of the built environment of a city, commonly called the urban form, is an important determinant of travel patterns (Schwanen, 2002). Where some cities are more favorable for public transport, others might favor walking and cycling due to the close commuting distance. The share of public transport for example becomes larger when the resident population is more strongly concentrated in the inner areas of a metropolitan area (van de Coevering & Schwanen, 2006). These areas came into existence prior to the Second World War and tend to be less orientated towards car use and more towards walking/cycling or public transport.

Van de Coeveringen & Schwanen (2006) argue that the part of the city built prior to the Second World War appears to be more directly associated with travel patterns than metropolitan-wide population density. Also, shared vehicles tend to be located in older, historic neighborhoods, which are likely to be more walkable and have less on-street parking (Celsor & Millard-Ball, 2007). It is therefore argued that in cities with a historic city center, the regime of car ownership is less established and more P2P shared cars will be found.

2.2.3 Niche developments

If the regime is less established or when there is more pressure on the regime, the niche of car-sharing might grow more easily. How well the niche is developed however, could also affect the interaction with the regime. Niches are often seen as protective spaces insulated from normal market selection in the regime and act as incubation rooms for radical novelties (Geels, 2002; Schot, 1998).

Smith & Raven (2012) add to this, in the context of sustainable transitions, that initial niches can be passive spaces where the selection pressures are felt less keenly for contingent rather than strategic reasons. As an example, an environmentalist milieu with different cultural values of whose members are willing to trade off performance on conventional terms on something performing better on environmental terms or is deemed more socially just. They also add to the shielding and nurturing of a niche the role of empowerment, to make niche innovations competitive with an either changed or unchanged selection environment (Smith & Raven, 2012).

From this theory it is argued that you need user groups, either through being *innovative*, or through *environmental and cultural values* to support a niche. Protective spaces, either through *niche markets* or *supporting policy,* could also help the niche to develop. Finally, the activities of *platform actors* across different scales for empowerment are discussed to capture more of the spatial differences.

2.2.3.1 User innovativeness

Possession of a car can be seen as a major contributor to and a reflection of a person's identity (Belk, 1988), making people reluctant to share. Deciding to contribute to a car-sharing platform thus requires willingness to trade off the feeling and ease of having an own car at all times, for being more sustainable, or as an extra source of income. Whichever motivation is at stake, adopting a new innovation or practice depends on the innovativeness of a user.

Rogers (2003) described the degree of innovativeness to which an individual is relatively early in adopting new ideas and practices than other members of a system. Although no different in age, he argued that early adopters generally have more years of formal education, and have a higher level of income or wealth (Rogers, 2003). Based on previous research on car-sharing and adoption of innovation, factors that are expected to influence the development of the niche of P2P car-sharing are discussed below.

Age:

Although Rogers (2003) argued that age does not influence the general level of innovativeness, adoption studies of more technological innovations show other results. In a study of the adoption of broadband internet in the UK, Dwivedi & Lal (2007) found a negative correlation between age and broadband internet adoption in line with previous anecdotal evidence. Also in other technological innovations like personal computing and even the adoption of solar panels, adopters tend to be younger than non-adopters (Labay & Kinnear, 1981; Lin, 1998).

Car-sharing is generally facilitated by an online platform, making it a technological innovation. Therefore, it is expected that the age of adopters will be lower than that of non-adopters. In previous surveys conducted among customers of car-sharing services in Europe, customers are found to be, for the most part between 26 and 49 years old (Loose, 2010). In Austria even 85% of participants were found to belong to the age group of 25 till 44 years (Prettenthaler & Steininger, 1999). In line with this research it is expected that in areas with a larger amount of people in this age group, car-sharing will be more successful.

Educational level:

Rogers (2003) argued that early adopters tend to have more years of formal education. Adoption studies on technological innovations like the adoption of (broadband) internet, and personal computers support this argument and show a correlation between level of education and adoption (Dwivedi & Lal, 2007; Kim & Jee, 2006; Lin, 1998). Also in a cross-country study on digitalization level, educational level is found as an explanatory factor (Billon, Marco, & Lera-Lopez, 2009).

In a study on the adoption of alternative fuel vehicles in Sweden, adopters were also found to be higher educated (Jansson, Marell, & Nordlund, 2010). Studies about memberships of car-sharing platforms also showed that members tend to be more highly educated (Coll et al., 2014; Loose, 2010;

Prettenthaler & Steininger, 1999). It is therefore argued that in cities with more people of a higher educational level, more shared cars are found.

Persons per household:

In a study on the adoption of alternative fuel vehicles in Sweden (like electric/hydrogen) Jannson et al. (2010) showed that multi-person households are more likely to adopt such a vehicle (Jansson et al., 2010). A study on car-sharing membership potential showed also a relation with the presence of children increasing the likelihood of being a member (Coll et al., 2014). However, the firm they studied offered children seats in their car fleet.

Other studies showed that one-person households are far more common in car-sharing neighborhoods (Celsor & Millard-Ball, 2007). A study on car-sharing in the Netherlands, which also takes P2P car-sharing into account, agreed with these findings (Meelen, Hobrink, & Frenken, Forthcoming). It is therefore suggested that cities with more one-person households have more shared P2P cars.

2.2.3.2 Environmental values and practices of inhabitants

Although demographics are used to explain adoption of numerous innovations as illustrated above, not all studies agree on the usefulness when dealing with 'green' practices and innovations. Peattie (2001) describes the 'green consumer mystery' in which trying to identify and segment green consumers on factors such as age, sex, income, and level of education produced inconclusive and contradictory results. Demographic factors are found to be less significant in the adoption of environmentally friendly products when compared to environmental concerns and situational factors (Bhate & Lawler, 1997). The presence of an environmentalist milieu with different cultural values might also provide a form of "passive shielding" of a certain niche practice (Smith & Raven, 2012). This stresses the importance of environmental values and practices.

Environmental awareness:

A study on Zipcar users located in Boston did not find any environmental reasons for users to join the car-sharing platform, but showed mostly monetary reasoning (Bardhi & Eckhardt, 2012). This could be different in the case of P2P car-sharing where the person offering the car already bears the full costs of the car while income of renting out could prove quite minimal if the car is not rented out that often. In a study in the Netherlands, where P2P car-sharing was also taken into account, environmental awareness proved to be positively related to the amount of shared cars (Meelen, Hobrink & Frenken, Forthcoming). It is thus expected that environmental awareness is positively related to the number of shared cars.

Other shared mobility:

Knowledge of a practice or product is often seen as an essential part in the adoption process (Rogers, 2003). Also in the adoption of green energy, knowledge is shown to be an important variable (Arkesteijn & Oerlemans, 2005). People might have more knowledge of car-sharing when they are also familiar with other sharing practices. Having experience with for example other forms of shared mobility, like bike sharing, might make people more likely to also share their car. Cities with activities on other sharing platforms might thus have more shared P2P cars.

Trust:

Another factor that could influence the decision to participate in car-sharing is trust. Since sharing tends to be a communal act that links us to other people, sharing goes hand in hand with trust (Belk, 2010). Online P2P platforms realize this and try to build trust through online ratings and testimonials (Belk, 2014; Cohen & Sundararajan, 2015). Other ways to establish trust is through verification through identification mend to provide information access and to decrease uncertainty (Hamari, Sjöklint, & Ukkonen, 2015; Wosskow, 2014). In a survey among car owners trust was also mentioned to be important. In the San Francisco bay area, half of the respondents mentioned a lack of trust in others in regards to their personal belongings as a reason to not participate in P2P car-sharing (Ballús-Armet et al., 2014).

While a platform can put efforts in trying to establish trust, social cohesion and trust in neighbors might also be important for P2P car-sharing. Crime rates and lack of social cohesion in neighborhoods were found to be related (Kawachi, Kennedy, & Wilkinson, 1999). Low crime rates might therefore indicate high social cohesion and trust, especially in victim-based crimes like theft. It is therefore expected that low vehicle theft within a certain city will result in supportive condition for the niche of car-sharing, leading to more P2P shared cars.

2.2.3.3 Protective market spaces

Niches are often seen as protective spaces isolated from normal markets in the regime and act as incubation rooms for radical novelties (Geels, 2002; Schot, 1998). Markets where private car ownership is less suitable thus form a group which can lead to more demand for car-sharing. Although the influence is expected to be low, to see how strong demand factors influence the number of shared P2P cars, potential market niches are described below.

International city:

Tourists could form a unique customer group since they often have no car available. Another group that might take the effort of applying are expats. People that temporarily live in a city might not buy a car due to the hassle of car ownership for such a short time. Registering for a car-sharing platform might be a solution for their mobility needs. It is therefore argued that international cities have a higher demand for shared cars, which could increase the amount of shared P2P cars if this demand id noticed by car owners.

University city:

Especially in North-America, car-sharing has expanded to suburban areas deployed at major colleges and universities (Shaheen & Cohen, 2013). The campus structure often deployed there have made students a perfect target group for offering car-sharing as a form of mobility to the cities close by. In Europe, this campus structure is less present since Universities are often located within city centers or at least easily reachable by public transport.

However, a city with a large population of students could form a user group that generally does not own a car either because they cannot afford to own one, or only need one occasionally. Combined with the assumption of smartness of this group, it could form an important user group of car-sharing. It is therefore expected that if there is a large student population, this creates a niche market stimulating demand for shared cars. If this demand is noticed this can then lead to more people sharing their car on a P2P platform.

2.2.3.4 Supporting policy

Government can play a role in providing information, managing social acceptance of different technologies, and supporting vulnerable technologies that require long term development (Kemp, 1994). Since governments on different levels (national, municipal) can have different policies, how policy influences car-sharing can differ spatially.

Sectoral policy:

In the case of car-sharing a lack of government support is seen as a barrier in the success of car-sharing initiatives (Enoch & Taylor, 2006). Another study found that policy, especially parking, does influence adoption of traditional car-sharing but not that from P2P car-sharing (Meelen, Hobrink & Frenken, Forthcoming). They argue that since P2P car-sharing does not require dedicated parking spots, it is less dependent on parking policy. However, policy stimulating B2C car-sharing could in turn contribute to the knowledge of the general concept of car-sharing, which in turn could increase the number of P2P shared cars. It is therefore expected that if there is dedicated sectoral policy present in the city, more shared P2P cars are seen.

2.2.3.5 Activities of platform actors

Coenen et al. (2012) argue that scales are actively constructed through socio-spatial struggles by actors seeking to achieve their goals. An actor seeking to achieve their goals thus also interact outside city boundaries.

Market concentration:

P2P car-sharing is not the only business model used. The B2C models, which is studied separately as part of this research project, also exist. Efforts to promote B2C platforms could increase the visibility of car-sharing altogether. Since visibility helps by spreading knowledge of the innovation it could increase the rate of adoption of car-sharing (Rogers, 2003). Since markets are geographically delineated, typically through municipality boundaries (Frenken, 2013), the activities within a market could differ spatially. A lot of activity of niche actors could increase the knowledge base, and change cultural values in favor of the niche-practice which in turn opens up new markets (Smith & Raven, 2012). It is therefore expected that when there is a high number of B2C shared cars, the number of P2P cars will also be higher. If there are a lot of CSOs active in a city, either P2P or B2C, the number of P2P cars is also expected to be higher.

3 Methodology

From theory, expectations are derived of the influence of the discussed independent variables on the dependent variable, the number of P2P shared cars. To test these expectations a quantitative research method is chosen to test the relationship between the independent variable and the dependent variable, the number of P2P shared cars. The level of analysis will be the city level to explain the expected spatial differences in the growth of car-sharing.

3.1 City definition

This research aims to explain the differential growth of P2P car-sharing in European cities. However, the definition of a “city” is not the same in each country. Where in some countries the municipal borders define the city, in other countries multiple municipalities make up the densely populated area that acts like one city.

The European Union defines “Nomenclature of Territorial Units for Statistics” (NUTS) regions of which NUTS3 is the most detailed level of analysis (Eurostat, 2015). However, the NUTS system built on older, country specific, territorial units and is not consistent across borders (Bettencourt & Lobo, 2015). The lack of a harmonized definition of a city undermines comparability, and thus the credibility of cross-country city analysis (European Commision, 2012). As a response to this issue, a harmonized city definition was created by the OECD and European commission to solve the comparability issues. To ensure comparability in this cross-country city level analysis, this city definition was chosen as most appropriate. This OECD-EC city definition defines a city based on high density population grid cells of one square kilometer (European Commision, 2012; OECD, 2012) (See Figure 2):

- First, all grid cells with a density of more than 1500 people per square km are selected.
- The contiguous cells with a high density are then clustered and caps are filled. Clusters with a minimum of 50 000 inhabitants are seen as an urban center.
- All municipalities with at least half of their population inside the urban center are selected to become part of the city.
- Finally, the city is defined ensuring that there is a link on the political level, that half of the city population lives in the urban center, and that 75% of the population of the urban center lives in a city.

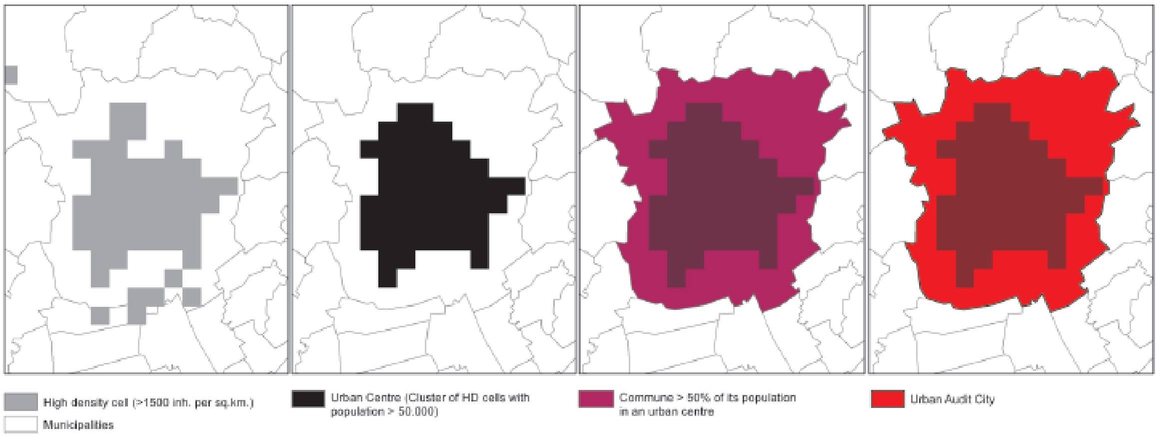

Figure 2: City definition OECD-EC (Source: European Commission, 2012)

For some cities, also "greater cities" are defined. These are cities with urban centers stretching far beyond the municipal borders (European Commision, 2012). Since the aim is to define the city as the zone that acts as one urban center, the greater city is taken rather than the city when there is a greater city present.

3.2 Sample selection:

From a population of all European cities, a sample is selected based on a few criteria. First, the city must lie in one of the following countries: United Kingdom (UK), The Netherlands (NL), France (FR), Germany (DE), and Belgium (BE). Second, the city must have more than 150,000 inhabitants based on the latest census. The first selection is to ensure a comparable geographical cluster of countries. The second selection is made to ensure a manageable sample size for which also a OECD-EC city definition exists to ensure data availability on this unit of analysis. This sample selection resulted in a selection of 177 cities within the territorial boundaries of the specified countries. The full list of cities and greater cities and their respective population is attached in Appendix A.

3.3 Operationalization and data collection

In the theory section, the relevant concepts and their relation towards the dependent variable are discussed. In this section, the concepts are translated in measurable variables and the sources for data collection are discussed.

3.3.1 Number of shared P2P cars

A list of car-sharing platforms was identified by an extensive internet search using key words related to car-sharing for each country. This resulted in a list of eighteen CSO's offering shared cars under the P2P business model. From these websites, the number of shared cars were collected. Since every platform displays its data in a different way, the data cannot be collected in the same manner for each website. The following steps were taken to collect the data to gather the highest level of detail as efficient as possible:

- When map views and list views were visible on the website. The data was mined through the "json" text. How this data is provided depends on the database structure used by the website. This means that the data needs to be extracted in a unique way for each website. When it is possible to download the "json" text files this is preferred, since this level of data often results in more detailed data. All the raw data files were kept in an accessible manner.
- If it was not possible to scrape the data as described above, the search tools of the sites were used to gather the number of cars per city when the search engine was openly accessible on the website.
- If it was not possible to gather the exact number of cars through a search, the cars were counted on the map when a map view was available.
- Some websites did not offer an overview of the cars they provided within cities. These CSO's were contacted directly to ask for the total number of shared cars per city provided by their platform.

Using these steps, data was collected for all identified car-sharing platforms leading to a complete overview of shared cars per city. The data was collected during the period November 2015 and January 2016. Most websites allowed searching the full database without specifying a date. In this way, all shared cares could be identified regardless of the fact that they are either not shared at a certain time, or that they are unavailable due to the fact that they are already booked. To ensure that the data collection resulted in a stable number of shared cars, the data collection was repeated for a small fraction of the cities at different times. No large differences were found between times of search leading to a stable and consistent number of shared cars.

3.3.2 Independent variables

The concepts that are argued to have an influence on the number of shared cars were operationalized to measurable variables based on their relevance to the concepts and data availability. While some data was collectable through statistics offices (either national or European), other variables had to be constructed based on own research to reflect the relevant concept. For all national and city level concepts that are found to be theoretically relevant, below is described how these are operationalized. How the concepts from theory are operationalized and how the data is collected for each variable is then summarized in Table 1.

3.3.2.1 Regime factors

Costs of car ownership and car use:

Costs of car ownership are generally organized at the national level. Taxes are set on purchasing and generally an annual fee is required to maintain registration on the car and use the open road. Zahedi & Oliver (2012) calculated the registration and circulation (road) tax for various European countries. Since the costs differ per vehicle type, a standard vehicle was used to calculate the costs. They used a four door 2011 Ford Fiesta with an engine capacity of 1.6 liter, which is a quite common vehicle type on the European roads. This led to the price in Euros for registration and circulation of a car on a national level.

Besides the costs of car ownership, driving a car also brings on variable costs like buying gasoline. Since tax on gasoline is also mostly set on the national level, gas prices could differ per country. Eurostat provides data on the price of gasoline to the consumer at the pump. For the variable costs of car use, the price of EURO 95 fuel at the pump (Euro/liter) is taken for the national level.

Since these factors only differ on the national level, the data will not be used for the city level analysis aimed for in this research. Instead a country variable will be taken into account to control for national differences such like these.

Car ownership:

For the city level variables, the aim was to collect the data using the same city definition as taken for the dependent variable. Eurostat collects and harmonizes data on the city level in the urban audit database, which adheres to the same city definition set by the European commission and the OECD. This database was used as the main source of data collection for the independent variables.

Data on car ownership was collected from this Urban audit database from Eurostat. The number of privately registered cars per city was taken to control for the variation in total number of cars per city. The total number of registered cars was divided by the number of inhabitants, also collected from the urban audit database, to get to a number of registered cars per capita as a measure of car ownership.

Public transport / model split

To measure the share of public transport in a city, the percentage of trips to work taken by public transport are taken as an indicator for the use of public transport within a city. The Urban audit database from Eurostat provided data on the percentage of trips to work per type of transportation for France, Belgium, UK, and Germany. For The Netherlands, the database contained no data. Data from the yearly conducted survey on means of transport in the Netherlands (OViN) is taken to complete the data on the use of public transport.

Population density:

When data was not available in the Urban Audit data, national statistics offices were used to collect additional data. The “Office of National Statistics” (ONS) for the UK, “Statistics Belgium” for Belgium, “Centraal Bureau voor de Statistiek” (CBS) for The Netherlands, “Institut national de la Statistique et des études économiques (Insee) for France, and the “Statistisches Bundesamt” (DEStatis) for Germany were used as additional data sources.

The population density was collected based on these statistical offices. For each country, the municipal or regional boundaries were chosen that matched the OECD-EC city definition used in this research to ensure comparable data. For a few cities and greater cities where the municipal area data from the national statistics offices did not correspond with the OECD-EC definition set for a city, data on population and surface area were used to calculate the population density for the city level to ensure a comparable level of analysis.

Historical city

To reflect if the urban form favors car use, the development history is of importance. De Vries (1984) conducted a study on European urbanization between 1500-1800. His book contained data on the European cities which reached a population of 10,000 inhabitants between 1500 and 1800. If a city reached such a population between 1500-1800 it is argued that this city has an older city center and is identified as a historical city. A variable was constructed giving all the historical cities a value of “1” and all the non-historical cities a value “0”.

3.3.2.2 Niche factors

Age

Stratified population data was used from the urban audit database from Eurostat as an indicator for the age of the population. Since the relationship between age and the number of shared cars is not expected to be linear, multiple age groups were taken as indicators for age. This has led to variables indicating the percentage of the population between 20-24, 25-34, and 35-44 years old.

Educational level

National differences in the educational system often results in difficulties in comparability between the educational level of the population across countries. The International Standard Classification of Education (ISCED) provides a way to compare different national education levels (OECD, European Union, & UNESCO-UIS, 2011). The Urban Audit from Eurostat provides data for the percentage of working age population for different ISCED levels per city. The percentage of working age population qualified at level 5 or 6 ISCED is taken as an indicator for level of education to identify the share of people highly educated. For Belgium, data was found on educational level per age group form the population census 2011. The age groups that fell within the boundaries of the working age population taken by Eurostat were added together. Then, the education groups were compared and matched up with the ISCED categories to ensure comparable data.

Persons per household

The urban audit database also provides data on living conditions and household composition. Data was collected on the number of one-person households and the total number of households within a city. From these numbers the percentage of one-person households was calculated. No data was available for the greater city definition used for some of the cities within the sample. For these cities, the percentage of one-person households is calculated by adding the numbers for the underlying cities to best match the geographical area that makes up the greater city.

Environmental awareness

To measure environmental awareness, voting behavior can be an indicator for how concerned people are with the environment. The votes for the green party with the national elections were identified per city. First, the parties were identified that are considered “green” which led to the following list of parties:

- Belgium: “Ecolo”, “Groen”
- Germany: “Bündnis 90/Die Grünen”
- France: “Europe Ecologie – Les Verts”
- The Netherlands: “Groenlinks”
- United Kingdom: “Green Party of England and Wales”, “Green party of Northern Ireland”, “Scottish Green Party.

All of these parties also collaborate in the elections for the European parliament under the name “European Green Party” indicating that they have similar values and goals which should result in comparable results between the countries.

The data collection was done through the official election websites of each country. For Belgium, there were no results available for the last national elections. For this reason, data is used from the municipal elections in 2012. For all data, only the “valid votes” were counted. All votes were collected at the level of the voting district. Since these boundaries are not always the same as those of the city boundaries that are taken in the city definition, the data is not directly comparable. All voting districts with at least partial overlap within the geographical boundaries of the city are counted as being part of that city.

Other shared mobility

To reflect how familiar people are with the concept of sharing, the existence of other sharing practices can be an indicator. One indicator for this is how familiar people are with other forms of shared mobility like for example bike sharing. Data was gathered using search engines and the website bikeshare.com which has indexed bike sharing initiatives. A variable was constructed in which all cities that are identified to have bike sharing were given a value of “1” and the cities were no bike sharing was found were given a value “0”.

Trust

To reflect the concept of trust, a search was conducted with regards to crime rates on the city level. Due to unavailability of data on the city level, a database from Eurostat having NUTS3 level data on vehicle theft for the year 2010 was used. This variable was adapted to the city level by dividing the number of incidents of vehicle theft by the total population per NUTS3 region in 2010. This led to an incident rate per 1000 inhabitants for each NUTS3 region. For each city it was evaluated which cities fall within the geographical boundaries of the NUTS3 region. Each city then was assigned the incident rate for the respective NUTS3 region.

International city

Tourism and the presence of expats both add to the international character of a city. One thing that facilitates both is the presence of an airport. Having an airport could thus be an indicator of how international the city is. Eurostat tracks airline travel through all European airports and provide a list of airports. Based on the name of the airports, the location of these airports was assessed. This resulted in a list of cities that have an airport. In the constructed variable the cities with an airport were identified as being international and assigned a "1". The cities that had no airport were assigned a "0".

University city

To indicate if a city has a university the CWTS Leiden ranking was used. This ranking ranks 750 major universities worldwide. If a university from this list is present in a city, the city is marked as being a university city. If no university is present from the list of major universities, the city is indicated as having no university.

Sectoral policy

The main municipality of each city of the sample was contacted by email in which municipalities were asked if they had policy specifically to car-sharing. If so, they were asked if this was policy to either stimulate the growth of car-sharing or to moderate the growth of car-sharing. From the contacted municipalities, 59 responded to date which results in a response rate of 34%. From the responses it was evaluated if they had active policy with regards to car-sharing. The cities that have active policy were assigned a "1", and the cities that did not have any policy were assigned a "0".

Market concentration

The Herfindahl index (or Herfindahl-Hirschman index, HHI) is a measure of the size of firms in relation to the industry and can be used, among other things, to describe the concentration of an industry (Rhoades, 1993). It is defined as the sum of the squares of the market shares of the firms within the industry. And gives a number ranging from zero to one indicating the competition in the market. Zero, in this case means perfect competition, and a value of one would mean one firm having the whole market (monopoly). The HHI is calculated to describe the market concentration between all P2P CSO's in one city by taking into account their relevant share of cars. This number is used as a variable to indicate the market concentration.

Another factor indicating market concentration is the presence of a B2C CSO. As part of this research, also the cities having B2C car-sharing were identified. The presence of B2C cars is also used to indicate the familiarity with shared mobility. The cities having B2C car-sharing were given a value of "1" and the cities without were given a "0".

To see whether the actual number of B2C cars also is of an influence in a city, the number of shared B2C cars are also operationalized as a variable. The number of shared B2C cars were also collected within this research project using the same methodology as described for the number of P2P shared cars (the full list of B2C car-sharing providers for which data is collected is provided in Appendix C).

In the table below (See Table 1) the variables and their operationalization are summarized. Data sources and the year from which the data originates are also mentioned.

Concept:	Operationalized Measured as variable:	Source:	Year:
Dependent variable:			
Number of shared p2p cars	# of shared cars	CSO websites and email contact. See appendix B	Nov 2015 – Jan 2016
Independent Variables:			
Regime (National level):			
Cost of car ownership	Registration tax Ford Fiesta (EUR) Circulation Tax Ford Fiesta (EUR)	Zahedi & Oliver, 2012 Zahedi & Oliver, 2012	2012 2012
Cost of car use	Price of EURO 95 at the pump (EUR)	Eurostat	2nd half 2014
Regime (City Level):			
Car ownership	# of registered cars # of registered cars per person (x100)	Eurostat	BE, NL, UK: 2011 DE:2014, FR: 2012
Public transport / Model split	% journeys taken by Public transport (rail, metro, bus, tram)	FR, DE, BE, UK: Eurostat NL: OViN	BE: 2008 FR, UK: 2011 DE: 2012 NL: 2010/2011/2012
Population density	Population density (popx100/km2)	BE: Statistics Belgium, DE: Statistische Ämter, FR: Insee, NL: CBS, UK: ONS	BE: 2008, DE: 2013, FR: 2012, NL: 2015, UK: 2011
Historical city	Historical city (City has population of more than 10.000 between 1500 – 1800)	De Vries, 1984	1500-1800
Niche (City level):			
Age	% of pop. 20-24 years of age % of pop. 25-34 years of age % of pop. 35-44 years of age	Eurostat	UK, FR, BE, DE: 2012 NL: 2013
Level of education	% of pop. qualified at level 5 or 6 ISCED	DE, UK, FR, NL: Eurostat BE: Statistics Belgium Census	DE, UK: 2011, FR, NL 2012, BE: 2011
Persons per household	% of one-person households	Eurostat	UK: 2011 DE, FR: 2012 BE, NL: 2013
Environmental awareness	% of green votes	BE: "Municipal elections" DE: "Bundestagwahl" FR: "Élections Légeslatives" NL: "2e Kamerverkiezing" UK: "UK general elections"	BE:2012 DE:2013 FR: 2012 NL: 2012 UK: 2015
Other sharing practices	Bike sharing present	Search engine and Bikeshare.com CSO Websites (see appendix)	2015
Trust	Vehicle Theft (per 1000 inhabitants)	Eurostat (NUTS3 level)	2010
International city	International city (1> Airport present)	Eurostat	BE: 2014 NL: 2013 DE, FR: 2012 UK: 2011
University city	University city (1> university present)	CWTS Leiden ranking	2015
Sectoral policy	Sectoral policy	Email municipalities	Jan/Feb 2016
Market concentration	# of B2C shared cars Presence B2C CSO Herfindahl index P2P	CSO Websites (see appendix C) CSO websites and email contact (see appendix C) Calculated based on own research	Nov 2015 – Jan 2016 Nov 2015 – Jan 2016 Nov 2015 – Jan 2016

Table 1: Operationalization table

3.3 Data analysis

When dealing with a continues dependent variable and more than two independent variables, a multiple linear regression model is most commonly applied. However, when the dependent variable is a count variable, the linear regression model has its shortcomings (Winkelmann, 2013). Count data consists of observations that have only nonnegative integer values ranging from zero to some maximum value, like a count of items of events occurring in a given geographical or spatial area (Hilbe, 2014).

Count data in general does not adhere to some of the assumptions made in a linear regression model. A linear regression model assumes the data to be normally or "Gaussian" distributed, which is not the case for count data which generally has a large share of low value observations with a decreasing number of higher values (Hilbe, 2014). To deal with this data distribution another probability distribution function is necessary.

Count model distribution functions adhere to the basic structure of the linear model, but the difference is that there is not a linear relationship between the predicted value and the predictors, but the linear relationship is between the natural log of the predicted value and the predictors (Hilbe, 2014). Two common types of count model distributions are the "Poisson" and the "Negative Binomial" probability distribution functions. The Poisson distribution has a single parameter to be estimated which results in the unique feature of the Poisson distribution, which is that the variance is equal to the mean. This equidispersion criteria is rarely met, which often results in over dispersion (Hilbe, 2014)

The negative binomial regression model has an extra parameter to deal with the over dispersion. This "dispersion parameter" is a measure of the adjustment needed to accommodate the extra variability in the data (Hilbe, 2014).

The dependent variable, the number of shared P2P cars, in this research consists of a count of items (cars) within a geographical area (City). The dependent variable can also never be negative since a city cannot have a negative number of shared cars, neither can a city have a non-integer value (fraction of a car). For this reason, a count model is used to analyze the city level data.

4 Results

Using the described methodology, a unique dataset was constructed with the number of shared P2P cars per city. First, a descriptive overview of the constructed dataset is provided illustrating overall impressions of the state of P2P car-sharing in European cities. Then the data on the city level is used to construct a model to explain the relationship of the operationalized independent variables on the number of shared P2P cars in city.

4.1 Descriptive statistics

In total a number of 33,149 shared P2P vehicles were counted that were shared on the moment of data collection. P2P cars are shared in almost every city with more than 150.000 inhabitants represented in the sample. As seen in Table 2 only two cities offer no P2P shared cars at all. 29.4% of the cities offer ten or less cars and the majority of the sample (67.2%) has a hundred or less shared cars. In six cities (3.4% of the sample) the total amount of shared cars was more than a thousand.

	Frequency	%	Cumulative %		Frequency	%	Cumulative %
< 1	2	1.1	1.1				
1 - 10	50	28.2	29.4				
11 - 20	25	14.1	43.5	<= 100	119	67.2	67.2
21 - 30	9	5.1	48.6	101 - 200	21	11.9	79.1
31 - 40	9	5.1	53.7	201 - 300	14	7.9	87.0
41 - 50	5	2.8	56.5	301 - 400	6	3.4	90.4
51 - 60	8	4.5	61.0	401 - 500	2	1.1	91.5
61 - 70	5	2.8	63.8	501 - 600	3	1.7	93.2
71 - 80	2	1.1	65.0	701 - 800	2	1.1	94.4
81 - 90	2	1.1	66.1	801 - 900	2	1.1	95.5
91 - 100	2	1.1	67.2	901 - 1000	2	1.1	96.6
101+	58	32.8	100.0	1001+	6	3.4	100.0
Total	177	100.0		Total	177	100.0	

Table 2: Number of shared P2P cars

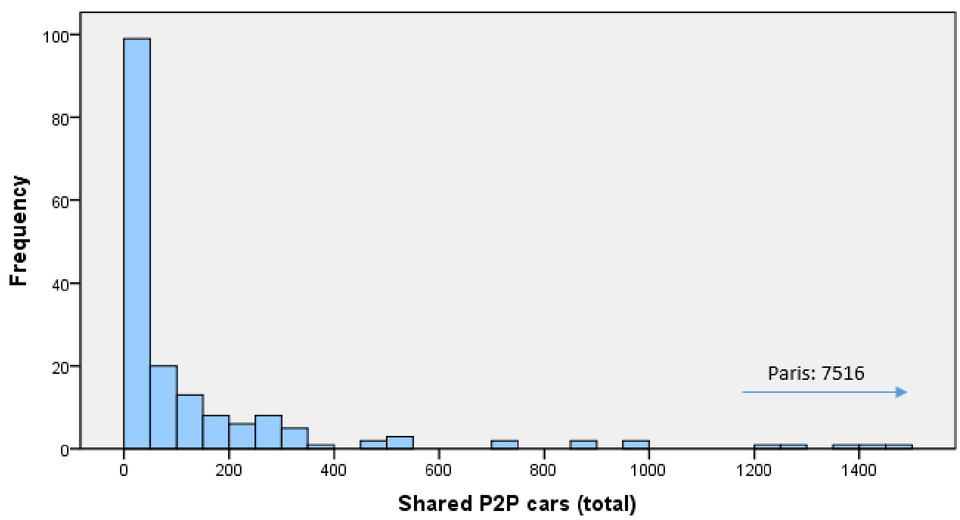

Figure 3: Distribution of shared P2P cars

The number of shared cars per city is distributed as represented in Figure 3. As also can be seen in the previous table, the frequency of observations decreases when the number of cars increases. As argued in the methodology section, the data does not follow a normal distribution but shows a distribution commonly seen for count data (Hilbe, 2014). Apparent in Figure 3 is the large number of shared cars for the city of Paris with a value of 7516 cars. This number is more than five (5.17x) times as high as the 2nd highest value, which is also a city in France (Lyon=1453).

4.2 Country comparison

From the descriptive statistics, a national difference can be noted in the number of shared cars. When comparing each country, a large difference can be seen between the mean and median number of cars. Where France, Belgium and The Netherlands show relatively high mean and median values, the UK and Germany show to have fewer cars on average.

The maximum values for the UK, The Netherlands, France, Germany, and Belgium correspond with the cities London, Amsterdam, Paris, Berlin, and Brussels respectively (see Table 3). These cities are also the capital city and the biggest cities based on population per country. Where The Netherlands, UK, Germany and Belgium do not have any cities with more than 150,000 inhabitants where no shared cars are observed, France has two cities without any shared P2P cars. These two cities are "*Fort-de-France*", and "*Saint Denis*" both located within overseas territories of the French republic. The geographical remoteness of these places from the mainland Europe could account for the reason why none of the platforms offer any P2P cars within these cities. Besides these two cities, all other cities with more than 150,000 inhabitants have at least one or more shared cars.

Country:	N	% of total N	Mean	Median	Minimum	Maximum	Std. Deviation
United Kingdom	60	33.9%	41.43	8.00	1	1435	185.923
The Netherlands	13	7.3%	201.00	107.00	34	884	242.172
France	46	26.0%	542.04	276.00	0	7516	1117.823
Germany	53	29.9%	50.06	24.00	3	545	85.335
Belgium	5	2.8%	92.60	137.00	7	159	72.435
Total	177	100.0%	187.28	34.00	0	7516	619.212

Table 3: Shared P2P cars per country

4.3 City comparison

In Table 4 the top three of cities per country are shown based on both total number of shared P2P cars and number of shared P2P cars per capita. Where the top three in total number of cars for France, Germany and Belgium are taken up by the largest cities within the countries (based on population), this is not the case for The Netherlands and the UK (See Table 4). In the UK the third place is taken up by Bristol, which is only the 14th city in the country based on population. For The Netherlands, the second place is taken up by Utrecht which is the fourth city based on population leading to a third place for the second biggest city in the Netherlands, Rotterdam.

When the number of shared cars is evaluated per capita, a different list of cities is seen. For their respective countries, Bristol, Utrecht, Montpellier, Heidelberg and Gent now show to be the cities where the most cars are shared per capita. Also significant differences are observed in the number of shared cars per capita for the top three per country. Where in France the top three has 17+ cars per 10,000 inhabitants, the top 3 of the UK and Germany have less than 4 shared cars per 10,000 inhabitants, indicating the influence of national differences on the number of shared cars.

	Total number of P2P cars		P2P Cars per capita (x10000)	
United Kingdom				
1	London (greater city)	1435	Bristol	2.18
2	Greater Manchester	228	London (greater city)	1.72
3	Bristol	95	Chelmsford	1.18
The Netherlands				
1	Amsterdam (greater city)	884	Utrecht	14.72
2	Utrecht	474	Amsterdam (greater city)	8.56
3	Rotterdam (greater city)	308	Haarlem	7.97
France				
1	Paris (greater city)	7516	Montpellier	20.20
2	Lyon	1453	Bordeaux	17.74
3	Lille	1386	Versailles	17.46
Germany				
1	Berlin	545	Heidelberg	3.29
2	Hamburg	257	Mainz	2.69
3	München	217	Freiburg im Breisgau	2.45
Belgium				
1	Bruxelles / Brussel	159	Gent	5.49
2	Antwerpen	139	Antwerpen	2.71
3	Gent	137	Bruxelles / Brussel	1.35

Table 4: Cities with the most P2P shared cars

Independent city-level variables:

Descriptive statistics of the independent variables on the city level that were argued to be relevant in the theory section are provided in Table 5. For each variable the number of cases is displayed for which data is available. As can be seen, only 26 cases have data for all theoretically relevant variables due to the unavailability of data. The variables that reduce the sample the most are *vehicle theft* and *sectoral policy*. Due to the limited sample size, these variables are only used as purely indicative variables and they are not used in the initial model configuration.

	N	Minimum	Maximum	Mean	Std. Deviation
# of shared B2C cars	177	0	3961	134.67	441.558
# of registered cars (x1000)	177	43.133	2401.619	178.53645	264.862879
# of registered cars per capita (x100)	177	25.58	57.38	41.6903	6.84925
Population density (popx100/km2)	176	2.647	88.003	17.62967	12.743924
% of journeys by PT	175	4.22	69.35	18.4808	9.68271
% of pop. 20-24 years	177	5.1	17.1	7.719	1.9348
% of pop. 25-34 years	177	10.4	20.9	14.155	2.1388
% of pop. 35-44 years	177	10.9	16.5	13.471	1.0473
% of pop. qualified at level 5 or 6 ISCED	171	13.10	60.30	33.3764	9.24998
% of one-person households	177	24.76	60.82	39.4396	8.45602
% of green votes	177	0.00	19.84	6.4921	4.51904
B2C CSO present	177	0	1	.81	
Bikesharing present	177	0	1	.53	
Historical city	177	0	1	.62	
University city	177	0	1	.47	
Airport present	177	0	1	.50	
Herfindahl index P2P	175	.250	1.000	.52965	.141304
Sectoral Policy	59	0	1	.29	
Vehicle Theft	116	.29	9.60	2.3342	1.64747
Valid N (listwise)	26				

Table 5: Descriptive statistics independent city level variables

4.4 Correlations and multicollinearity

For each city level variable, the correlation with the dependent variable, the number of shared cars, was assessed (See Appendix D). To deal with the nature of count data when assessing the correlations and multicollinearity, the natural log was taken for the dependent variable "number of shared P2P cars" and the independent variable "number of shared B2C cars". Although log transforming count data is not common practice during model development, it is however useful for purely illustrative purposes (O'Hara & Kotze, 2010).

A rather strong (0.4 >) and significant Pearson correlation is seen between the dependent variable and the independent variables *B2C cars (log), Number of registered cars, percentage of journeys to work by Public transport, percentage of population highly educated, percentage of one-person households, Historical city, presence bike sharing, presence airport, sectoral policy* and *vehicle theft*. Although purely illustrative, these correlations are mostly in line with the expectations from theory. However, that *vehicle theft* tends to be positively related with the natural log of *shared P2P cars* is rather surprising. This indicates that when more cars are stolen, more shared cars are seen, which is contradictory to what someone would expect on the basis of the concept of trust.

The independent variables were also evaluated for signs of multicollinearity. To do so, the collinearity statistics were evaluated for the independent variables. Since the variables *vehicle theft* and *sectoral policy* would significantly reduce the number of valid cases, these variables were not taken into account during this assessment.

The variance inflation factor (VIF), which indicates the degree to which the precision of the model is degraded by multicollinearity (Schroeder, 1990), was evaluated. The natural log of B2C cars showed a rather high VIF value (VIF= 7.2), which is above the threshold of 5 taken which could indicate potential multicollinearity problems (Rogerson, 2010). Based on the potential multicollinearity, this variable is excluded in the analysis. Instead, only the dummy variable is used for the presence of B2C car-sharing within a city, which did not show any multicollinearity issues.

To account for expected differences on the national level, a country variable was then added. After adding this variable, the variable *percentage of one person households* showed to be strongly negatively correlated with the country variable for the UK (Pearson= -.726). An explanation for this could be that on average less one person households are observed in the UK. This can also be observed when comparing the mean for this variable for the UK (30.9%) with the mean of one person households for all countries (39.7%). When assessing the collinearity statistics, also an increase in the VIF was observed for the variable *percentage one-person households*. No other independent variables showed to be highly correlated with the country variable, and also no significant increase for the collinearity statistics for the other independent variables was observed when the country variable was added.

4.5 Model configuration and assessment of model fit

As described in the methodology, the dependent variable consist of count data which requires a count model rather than a linear regression model. One distribution that deals with count data is the Poisson distribution. However, data is not always Poisson distributed. If a Poisson model is over dispersed, the model may underestimate the standard errors and overstate the significance of the regression parameters which can lead to misleading results (Ismail & Jemain, 2007).

In this instance, the data was found to be over dispersed when a Poisson model was applied indicating that the variance of the data is not equal to the mean. To deal with this type of data a negative binomial regression model was then chosen.

To ensure that the model represents the largest part of the data set possible, the model is developed using the variables that have a N of more than 170. For this reason, the variables *sectoral policy* and *vehicle theft* were not used in the first configuration of the model. Following Meelen, Hobrink & Frenken (Forthcoming), the *number of privately registered cars* is used as a control variable to control for the variation in total number of available cars per city. This has led to the set of variables represented in model 1 in Table 6.

Based on this configuration, the model was evaluated on how well the model fits the data. The difference between the predicted values of the model versus the observed values and the presence of any non-random patterns in the plotted standardized deviance residuals can be used to evaluate the model fit (Hilbe, 2014). If evidence of poor fit or non-random patterns are found, this could indicate over dispersion or misspecification of the model which might require an alternative count model (Hilbe, 2014).

Figure 4 shows the observed P2P cars versus the predicted value of the model. When all observations lie close to the fit line, this indicates that the model is able to predict the observations quite well. All observations show to be close to the fit line except one, which is identified to be the observation for the city Paris. The city Paris showed a large difference between the observed value (7,516) of shared cars and the predicted value (146,746), which could be an indication of Paris being an outlier.

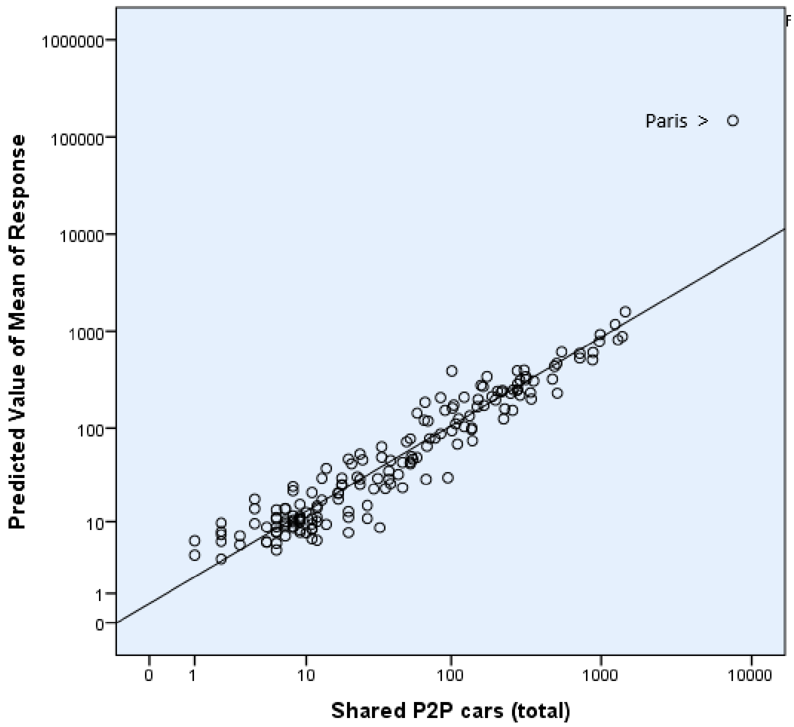

Figure 4: Observed number of P2P cars versus Predicted number of P2P cars

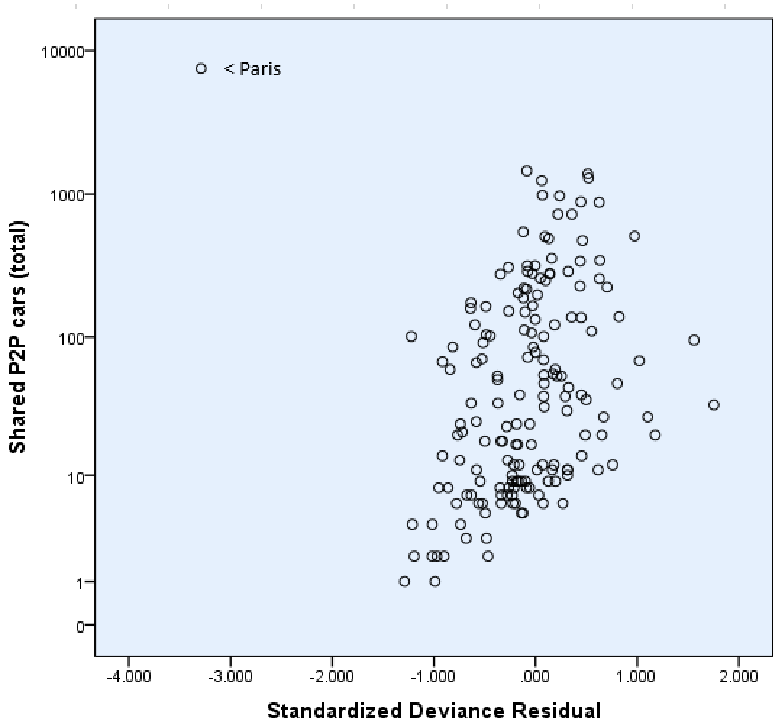

Figure 5: Standardized deviance residuals

The standardized deviance residuals were also evaluated as seen in Figure 5. The city of Paris showed to have a standardized deviance residual of more than three. No other non-random patterns are seen which could indicate a poor fit of the model (Hilbe, 2014).

The Cook's distance, which is a measure for the influence of a single observation on the overall model (McDonald, 2002), was also assessed. Based on the above observations and the cook's distance (=.866), Paris is determined to have a too large influence on the overall model and is determined to be an outlier. For this reason, the observation for Paris is removed from the dataset to improve the model fit. How this affect the model results can be seen in the differences between model 1 (containing all observations) and model 1’ (excluding Paris) (See Table 6). After removing Paris, the model fit was evaluated again after which no non-random patterns in residuals or extreme predicted values were observed.

	Model 1	Model 1'	Model 2	Model 3	Model 4	Model 5
BIC:	1630.916	1584.088	1558.159	1560.017	481.234	1179.882
AIC:	1562.188	1515.492	1511.299	1516.281	449.117	1138.836
Pearson Chi2/Df:	1.195	1.337	1.321	1.272	1.536	1.061
N:	168	167	168	168	55	114
	B	**B**	**B**	**B**	**B**	**B**
United Kingdom	-.327	-.385	-.475	-.930**	-1.740**	
	[.3406]	[.3117]	[.2905]	[.2403]	[.4604]	
The Netherlands	1.753**	1.535**	1.180**	1.166**	.967*	1.083**
	[.3754]	[.3440]	[.2604]	[.2668]	[.4117]	[.2296]
France	2.431**	2.407**	2.328**	2.078**	1.338**	2.178**
	[.3193]	[.2934]	[.2708]	[.2593]	[.5007]	[.2567]
Germany	-.429*	-.518*	-.621**	-.502*	-.505	-.548*
	[.2597]	[.2371]	[.2328]	[.2340]	[.4170]	[.2050]
Belgium	0	0	0	0	0	0
# of registered cars(x1000)	.002**	.003**	.003**	.003**	.005**	.004**
	[.0003]	[.0003]	[.0003]	[.0003]	[.0012]	[.0004]
# of registered cars per capita (x100)	.007	.003				
	[.0130]	[.0121]				
Population Density (popx100/km2)	-.006	-.003				
	[.0051]	[.0048]				
% of journeys by PT	.021*	.021**	.017**	.017*	.013	.008
	[.0085]	[.0080]	[.0067]	[.0070]	[.0180]	[.0067]
% of pop. 20-24 years	-.156**	-.142**	-.105**	-.073**	-.041	-.094**
	[.0441]	[.0403]	[.0302]	[.0279]	[.0563]	[.0314]
% of pop. 25-34 years	.162**	.151**	.136**	.134**	.153**	.113**
	[.0384]	[.0352]	[.0293]	[.0300]	[.0518]	[.0308]
% of pop. 35-44 years	-.057	-.059				
	[.0727]	[.0669]				
% of pop. qualified at level 5 or 6 ISCED	.009	.014+	.016*	.021**	.017	.022**
	[.0081]	[.0075]	[.0067]	[.0067]	[.0122]	[.0071]
% one-person households	.020	.026*	.032**		-.035	.028
	[.0140]	[.0128]	[.0120]		[.0249]	[.0125]
% of green votes	.010	.007				
	[.0149]	[.0135]				
B2C CSO present	.201	.209+	.222+	.171	-.170	.318**
	[.1339]	[.1231]	[.1173]	[.1180]	[.2530]	[.1209]
Bikesharing present	-.134	-.100				
	[.1221]	[.1113]				
Historical city	.308*	.217+	.222*	.352**	.453*	.341**
	[.1236]	[.1139]	[.1091]	[.1047]	[.2208]	[.1191]
University city	.312*	.175				
	[.1325]	[.1228]				
Airport present	.185	.125				
	[.1131]	[.1030]				
Herfindahl index P2P	-.646*	-.626+	-.654+	-.621+	-.424	-.147
	[.3790]	[.3519]	[.3477]	[.3535]	[.5766]	[.4726]
Sectoral Policy					.361	
					[.2227]	
Vehicle theft						.032
						[.0312]

**. Correlation is significant at the 0.01 level

*. Correlation is significant at the 0.05 level

+. Correlation is significant at the 0.10 level

Table 6: Negative binomial regression model results

From model 1’, variables that appeared to not show significant results were removed step by step by least significance. After each step, the model fit was evaluated. To assess the fit of a negative binomial regression model, the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC) can be used. If a negative binomial model has substantially lower AIC and BIC set of statistics than other models, then it can be regarded as a better-fitted model (Hilbe, 2014).

If removing the variable led to adding additional cases, the model fit was evaluated on an even number of cases, since both AIC and BIC values have to be compared on an equal number of cases (Hilbe, 2014). After that, the cases were added which logically results in a slightly higher BIC and AIC value. This results in model 2 displayed in Table 6 which shows to be a better-fitted model indicated by the lower BIC and AIC values. This indicates that removing these variables leads to a model that better fits the observed data.

As described above, the *percentage of one-person households* showed to have a VIF value that could indicate that the variable is collinear with the country variable for the United Kingdom. To see how this affects the model, model 3 shows the results without the variable *one-person households*. When this model is compared to model 2 it can be seen that the BIC and AIC increase, indicating that the configuration of model 2 is a better fit with the data than the configuration of model 3.

To the configuration of model 2, the variables were added which had a smaller number of cases leading to configurations shown in model 4 and model 5. In model 4 the variable *sectoral policy* was added which reduces the number of cases to 55. In model 5 the variable *vehicle theft* was added which reduces the number of cases to 114. The BIC value, indicating the goodness of fit of the model was evaluated for model 4 and 5 with and without the variables holding the number of observations constant. Adding the variables sectoral policy or vehicle theft both did not lead to an increase in the model fit. Overall, based on the above evaluation, model 2 shows to be the best representation of the dataset.

4.6 Model results

The *number of registered cars*, which is used to control for the variation in number of registered cars within a city, shows to be slightly positively related with the number of shared cars. These results show to be significant throughout all configurations of the model. The *number of registered cars per capita* and *population density* show also a positive relationship but both did not lead to significant results.

The *percentage of journeys by public transport* shows a significant positive relationship with the number of shared cars in configuration 1 to 3. The *percentage of the population 20-24 years of age* shows to be negatively related to the number of shared cars and also shows to be significant in configuration 1 to 3 and 5 on the 1% level. The *percentage of the population 25-34 years old* shows to be positively related and this result is significant throughout all model configurations. However, the age *group of 35-44 years* did not lead to significant results.

The *percentage of working age population qualified at level 5/6 ISCED* showed to be positively related to the number of shared cars but the results became only significant different after removing Paris as an outlier from the model. The *percentage of green votes* did not lead to significant results. The variable indicating the *presence of B2C car-sharing* was also found significantly positively related after removing Paris as an outlier. If a city is a *historic city* a significant positive influence on the number of shared cars is observed throughout all model configurations. The *Herfindahl index* as a measure of market concentration shows a negative significant relationship with the number of shared cars.

When the variables *sectoral policy* and *vehicle theft* added to configuration 4 and 5 both did not lead to any statistically significant results. The limited number of observations could contribute to this result. Also, the limited number of observations make these configurations less representative to evaluate the results for the other variables included in these models, since only a small part of the dataset is used. Overall, based on the above evaluation on model fit criteria, model 2 shows to be the best representation of the constructed dataset and will be used for further interpretation of the results of the analysis.

4.7 Transition of car-sharing

From theory it was expected that when there is a lot of pressure on the regime, or the regime is less established in a certain city, the niche of car-sharing would develop more easily in that specific area indicated by a higher number of shared P2P cars. This number of shared cars is expected to be even higher when niche activities and support result in growth of the niche of car-sharing. How the model results reflect these theoretical expectations is discussed below. Finally, the main results and effects shown by model 2 are summarized in Table 9.

4.7.1 Regime factors

How well the regime is established and how much pressure there is on the regime could influence the stability of the regime. The country and city level differences are discussed in the following paragraphs.

Costs of car ownership and car use:

If costs of car ownership and car use are high, which indicate a high pressure on the regime of personal car use, a higher number of shared cars was expected. With the cost of car ownership and use mostly varying on the national level, it is expected to see the effects of differences in the country variables.

As seen in Table 7 the country variables do appear to account for a lot of differences in the number of shared cars. For Germany, half of the number of cars are expected when compared to Belgium while controlling for the other variables. For the Netherlands 3.3 times as many cars are expected and for France 10.3 times as many cars as compared to Belgium (reference country). The United Kingdom shows to have 38% less shared cars compared to the base country Belgium, but this result is not significantly different from Belgium.

	Model 2		
	Exp (B)	% Per Unit	% Per SD
United Kingdom	.622	-37.8	
The Netherlands	3.253	325.3	
France	10.260	1026.0	
Germany	.537	-46.3	
Belgium	1	1	
# of registered cars(x1000)	1.003	0.3	79.46
% of journeys by PT	1.017	1.7	16.46
% of pop. 20-24 years	.901	-9.9	-19.15
% of pop. 25-34 years	1.146	14.6	31.23
% of pop. qualified at level 5 or 6 ISCED	1.016	1.6	14.80
% one-person households	1.033	3.3	27.90
B2C CSO present	1.248	24.8	
Historical city	1.286	28.6	
Herfindahl index P2P	.520	-48.0	-10.02

Table 7: Change in number of P2P cars

In Table 8 the values and the mean of the cost of car use and ownership are provided per country. A large difference in tax on registration and circulation can be seen between the five countries. The costs of car ownership are the highest in the Netherlands for buying a car and the yearly circulation (road) taxes. These higher costs compared to Belgium could explain why in The Netherlands more shared cars are seen. France however, which has lower costs of car ownership than Belgium shows to have more than ten times as many cars which indicates that not only costs of car ownership and car use can explain the national differences. On the basis of these results it cannot be concluded that costs of car use and ownership have an influence on the number of shared cars, but a large influence of national difference in the number of shared cars is observed.

Circulation tax on a Ford Fiesta	United Kingdom	The Netherlands	Germany	France	Belgium	Mean
N	60	13	53	46	5	177
Registration tax on a Ford Fiesta	65.83	7080.7	26.3	306.5	123	633.37
Circulation tax on a Ford Fiesta	131.67	444	299.92	160	248.29	215.65
Price in EUR of Euro 95 at the pump	1.47	1.56	1.36	1.34	1.38	1.41

Table 8: Costs of car use and ownership per country

Car ownership:

The total number of privately registered cars, which was used to control for the availability of cars to share, showed to be slightly positively related to the number of shared P2P cars in all model configurations. When controlling for all other predictors in the model, with an increase of 1000 cars, an increase of 0.3% in the number of shared cars is seen (See Table 7). This could be explained by the fact that if more cars are available in a city, more cars are available which could be shared.

To better reflect car ownership, the number of cars per capita was assessed in the model. From theory it was expected that when there is lower car ownership per capita, indicating a lower presence of the regime, more shared cars will be found. However, since vehicle ownership is a necessity for P2P car-sharing this relationship was expected to be less visible.

The results obtained from the model showed no statistically significant relationship for the number of P2P shared cars and the number of privately registered cars per capita. As argued from theory, that this relationship showed not to be statistically significant could be explained by the fact that to share a car, having a car is a necessity. However, when there are a lot of shared cars in the neighborhood, this might result in a reduction of car ownership when people choose to lend a car instead (Loose, 2010; E. Martin et al., 2010).

Public transport:

Another indicator for the strength of the car regime is the availability of public transport. It was expected that if people are less car dependent, indicating a lower presence of the regime of personal car use, indicated by available public transportation, more shared cars are found. The model results support this expectation. When controlling for all other predictors in the model, when one percent more journeys to work are taken by public transport, the number of shared cars is 1,7% higher. Per standard deviation of percent of trips to work by public transport, the model shows 16.5% more shared cars (see Table 7). These results show that if Public transport is a viable option for trips to work, more cars are shared on P2P car-sharing platforms. This supports results from previous research indicating that when a car is not necessary for daily use car-sharing offers a good alternative (Duncan, 2011; E. Martin et al., 2010).

Population density:

It was expected that cities having a high population density would have more shared cars. However, no statistically significant results were found supporting this expectation. One reason for this can be that population density on the city level might not truly reflect the urban form of the city. Cities with a densely populated city center might reflect a lower population density when surrounding neighborhoods are taken into account (Abbate & Salvucci, 2011). Also, although the OECD city definition takes population density into account, the role of administrative boundaries within this city definition could also play a role in the fact that the population density might not truly reflect the urban form of the city (Schwarz, 2010).

Also, the selection criteria of a population higher than 150.000 inhabitants used in this research might have resulted in the exclusion of geographical areas having a lower population density, resulting in the fact that population density in cities, which have a higher population density in general, appears to have no significant effect. Studies having a more geographical coverage might result in different conclusions.

Another explanation in the case of P2P car-sharing is that population density is of lesser importance to the feasibility of P2P car-sharing. Where a B2C CSO needs a certain level of utilization to be cost-competitive (Celsor & Millard-Ball, 2007), this might be of lesser importance for someone sharing their own car. Previous research also showed that population density might be of lesser importance for P2P car-sharing (Meelen, Hobrink & Frenken, Forthcoming) and that P2P car-sharing might offer a more scalable alternative to traditional car-sharing for less densely populated area's (Hampshire & Gaites, 2011).

Historical city:

It was expected that if a city is historic, indicating a less established regime of personal car use, more shared cars are seen. Cities with a historic urban center might be less orientated towards car use and might favor walking and cycling (van de Coevering & Schwanen, 2006). In line with this expectation, the model results show that having a historical city center has a positive effect on the number of shared P2P cars. As reflected in model configuration 2, in cities having a historical center 28.6 % more shared P2P cars are seen (see Table 7) when correcting for all other variables. Thus, in line with the expectations, when the urban form is less favorable for the current car regime, and other means of transportation are also feasible, more cars tend to be shared on a car-sharing platform.

4.7.2 Niche factors

Even when there is pressure on the regime, which can create "windows of opportunity" for the niche of car-sharing to grow, certain niche activities are needed to lead to the growth of car-sharing. How the model results reflect the practices relevant from theory are discussed below.

4.7.2.1 User innovativeness

It was expected that when there is a large share of innovative users, the adoption process of the concept of car-sharing would go more easily, leading to a higher number of shared P2P cars. the results related to user innovativeness are discussed in the next paragraphs.

Age:

One factor expected to be of influence is that a younger city population would result in an early adoption of car-sharing. This relationship however was not expected to be linear since having a driver's license and a car are necessities for sharing your car on a P2P car-sharing platform.

This is also reflected in the model results. When there is a larger percentage of the age group 20-24 years old, less shared cars are expected. For 1 percent increase in this age group, the number of shared P2P is expected to be 9.9% lower. This could be explained by the fact that vehicle ownership in this age group is lower (Dargay, 2002). Also car ownership among the younger generation tend to decrease. In a study on travel trends among young adults in Germany, a reduction of car ownership was found combined with a shift to alternative modes of transportation (Kuhnimhof, Buehler, Wirtz, & Kalinowska, 2012). This could explain why the presence of a larger group of people 20-24 years old, leads to less shared P2P cars.

A contrary relationship is observed for the group of people 25-34 years of age. When this group is 1% larger, the number of shared P2P cars is expected to be 14.6 % higher. These results also correspond with earlier surveys on car-sharing users showing that users are mostly of that age group (Loose, 2010; Prettenthaler & Steininger, 1999). While still relatively young, which could lead to early adoption, this age group is also more likely to own a car than compared to the age group 20-24 years old.

The group 35-44 of age did not show any statistically significant results on the number of shared cars, which could indicate that people of a higher age group do not significantly contribute to the level of innovativeness in a city, which is in line with what is expected from theory.

Educational level:

Early adopters also tend to have more years of formal education (Rogers, 2003). In line with this argument it was hypothesized that high level of education would have a positive influence on the number of shared P2P cars. Model configuration two shows a positive, statistically significant relationship on the 5% level, with the number of shared cars. When controlling for all other variables, with a one percent larger group of the working age population qualified at level 5/6 ISCED, 1.6% more shared cars are seen. Per standard deviation increase of this group, this results in a 14.8% increase in the number of shared cars (See Table 7). These results are in line with what was hypothesized. Also, previous studies on car-sharing users showed a positive relationship with level of education (Coll et al., 2014; Loose, 2010; Prettenthaler & Steininger, 1999). Although leading to a higher level of innovativeness as explained by Rogers (2003), higher level of education is also associated with more central employment, environmental consciousness and with the ability to calculate the real costs of owning a car (Coll et al., 2014). These reasons might contribute to the explanation why a higher level of education showed to be beneficial for the adoption of P2P car-sharing.

Persons per household:

The model results showed that the number of one-person households is positively related to the number of shared P2P cars. When there are one percentage more one-person households, an increase of 3.3% in the number of shared cars is expected. Per standard deviation increase in this group, 27.9% more shared P2P cars are expected. This is in line with what is expected from theory that the presence of one-person households leads to more shared cars. An explanation for this result can be that one-person households are less car dependent. A household with children for example might be more dependent on a car and find it less practical to travel by public transport. Specific requirements like children seats make them more dependent on their own car (Celsor & Millard-Ball, 2007).

4.7.2.2 Environmental values and practices

When people have a preference for environmental values and practices and trust their neighbors, the niche practices of P2P car-sharing were expected to be higher. For each concept the results are discussed below.

Environmental awareness:

Indicated by a high percentage of people voting for the green party, high environmental awareness was expected to have a positive effect on the number of shared P2P cars. The model results however showed no significant influence of this variable on the number of shared cars.

In Meelen, Hobrink & Frenken (Forthcoming), it was found that environmental awareness, demonstrated by the preference for a green political party, positively relates to the number of shared cars. The model results however show no significant relationship between the number of green votes and the number of shared cars within a city.

This could either mean that environmental reasons do not matter in car-sharing participation as found in a study of Zipcar users in Boston (Bardhi & Eckhardt, 2012) and that motivations are mostly based on economic reasoning. Also a survey on why people would consider offering their car P2P car-sharing, monetary rewards were given as the main reason (Ballús-Armet et al., 2014).

Another explanation is that the number of green votes does not necessary reflect environmental awareness of the population in a city. Voting behavior tend to be based on more factors than only environmental awareness. Current social issues, economic reasoning or even religion might influence the decision process to vote for a certain political party (Botterman & Hooghe, 2012; Swank & Eisinga, 1999). Since political parties have to form opinions on multiple topics, it could be that a person agrees with the environmental agenda of the in this research determined 'green" party, but does not agree on other topics and therefore the person does not vote for this party. Also other parties for which the environment is less central could still have values that agree with the opinion of someone who is environmentally aware.

Strategic voting could also influence the decision to vote for a certain party. Voters are less likely to vote for a party when it has little chance of winning, which is increased when the two leading parties are running close (Alvarez, Boehmke, & Nagler, 2006). In the case of a 'green' party this effect might be substantial. With a median of 6.5% of the valid votes for the green party (see Table 5), it could thus be that people strategically decide to vote for the larger parties within a country.

Other shared mobility:

With knowledge of a practice being an important part in adoption (Rogers, 2003), it was expected that if people are more familiar with the concept of sharing and shared mobility, people wil also be more likely to share their own car on a P2P car-sharing platform. The model shows that Bike sharing does not significantly influence the number of shared P2P cars. An explanation for these results can be that for business platforms, like bike sharing, a certain population threshold is often used to determine the feasibility of the platform within a city (Celsor & Millard-Ball, 2007). For this reason, bike sharing might only be present in larger cities while P2P car-sharing is present in almost every city within the sample.

Trust:

The number of vehicles stolen per 1000 inhabitants did not lead to significant results when this variable was added to the model configuration (see Table 6, model 5), indicating that trust has no significant influence on the number of shared P2P cars in a city. A reason for this effect could be that the perceived fear of crime does not necessarily reflect the actual crime rate. Studies show that the risk of criminal victimization is significantly overestimated and that perceived crime risks are associated with neighborhood racial composition or other influences like media coverage which do not reflect the actual crime risk (Quillian & Pager, 2010; Sparks & Ogles, 1990). This discrepancy between perceived risk of victimization and actual risk might explain why the actual crime rate of vehicle theft does not significantly influence the number of shared cars. A decision to either share a car on a P2P platform might be influenced more by personal perceived risk of car theft, either realistic or not, than the actual risk that a car gets stolen.

4.7.2.3 Protective market spaces

International city:

A city having a lot of tourism could be an attractive market for car-sharing since tourists often do not have their own car, leading to a protective market space where personal car ownership is less suitable. This group could therefore open up a market niche, which could increase the demand for car-sharing. Through this demand more and more people living in that city might choose to share their car if they notice that there is an interest. If either a city has an airport or not as a measure for the internationality of the city did not lead to significant results.

An explanation for this can be the registration requirements often needed for P2P car-sharing platforms might withhold tourist and internationals to sign up as a member of a car-sharing platform. The process that is necessary to get registered as a user might be too much of a hassle compared to lending a car in a more traditional way from a car rental agency. This could explain why this market niche is less apparent than expected.

Another reason that could explain this result is that demand side factors tend to have less influence on the number of P2P shared cars. As argued from theory, sharing a P2P car is a personal decision and the number of shared cars in the city only reflect supply. That this niche market did not lead to significant results could thus be an indication that P2P car-sharing is less demand driven.

University city:

Another factor that was expected to lead to a protective market space for car-sharing is the presence of a university. Although a significant positive relationship is observed in model 1, after removing Paris as an outlier, the variable University city did not lead to any significant results. This result can be explained by the fact that the campus structure in Europe is less apparent. The student population that need access from campus to nearby cities as apparent in north-American cities (Shaheen & Cohen, 2013) might be less big since universities are often centrally located.

As argued above, these results also show that protective market spaces leading to a demand for P2P car-sharing do not significantly contribute to the number of shared P2P cars. As mentioned from theory, this illustrates that P2P car-sharing tend to be less demand driven.

4.7.2.4 Supporting policy

From theory the results on the influence of policy on P2P car-sharing were mixed. Where Enoch & Taylor, (2006) found that a lack of government support can be a barrier, Meelen, Hobrink & Frenken (Forthcoming) found that for P2P car-sharing policy is of less importance. When the variable sectoral policy was added to the model (see Table 6, model 4) the results were as follows.

Sectoral policy:

Although positively related, the model results show no statistically significant results for the influence of policy on the number of shared cars. This could be caused by the fact that P2P car-sharing is less dependent on for example parking policy (Meelen, Hobrink & Frenken, Forthcoming). Where B2C car-sharing is dependent on dedicated parking spots in public spaces, P2P car-sharing has no need for this since it builds on private car ownership and a car owner is expected to already own a parking permit or to have a parking space on their own property.

Another reason could be that the smaller number of observations for this variable (N=59), due to the lack of data, was not sufficient to lead to any statistically significant results. For that reason, the influence of supporting policy remains unclear based on these results.

4.7.2.5 Activities of platform actors

Efforts to promote P2P car-sharing by platform actors was expected to be positively related to the number of shared cars. When more platform actors are active within a city these efforts are expected to be larger due to competition. The results of the concept of market concentration is discussed below

Market concentration:

The Herfindahl index was used as a measure of market concentration. The model results show that the Herfindahl index is negatively related to the number of shared cars, meaning that if the market is concentrated (high HHI) this results in less shared cars. When more platforms are active (low HHI) more shared P2P cars are expected. These results confirm the expectation that when more platform actors are active within the market, their promotional efforts might increase the number of people that decide to share their car on a car-sharing platform.

Also, the model results show that the presence of B2C car-sharing has a positive influence on the number of shared P2P cars. When a B2C CSO is present, 24.8% more shared cars are expected. This suggests that active promotion of car-sharing by platform actors has a positive effect on the number of shared cars.

Concept	Main results / Effect on number of shared P2P cars
Regime factors	
Country differences	*FR, NL showed more, and UK, DE showed less P2P cars compared to BE, indicating a large influence of national differences.*
Car ownership	*Number of registered cars showed a slight positive effect. Number of cars per capita did not lead to statistically significant results.*
Public transport	*More trips taken by PT shows to have a positive effect.*
Population density	*Did not lead to statistically significant results, indicating that the number of P2P cars is less dependent on population density.*
Historical city	*Presence of a historic city center showed to have a positive effect.*
Niche factors	
Age	*Pop. 20-24 years old showed to have a negative effect, while the pop. 25-34 years old has a positive effect. The age group 35-44 showed no statistically significant effect.*
Educational level	*Higher level of education showed to have a positive effect.*
Persons per household	*More one-person households showed to have a positive effect.*
Environmental awareness	*Political preference did not show a statistically significant effect.*
Other shared mobility	*Presence of other shared mobility showed no statistically significant effect.*
International city	*Presence of an airport showed no statistically significant effect.*
University city	*Presence of an university showed no statistically significant effect.*
Market concentration	*Presence of more CSO's (either P2P or B2C) showed to have a positive effect.*

Table 9: Summary of main results and effects (model 2)

5 Discussion

5.1 Limitations of the research

In this research a unique data set was constructed showing the current state of P2P car-sharing in European cities. It gives one of the first quantitative insights on city level factors that influence the growth of car-sharing. To ensure replicability, which is the extend to another researcher is able to replicate the findings (Bryman, 2008), logs are kept during the whole research project of the actions and decisions taken which is available upon request.

However, some caution should be taken with the interpretation of the results. Internal validity is “the extent to which a causal relationship can be established, whereby certain conditions are shown to lead to other conditions, as distinguished from spurious relationships” (Yin, 2014). With peer-to-peer car-sharing being a relatively new phenomenon, for most variables the directions are clear. However, for example policy regarding car-sharing (although observations are limited) can be either made to stimulate car-sharing, or to deal with issues created by the amount of shared cars. Since no longitudinal study is conducted, caution is taken and should be taken with interpretation of causal relationships.

External validity is the possibility to generalize findings to the real world (Yin, 2014). This research has some limitations with regards to the generalizability of the findings. Since the cities within the sample are purposively chosen based on certain criteria like population and geographical location, the results cannot be generalized to cities with a smaller population than 150.000 inhabitants. Although the influence of country factors was captured by the country variables, the strong effect of these variables indicate that national differences have a large influence on the state of car-sharing. For this reason, caution should be taken with generalizing these findings to cities in other countries. Also, one of the assumptions of a count model is a randomly chosen sample (Hilbe, 2014), making the predicted values of the model less representative for cities outside the sample.

This research also assumes factors like a developed infrastructure like good roads and the access to Internet to be widely available. Since car-sharing platforms are facilitated by internet and basic infrastructure for auto mobility is necessary for car use, the findings from this study are not applicable to developing cities that might follow a different development track than European cities have experienced in the past. However, since the aim of this research was to explain the differential growth of car-sharing in cities with a population higher than 150.000 within certain geographical boundaries, and the sample contains the whole population of cities that meet these criteria, the results give a good representation.

5.1.1 Number of shared cars

Another factor that should be kept in mind is the difference between the observed number of shared cars and the actual number of shared P2P cars. Due to the nature of the data that was collected, the number of shared P2P cars might be an overrepresentation of the actual number of shared cars for two reasons.

The first reason is that since the nature of P2P shared cars is that personal use is combined with sharing on a platform, a car will not be available on the moments that the car is used for personal trips. Since data was gathered by searching without indicating a time or date, cars were counted regardless of their availability at that exact moment. Cars that are for example only available during weekends or only during weekdays are thus all counted as equally available.

The second reason that might lead to an overrepresentation is that in many cities cars were shared on more than one P2P CSO. Since offering your car is often without any costs, this leads to the possibility that a single car is offered on more than one platform. Due to the nature of the data it was not possible to identify cars that were already counted on another platform. For this reason, some cars might be counted twice if they are shared on more than one platform leading to an overrepresentation of the number of cars within a city.

Another factor that should be kept in mind with regards to the total number of shared cars is that the aggregate number of cars of all cities within one country does not represent the total number of cars per country. The sample only contains cities with a population higher than 150.000. Smaller cities and rural areas are thus not included. Since almost in every city shared cars are found, it is expected that smaller cities will also have some shared cars. Although it is expected that the largest share of cars is within the larger cities, the aggregate number of cars for a country might slightly underrepresent the total number of shared cars within a country.

5.1.2 Measuring the success of P2P car-sharing

While in business to consumer car-sharing models the supply of cars is often closely linked to demand, this is not necessary the case for P2P car-sharing. The number of cars as an indicator for the growth of car-sharing used in this research does not reflect the actual usage of these cars. While some cars might be rented out regularly, others might not be rented out at all. Although this research illustrates in which cities there is a large supply of P2P cars, it does not indicate if these cars are actually used. P2P cars however tend to be more often used in cities compared to rural areas (Correspondence SnappCar, April 2016). The city level analysis conducted in this research thus show the number of vehicles that are expected to be more often used, since cars in rural areas are not taken into account, making it a good indicator for the success of P2P car-sharing.

Also, the demographic characteristics shown to be of importance for P2P car-sharing in this research mostly indicate the demographic characteristics of the supplier and not the user, since the number of shared cars is not a direct reflection of the user side.

5.1.3 Use of secondary data sources / official statistics

While the use of secondary data sources and official statistics has some practical advantages as saving considerable time and expenses and avoids the problem of reactivity in interview or survey data (Bryman, 2008), it does have some disadvantages. First of all, the cross-national nature of this research poses the question of the comparability of the data between countries. Although the Eurostat urban audit is used as the main source of data to ensure comparability, this database is constructed using data collected by the respective national statistics offices for each country. National differences in definitions, methodology, and year of data collection for certain variables might result in less comparable data.

Another remark often made with the use of official statistics is that of the “ecological fallacy”. This is the error of assuming that conclusions about individuals can be made from findings based on aggregate data (Bryman, 2008; Selvin, 1958). For this reason, the socio-demographic variables used might not truly reflect the socio-demographics on the individual level. An interesting direction for further research could be to see if the variables shown to be important in this research also hold on the individual level.

A remark related to this is that this research contained an analysis on the city level. This level of detail could result in that for example neighborhood differences within a city are less notable because an aggregate of all the neighborhoods are taken which might not completely reflect all the individual neighborhoods.

5.1.4 Historic city

One common critique on indicating a city as being a historic city is that changes throughout the years could influence the urban form of a historic city. For example, the severity to which a city is bombed in the Second World War could influence the existence of an old city center. It could be argued that if a city had a population of more than 10,000 inhabitants between 1500 and 1800, which is used to define a historic city in this research, this might not necessary reflect the presence of an old historic city center.

To account for this critique, a variable was constructed correcting for the cities, which were severely bombed during the second world war. However, this variable was not found to lead to any significant results. This could be explained by the fact that devastated cities through war, although there are some exceptions, were mostly rebuild in their old form, or at least following the same street network. (Brakman, Garretsen, & Schramm, 2004; Diefendorf, 2009; Hasegawa, 1999). When reconstruction efforts tend to mostly follow the patterns of the old city structure, it can be argued that the effects of war destruction are rather limited and the definition of a historic city taken in this research reflects the historic urban form correctly.

5.2 Theoretical implications

Coenen et al., (2012) stresses the importance of a more spatial perspective in transition literature and that the territorial embeddedness of institutional arrangements could explain regional differences. Also, the geographies of actor networks, transfer of knowledge, and the embeddedness in global networks are deemed to be of importance (Sengers & Raven, 2015).

By taking a spatial perspective in identifying niche activities within a context of a regime that differs spatially in how well it is established, this research tried to identify these spatial differences in the case of car-sharing. The niche and regime division and their interaction provided a useful way to frame the concepts relevant from theory to car-sharing. The insights gained from the results of measuring these concepts show the usefulness of using such a framework in this empirical case. This research also showed empirically that niche activities and regime presence indeed differ spatially both on the city and national level, confirming the importance of the spatial perspective in the MLP literature.

The results also demonstrate the importance of *platform actors* in the growth of the niche of P2P car-sharing. When there are more activities indicated by more platform providers, more shared cars tend to be found. The spatial differences in these actor activities thus form an important part in the niche (Sengers & Raven, 2015).

These results lead to the suggestion to have in future research a greater focus on how these platform actors operate geographically by examining the role of geographical proximity of platform providers. When an actor, in this case the platform provider, seeks to expand their business they might choose to do this first to places close to them. Boschma et al (2005) describe the importance of proximity for knowledge creation and innovation. Although not the only form of proximity relevant, geographical proximity might be relevant in the spreading of knowledge (Boschma, 2005). It may therefore be the case that when the platform spreads to another city, it first spreads to a city that is close to a city the platform is already active in. An event analysis of how these platform actors tend to operate and how they strategize to expand towards a new city or country could give more insight in the role of proximity in the expansion of car-sharing, and further deepen the insights in the spatial dimension of transitions.

Another theoretical implication that can be made from the results is that the results show that protective market niches, indicated by a university or an international city, do not explain the growth of a niche in P2P car-sharing. With market driven innovations, that need to be shielded from the selection environment of the regime, the protective (market) space is of great importance (Geels, 2001). However, the case of P2P car-sharing indicates that when the practice is less demand driven, which appears to be the case with P2P car-sharing, protective market spaces tend to play less of a role.

5.3 Policy implications

Although not directly derived from this research, the observed national differences indicate an influence of the institutional context on the national and city level. Legislation and policy related to car use and ownership could thus matter when a country or city wants to stimulate P2P car-sharing. Although further research is needed to identify the role of policy on P2P car-sharing, three policy implications can be directly derived from the obtained results.

First of all, that population density showed to have no influence on the adoption of P2P car-sharing indicates that P2P car-sharing is more scalable to less dense cities and suburban areas. Stimulating P2P car-sharing in those areas could thus lead to the further adoption of car-sharing in general in places where B2C car-sharing is not feasible due to limited demand.

Secondly, another factor that leads from this research is that P2P car-sharing is not really demand driven. Factors that indicate niche markets did not lead to an increase in shared cars. This suggests that if a city wants to increase the supply of P2P car-sharing, this does not necessarily work through stimulating demand. Rather stimulating the supply of car-sharing for example by discounting parking permits when offering a car on a P2P car-sharing platforms, might further stimulate the number of shared cars. However, since this research did not give any insight in the demand side of P2P car-sharing, it is hard to say if policy measures stimulating supply will actually result in an increase of the overall use of car-sharing.

Finally, the results showed that P2P car-sharing tend to be more successful in historic cities. Also, when more people tend to take public transport to work, more shared P2P cars are found in a city. Historic cities tend to favor more walking and cycling due to close commuting, and also the share of public transport tends to be larger when resident population is more concentrated (Schwanen, 2002; van de Coevering & Schwanen, 2006). Increasing the availability of public transport and steering urban planning in the direction of less car use by making neighborhoods more favored to walking or cycling might make people less car dependent which in turn could further stimulate P2P car-sharing.

5.4 Suggestions for further research

This research showed the importance of socio-demographic variables like age and level of education on the city level. Further research could test if these results hold on the individual level by conducting a survey among members of the P2P car-sharing community. Other socio-demographics, which were not available on the city level should then also be taken into account. For example, previous research indicates that income level can play an important role. Early adopters are found to have a higher level of income or wealth than later adopters (Rogers, 2003). However, in the case of car-sharing, Coll et al., (2014) showed a negative correlation between income and membership potential. What might explain this negative correlation is that car-sharing membership holds the promise of reducing the costs of private car use (Duncan, 2011) and could make a car accessible to lower income groups that did not have a car before. This however might not be the case for the supply of P2P shared cars, since you need to own a car to offer one on a platform. It would therefore be interesting to see how these sociodemographic factors are related to car-sharing on the personal level.

Since this research only gives insights into the supply side of P2P car-sharing, such a survey could also make a divide between members that offer their car and members that rent a car. Getting more insight in the socio-demographics of the group that rent a P2P car could also give more insight in the demand side of P2P car-sharing, possibly leading to insights on how to stimulate demand of P2P car-sharing. How the group that supply cars and the group that rent cars differ could thus be an interesting direction for further research.

Another direction for future research could be a case study for the city of Paris, France, which showed to be an outlier in the dataset used in this research. The large number of P2P cars observed in this city makes it an interesting case for a more in-depth analysis on for example the neighborhood level, to try to explain the success of P2P car-sharing in this particular city.

Finally, another suggestion for further research is to further identify the role of spatiality on the landscape level. While the landscape pressures identified in the theory section, like climate change and the economic crisis, are assumed to be constant geographically, it might be the case that these pressures are felt less on some places and more severe in others. For example, the effects of the recent global financial crisis had resulted in locally varying impacts and consequences (R. Martin, 2011). Future research could thus pay more attention to the spatial differences in the influence of seemingly global landscape pressures.

6 Conclusions

The aim of this research was twofold. The first aim was to describe the current state of P2P car-sharing in cities for the countries United Kingdom, The Netherlands, France, Germany and Belgium. By indexing the number of shared cars per city during November 2015 until January 2016 the total number of shared cars per city were identified under the P2P car-sharing model. It was illustrated that large national differences exist in the growth of P2P car-sharing per country. The second aim of this research was to explain the spatial differences in the growth of P2P car-sharing. Using a multi-level perspective, the spatial differences in the growth of car-sharing in cities were identified.

It was argued that when the current regime of personal car use is less established or more pressure is put on the regime, more cars tend to be shared on P2P platforms. Using a negative binomial regression model, the city level variables were identified that indicate the level of establishment of this regime of personal car ownership and use.

Cities where the regime of personal car use is less established generally have a larger share of people taking trips by public transport, and have a historic city center less suitable for car use. Surprisingly, population density showed to have no influence on the number of shared cars, which could indicate that P2P car-sharing is more scalable to less densely populated places, making P2P car-sharing a viable alternative to the B2C car-sharing model for more rural areas.

On the niche level, user groups, either through being *innovative*, or through *environmental and cultural values* were expected to be relevant. *Protective market niches* or *supporting policy* and activities from *platform actors* were also argued to be relevant to empower the niche.

User innovativeness, indicated by younger age (24-35yrs) and higher level of education showed to have a positive effect on the adoption of P2P car-sharing. The group 20-24 years of age showed to have a negative effect on adoption, which could be explained by the general lower level of car ownership with this age group making them unable to share a P2P car. The presence of one-person households also showed to be of importance, which might be explained by the fact that having no other members in the household, the demand for the car is lower, leading to idle capacity which can be shared on a P2P platform.

Although deemed relevant in previous research, environmental values and practices indicated by the percentage of "green" votes showed no effect on the number of shared cars on the city level. Also, protective market spaces indicated by either the internationality of the city or being a university city showed to be not important for the number of shared cars, indicating that P2P car-sharing tend to be less demand driven and more focused around a personal decision to share their car on a car-sharing platform. Activities of platform actors showed to be a significant contributor indicated by that more platform operators are active in a city (either P2P or B2C) more P2P shared cars are found which shows the importance of activities of actors to empower the growth of the niche.

This research identified and confirmed several city level factors influencing the success of P2P car-sharing adding to the literature on the growth of car-sharing, especially P2P car-sharing. Also, by showing the city and national differences in the success of car-sharing, it showed empirically the importance of a spatial perspective for niche and regime interactions in innovation research. For Future MLP research, paying attention to this spatial perspective could lead to a better understanding of development and spreading of innovation.

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9 List of Abbreviations

AIC	:	Akaike Information Criterion
B2C	:	Business-to-consumer
BE	:	Belgium
BIC	:	Bayesian Information Criterion
CBS	:	“Centraal Bureau voor de statistiek” (Dutch Central Bureau for statistics)
CSO	:	Car-sharing Operator
CWTS	:	Centre for Science and Technology Studies
DE	:	Germany
DEStatis	:	“Statistisches Bundesamt” (German Statistics Office)
EC	:	European Commission
EU	:	European Union
EUR	:	Euro
FR	:	France
GDP	:	Gross Domestic Product
GHG	:	Green House Gas
HHI	:	Herfindahl-Hirschman Index
Insee	:	“Institut national de la Statistique et des études économiques” (French National Institute for statistics)
ISCED	:	International Standard Classification of Education
MLP	:	Multi-Level Perspective
NL	:	The Netherlands
NUTS	:	Nomenclature of Territorial Units for Statistics
OECD	:	Organization for Economic Cooperation and Development
ONS	:	Office of National Statistics (United Kingdom)
OViN	:	“Onderzoek Verplaatsingen in Nederland” (Survey on means of transport in the Netherlands)
P2P	:	Peer-to-peer
Pop.	:	Population
PT	:	Public Transport
SD	:	Standard Deviation
UK	:	United Kingdom
VIF	:	Variance Inflation Factor

Appendix A: Full list of cities with more than 150,000 inhabitants

United Kingdom

City name	Population
London (greater city)	8,362,500
Greater Manchester	2,708,600
West Midlands urban area	2,446,600
Liverpool (greater city)	1,065,900
Tyneside conurbation	835,000
Leeds	759,600
Greater Nottingham	647,400
Glasgow	595,800
Sheffield	558,700
Bradford	525,500
Portsmouth (greater city)	525,200
Edinburgh	485,100
Leicester (greater city)	483,700
Bristol	435,000
Kirklees	426,900
Cardiff	350,100
North Lanarkshire	337,800
Cheshire West and Chester	330,600
Wakefield	328,700
Coventry	326,500
Wirral	320,300
Reading (greater city)	315,400
Doncaster	303,200
Belfast	281,100
Brighton and Hove	276,900
Sunderland	275,900
Medway	269,700
Southend-on-Sea (greater city)	263,700
Plymouth	258,600
Rotherham	258,500

City name	Population
Kingston-upon-Hull	257,400
Milton Keynes	254,000
Derby	251,000
Stoke-on-trent	250,100
Preston (greater city)	249,400
Southampton	240,800
Swansea	240,000
Barnsley	234,700
Aberdeen	226,100
Northampton	215,700
Swindon	213,000
Luton	206,900
Warrington	204,400
York	201,200
Stockton-on-Tees	192,800
Bournemouth	187,700
Peterborough	187,400
Bath and North East Somerset	178,900
Basildon	177,400
Colchester	176,800
Wycombe	173,600
Basingstoke and Deane	171,200
Chelmsford	169,800
Telford and Wrekin	168,100
Bedford	160,300
Thurrock	160,200
North East Lincolnshire	159,800
Maidstone	158,300
Falkirk	157,000
Oxford	153,700

The Netherlands

City name	Population	City name	Population
Amsterdam (greater city)	1,033,279	Almere	195,213
Rotterdam (greater city)	978,040	Breda	178,140
s-Gravenhage	505,856	Nijmegen	166,382
Utrecht	321,916	Enschede	158,627
Eindhoven	218,433	Apeldoorn	157,315
Tilburg	208,527	Haarlem	153,093
Groningen	195,418		

France

City name	Population	City name	Population
Paris (greater city)	6,707,750	Dijon	245,685
Lyon	1,321,495	Lens - Liévin	242,680
Lille	1,119,832	Nîmes	239,919
Marseille	1,045,805	Le Havre	237,066
Bordeaux	730,116	Metz	217,799
Toulouse	725,052	Caen	217,281
Nantes	602,853	Reims	209,421
Nice	520,990	Brest	206,661
Rouen	488,706	Saint Denis	199,243
Strasbourg	473,495	Limoges	198,109
Montpellier	434,189	Cergy-Pontoise	194,734
Toulon	425,609	Dunkerque	194,642
Rennes	408,428	Valenciennes	190,896
Grenoble	405,156	Lorient	186,967
Saint-Etienne	374,922	Le Mans	184,466
Aix-en-Provence	358,122	Versailles	181,024
Clermont-Ferrand	282,737	Besançon	177,517
Tours	280,405	Avignon	176,729
Orléans	275,083	Amiens	175,024
Angers	267,119	CA de Sophia-Antipolis	174,277
Perpignan	259,165	CC de la Boucle de la Seine	170,904
Nancy	256,004	Fort-de-France	162,081
Mulhouse	253,504	Douai	151,551

Germany

City name	Population
Berlin	3,421,829
Hamburg	1,746,342
München	1,407,836
Köln	1,034,175
Frankfurt am Main	701,350
Stuttgart	604,297
Düsseldorf	598,686
Dortmund	575,944
Essen	569,884
Bremen	548,547
Leipzig	531,562
Dresden	530,754
Hannover	518,386
Nürnberg	498,876
Duisburg	486,855
Bochum	361,734
Wuppertal	343,488
Bielefeld	328,864
Bonn	311,287
Münster	299,708
Karlsruhe	299,103
Mannheim	296,690
Augsburg	276,542
Wiesbaden	273,871
Gelsenkirchen	257,850
Mönchengladbach	255,430
Braunschweig	247,227

City name	Population
Chemnitz	242,022
Aachen	241,683
Kiel	241,533
Halle an der Saale	231,565
Magdeburg	231,021
Krefeld	222,058
Freiburg im Breisgau	220,286
Lübeck	212,958
Oberhausen	209,097
Erfurt	204,880
Mainz	204,268
Rostock	203,431
Kassel	194,087
Hagen	185,996
Saarbrücken	177,201
Hamm	176,048
Mülheim a.d.Ruhr	166,640
Ludwigshafen am Rhein	161,518
Potsdam	161,468
Leverkusen	160,819
Oldenburg (Oldenburg)	159,610
Osnabrück	156,315
Solingen	155,768
Herne	154,417
Heidelberg	152,113
Neuss	151,070

Belgium

City name	Population
Bruxelles / Brussel	1,174,624
Antwerpen	512,230
Gent	249,754

City name	Population
Charleroi	204,826
Liège	382,009

Appendix B: Full list of P2P car-sharing operators

Name	Country	Business Model	Website address:
easyCar club	United Kingdom	P2P	https://carclub.easycar.com/
Rentecarlo	United Kingdom	P2P	https://www.rentecarlo.com/
Ridelink	United Kingdom	P2P	https://ridelink.com/
Snappcar	The Netherlands	P2P	https://www.snappcar.nl/
WeGo	The Netherlands	P2P	http://www.wego.nu/
MyWheels P2P	The Netherlands	P2P	https://mywheels.nl/
MyWheels ANWB	The Netherlands	P2P	https://mywheels.nl/
Koolicar	France	P2P	https://www.koolicar.com/
Drivy	France	P2P	https://www.drivy.com/
Ouicar	France	P2P	https://www.ouicar.fr/
Drivy	Germany	P2P	https://www.drivy.de
Tamyca	Germany	P2P	https://www.tamyca.de
Snappcar	Germany	P2P	https://www.snappcar.de/
CarUnity (p2p)	Germany	P2P	https://www.carunity.com/
Autodelen (Autopia)	Belgium	P2P	http://www.autodelen.net/
CarAmigo	Belgium	P2P	https://www.caramigo.be/nl
Tapazz	Belgium	P2P	https://tapazz.com
Dégage	Belgium	P2P	http://www.degage.be/autodelen/

Appendix C: Full list of B2C car-sharing operators

Name	Country	Business Model	Website address:
City Car Club	United Kingdom	B2C	http://www.citycarclub.co.uk/
Zipcar	United Kingdom	B2C	http://www.zipcar.co.uk/
DriveNow	United Kingdom	B2C	https://uk.drive-now.com/
Hertz 24/7	United Kingdom	B2C	https://www.hertz247.com/netherlands/nl-nl/Location
Co-wheels	United Kingdom	B2C	http://www.co-wheels.org.uk/
ecar	United Kingdom	B2C	http://www.e-carclub.org/locations/
SammSamm	The Netherlands	B2B	http://www.sammsamm.nl/
MyWheels B2C	The Netherlands	B2C	https://mywheels.nl/
Greenwheels	The Netherlands	B2C	https://www.greenwheels.com
Connectcar	The Netherlands	B2C	http://www.connectcar.nl/
Car2go	The Netherlands	B2C	https://www.car2go.com/nl/
Studentcar	The Netherlands	B2C	http://www.studentcar.nl/
Zipcar	France	B2C	http://www.zipcar.com
Autolib	France	B2C	https://www.autolib.eu/en/
KeyLib	France	B2C	http://keylib.fr/voitures-2/
Bluecub	France	B2C	https://www.bluecub.eu/en/
Bluely	France	B2C	https://www.bluely.eu/en/
Citiz	France	B2C	http://citiz.coop/stations
Mobigo Autopartage	France	B2C	http://mobigo.citiz.coop/
Citélib	France	B2C	http://citelib.com/
Autocité+	France	B2C	http://www.sara-angers.fr/deplacement/autocite-plus-angers-autocite+.php
Lilas Autopartage	France	B2C	http://www.lilas-autopartage.com/
City Roul	France	B2C	http://www.cityroul.com/nos_stations/
Marguerite	France	B2C	http://www.imarguerite.com/particuliers/stations
Auto Bleue	France	B2C	https://www.auto-bleue.org/fr/les-stations
Modulauto	France	B2C	http://www.modulauto.net/index.php/les-voitures
TOTEM mobi	France	B2C	http://www.totem-mobi.fr/
Communauto	France	B2C	https://www.communauto.paris/
AutoCité	France	B2C	http://autocite.besancon.fr/site-web/stations.html
Cambio	Germany	B2C	http://www.cambio-carsharing.de/?l=en

Stattauto Munchen	Germany	B2C	http://stattauto-muenchen.de/alle_stationen.shtml
DB Flinkster	Germany	B2C	https://www.flinkster.de/
Car2Go	Germany	B2C	www.car2go.com
DriveNow	Germany	B2C	https://de.drive-now.com/
Multicity	Germany	B2C	https://www.multicity-carsharing.de/
citeecar	Germany	B2C	https://www.citeecar.com/Home
Stadtmobil	Germany	B2C	http://www.stadtmobil.de/
Quicar	Germany	B2C	https://web.quicar.de/navigation_links/so_gehts/pages/unsere_stationen
teilAuto	Germany	B2C	http://teilauto.dbcarsharing-buchung.de/
Book-n-Drive	Germany	B2C	https://book-n-drive.dbcarsharing-buchung.de
Greenwheels	Germany	B2C	https://www.greenwheels.com/book/search/search
Hertz 24/7	Germany	B2C	https://www.hertz247.com/hourly-car-rental-locations/de/deutschland/
Share a Starcar	Germany	B2C	https://www.share-a-starcar.de/de/carfinder.html
Stadtwerke Augsburg Carsharing	Germany	B2C	https://www.swa-carsharing.de/
BeiAnrufAuto e.V.	Germany	B2C	http://www.beianrufauto.de/doc/InfoBeiAnrufAuto.html
Stattauto Bonn	Germany	B2C	http://www.stattauto.com/
Willmobil	Germany	B2C	http://willmobil.de/stationenkarte.htm
Stattauto Kiel & Lübeck	Germany	B2C	http://www.stattauto-hl.de/
My-e-car	Germany	B2C	https://www.my-e-car.de/de/standorte/standortfinder.html
Grüne Flotte	Germany	B2C	http://www.gruene-flotte-carsharing.de/stellplaetze/
Stadtmobil Südbaden	Germany	B2C	https://www.stadtmobil-suedbaden.de/fuhrpark-standorte/
Stattauto Kassel	Germany	B2C	http://stattauto.net/
Flexicar	Germany	B2C	http://www.flexicar.de/stationen/leverkusen/
Stadtteilauto München	Germany	B2C	http://www.stadtteilauto.de/
Stadtteilauto Carsharing Münster	Germany	B2C	http://www.stadtteilauto.com/index.htm
Stadtteilauto Carsharing Osnabrück	Germany	B2C	http://www.stadtteilauto.info/
Move About	Germany	B2C	http://www.move-about.de/Standorte
sGO! Solingen	Germany	B2C	http://www.sgo-carsharing.de/
Drive carsharing	Germany	B2C	https://drive-cs.dbcarsharing-buchung.de/
Ford-carsharing	Germany	B2C	http://www.ford-carsharing.de/

Einfach mobil	Germany	B2C	http://www.einfach-mobil.de/
CarUnity	Germany	B2C	https://www.carunity.com/
App2drive	Germany	B2C	https://www.app2drive.com/
Cambio	Belgium	B2C	http://www.cambio.be/
Zencar	Belgium	B2C	https://www.zencar.eu/nl/

Appendix D: Correlation matrix

	Log of P2P cars	Log of B2C cars	# of registered cars (x1000)	# of registered cars per capita (x100)	Population density (popx100/km2)	% of journeys by PT	% of pop. 20-24 years	% of pop. 25-34 years	% of pop. 35-44 years	% of pop. qualified at level 5 or 6 ISCED	% one-person households	% of green votes	B2C CSO present	Bikesharing present	Historical city	University city	Airport present	Herfindahl index P2P	Sectoral Policy	Vehicle Theft	Belgium	Germany	France	The Netherlands	United Kingdom
Log of P2P cars	1																								
Log of B2C cars	.436**	1																							
# of registered cars	.460**	.440**	1																						
# of registered cars per capita (x100)	.197**	-.462**	-.222**	1																					
Population density (popx100/km2)	.211**	.462**	.490**	-.552**	1																				
% of journeys by PT	.459**	.655**	.580**	-.352**	.581**	1																			
% of pop. 20-24 years	.213**	.179*	-.023	-.208**	.104	.015	1																		
% of pop. 25-34 years	.247**	.597**	.240**	-.556**	.464**	.431**	.529**	1																	
% of pop. 35-44 years	-.111	.265**	.177*	-.328**	.372**	.291**	-.382**	.289**	1																
% of pop. qualified at level 5 or 6 ISCED	.502**	.518**	.247**	-.144	.260**	.433**	.458**	.553**	.135+	1															
% one-person	.420**	.655**	.081	-.195**	.247**	.419**	.236**	.385**	-.101	.415**	1														
% of green votes	.231**	.585**	.056	-.139+	.175*	.441**	.213**	.392**	.051	.328**	.599**	1													
B2C CSO present	.036	.566**	.134+	-.333**	.257**	.198**	.129+	.325**	.194**	.177*	.257**	.209**	1												
Bikesharing present	.446**	.538**	.180*	-.095	.207**	.379**	.158*	.262**	.021	.290**	.569**	.403**	.277**	1											
Historical city	.538**	.350**	.242**	-.082	.107	.280**	.373**	.277**	-.281**	.440**	.361**	.257**	.099	.259**	1										
University city	.302**	.695**	.306**	-.451**	.335**	.431**	.441**	.556**	.022	.489**	.462**	.389**	.392**	.452**	.416**	1									
Airport present	.442**	.408**	.287**	-.047	.127+	.291**	.335**	.286**	-.221**	.251**	.429**	.329**	.099	.323**	.437**	.469**	1								
Herfindahl index P2P	-.302**	-.280**	-.111	.011	-.002	-.260**	-.026	-.167*	.054	-.197*	-.308**	-.288**	-.111	-.246**	-.198**	-.126+	-.100	1							
Sectoral Policy	.536**	.663**	.247+	-.407**	.491**	.458**	.209	.674**	.289*	.511**	.564**	.533**	.214	.423**	.298*	.497**	.283*	-.298*	1						
Vehicle Theft	.476**	-.114	.410**	.261**	-.048	.118	.014	-.061	-.166+	.083	-.413**	-.237*	-.152	-.152	.244**	.023	.119	.043	.186	1					
Belgium	.034	.111	.020	-.022	.149*	.039	-.083	.138+	.070	-.022	.115	.150*	.082	-.045	.065	.113	.103	.029	.294*	.066	1				
Germany	-.131	.455**	-.057	-.197**	.071	.333**	-.213**	.114	.062	-.063	.606**	.547**	.281**	.318**	-.067	.177*	.065	-.273**	.204	-.414**	-.111	1			
France	.604**	-.219**	.080	.645**	-.257**	.035	.123	-.265**	-.410**	.123	-.023	-.055	-.411**	.092	.283**	-.170*	.209**	-.094	-.119	.493**	-.101	-.387**	1		
The Netherlands	.186*	.121	-.067	-.239**	.217**	-.138+	.142+	.173*	.236**	.260**	.218**	-.185*	.135+	.265**	-.045	.083	-.107	.076	.146	-.268**	-.048	-.184*	-.167*	1	
United Kingdom	-.547**	-.343**	.011	-.268**	-.003	-.291**	.043	-.009	.165*	-.195*	-.726**	-.428**	.006	-.523**	-.195**	-.099	-.235**	.298**	-.340**	.413**	-.122	-.468**	-.424**	-.202**	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

+. Correlation is significant at the 0.10 level (2-tailed).