THE RELATIONSHIP BETWEEN PUBLIC AND PRIVATE BICYCLE USE: THE CASE OF SEVILLE

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ABSTRACT:
Despite the success achieved by Public Bicycle Sharing Systems (PBSS) across the world, several researchers provide evidence on their limitations and constraints in a medium-long term, and bicycle ownership may be considered as a complementary tool to promote a 'bicycle-culture'. This paper aims to cover the gap about the interaction between both systems (public bicycle / private bicycle) and which are the key aspects to explain the bicycle-buying decision. After a fieldwork based on surveys conducted in Seville (Spain), one of the cities currently acknowledged worldwide for its successful policy of promoting cycling, we apply a Discrete Choice Model. Our findings show that among the socio-demographic factors that favor the move from the PBSS to the private bicycle are: having a higher level of education, being more progressive ideologically-speaking, and being a resident of the city itself; while age and gender do not appear to be conclusive. Experienced users, for whom the bicycle is a part of his /her healthy lifestyle, state a greater willingness to buy a bicycle. And the main obstacles to make the jump from the PBSS to the private bicycle, and that any action plan to support private bicycle usage should take into account, are: the lack of proper parking at the origin/destination, and fear of theft.

KEYWORDS: Public Bicycle Sharing System**,** Bicycle Ownership, Bicycle-buying decision, Cyclists' perceptions, Discrete Choice.

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1. Introduction.

The rise in motorization in developed countries since the second half of the 20th century has contributed towards raising citizens' quality of life, but at the same time has given rise to negative externalities, such as energy dependency, traffic congestion, and damage to the environment and public health (Rietveld, 2001). Alternatively, non-motorized means of transport, such as the bicycle, are regarded as synonymous with health and energy savings and efficiency, as a growing number of research studies have shown (Castillo-Manzano and Sánchez-Braza, 2013a, 2013b; Krizek, 2007; Martens, 2007; Moudon et al., 2005; Sener et al., 2009, amongst others).

Pucher et al. (2010) and Yang et al. (2010) review the actions undertaken by governments worldwide to promote bicycle use with the *Public Bicycle-Sharing System* (PBSS) standing out. Having originated in northern European countries, such as the Netherlands and Denmark, PBSSs have achieved high levels of popularity in recent years around the periphery of Europe, and have acquired the status of a veritable *urban mode of transport* (Anaya and Castro, 2012).

Despite their success, some research exists that restrict the benefits of PBSSs in the short term; once the investment has been made and the initial *boom* starts to fade away, demand can stagnate, causing major limitations, as addressed by authors such as Bouf and Hensher (2007), Castillo-Manzano and Sánchez-Braza (2013a, 2013b), Fishman et al. (2012, 2013), Lin and Yang (2011). Of these, the most important are: poor quality of service due to a lack of comfort and units in a poor state of repair; the inappropriate location of stations for intermodality; non-competitive cost; the inflexibility of the timetable; a lack of agility in the granting of loans and the return of deposits; an oversubscribed or congested system; break-downs and damage caused by vandalism; issues with redistribution from full to empty stations; time and space restrictions on the user, who cannot take bicycles outside the designated area or exceed the time limits on usage and/or legal constraints (compulsory helmet use). Authors such as Lin and Yang (2011), Lin et al. (2013) and Nakamura and Abe (2014) analyze other limitations of PBSSs with respect to urban planning (especially in city centers), the need for sufficient available space to install the number of racks required to cover the demand for bicycles, and the other inconveniences that they might cause by hindering or obstructing other leisure activities.

According to Anaya and Castro (2012), all these circumstances cover PBSSs in uncertainty, especially in the current framework of budgetary constraints. Thus, although the public bicycle may boast many advantages over bicycle ownership (users do not need to worry about theft or vandalism, the existence of a place to park at the trip origin and destination, and bicycle maintenance; see Fishman et al., 2012 and Rietveld and Koetse, 2003), on its own it cannot achieve the full development of the bicycle as a system of urban transport. In fact, previous studies such as Aldred and Jungnickel (2013) and Maness (2012) provide evidence that bicycle ownership may be a proxy indicator of a tendency towards a greater frequency of trips being made by bicycle, as a

result of which the private bicycle may be considered as a complementary tool to promote a 'bike-culture'.

A literature review shows how, in comparison to the widespread interest aroused by PBSSs (Fishman et al., 2013; Pucher et al., 2010; Shaheen et al., 2010; Yang et al. 2010, among many others), bicycle ownership has been less often studied and usually associated with bicycle use (Xing et al., 2010). In this respect, Handy et al. (2010) find links between determinants of both bicycle ownership and bicycle use on three levels: 1) the user's individual profile (with a broad analysis of socio-demographic characteristics, such as age, gender, education, income level etc., by Emond et al., 2009; Owen et al., 2010 and Pinjari et al., 2009 and, to a lesser extent, of personal preferences and attitudes, such as lifestyle, health and environmental-related issues or economic aspects by Geus et al., 2008 and Moudon et al. 2005); 2) social structure, based on cultural norms, ideologies, habits and traditions that might encourage / discourage cycling (e.g., Gatersleben and Haddad, 2010 explain how promoting public cycling has changed social perception of the bicycle; Beck and Immers 1994 consider the bicycle theft problem; McCarthy (2011) examines a certain "*anti-bike culture*"; Delbosc and Currie (2013), analyze the decline in young people in developed countries taking out their driving licenses); 3) elements of the infrastructure and the physical environment that go from the obstacles that the terrain presents and correct adaption to the urban space (Heinen et al., 2010; Larsen et al. 2013; Sallis et al., 2013; Snizek et al., 2013) to the positive implementation of specific facilities for cyclists at trip origin/destination (lockers, changing rooms, showers (Hunt and Abraham, 2007); and, above all, safe bike-parking and storage (Salleh et al., 2014) in public/private spaces (Aldred and Jungnickel, 2013) and facilitating intermodality with other means of urban transport (Rietveld, 2001)).

Although the studies cited provide conclusions as to the determinants of both bicycle ownership and bicycle commuting, we agree with Chatterjee et al. (2013) and Fishman et al. (2013) that this is still a recent topic with major shortcomings. One is clearly the interaction between PBSSs and the private bicycle. In fact, the only precedent found is the analysis by Buck et al. (2013) of the user profile for the two systems, although said study does not consider the relationship between the two. Finally, Bouf and Hensher (2007) report on the possible *knock on effect* of the PBSS in the city of Lyon, which results in higher sales and use of private bicycles.

The motivation for this paper is, therefore, to fill the knowledge gap concerning the opinions and attitudes of users (members of a PBSS) regarding barriers and facilitators for the transition to bicycle-buying decisions. According to Damant-Sirois et al. (2014) and Handy et al. (2014), user perception may determine this trend. We therefore understand that specific field study-based analyses using interviews to collect data on demographic aspects, mobility patterns and trip preferences could shed some light on the possible indirect impact of PBSSs on the bicycle-buying decision.

In short, our paper takes a new approach and analyzes the relationship between the public bicycle and the private bicycle by testing the way that they complement each other and that one is substituted for the other, and determining the factors that influence the choice of their alternative or joint use through fieldwork based on surveys and treated with a Discrete Choice Model. The structure is the following: after this introduction, Section 2 lays out the empirical framework and the methodology for the case under study, the city of Seville (Spain); Section 3 includes the estimation results and discussion, and Section 4 presents the conclusions.

2. Empirical framework.

2.1. Case study and sampling.

The database was created using surveys of PBSS users in Seville, Spain. Recent years have seen a major transformation of Seville's (pop.704,980) urban space into a sustainable mobility model. Since 2007, bicycle promotion has stood out, with measures such as the construction of a 140 kilometer bicycle lane network and the implementation of a PBSS, named *SEVICI*, with 260 stations, 2,650 *smart-bikes* and 5,163 tracks, managed by the JCDecaux company. The success of these policies has meant that the city is currently in fourth place worldwide in the prestigious *Copenhagenize Index* (Copenhagenize, 2013), only behind Amsterdam, Copenhagen and Utrecht. It is also singled out by experts in sustainable mobility, such as the European Environment Agency (2013), Lonely Planet (2012) and Reuters (2012). The latest acknowledgment it has received was awarded by the US tv channel CNN, which in August 2014 placed Seville second in the World's Best Cycling Cities (http://edition.cnn.com/2014/08/17/travel/best-cycling,-cities/).

Returning to the present research, the survey campaign was conducted in three successive waves, so as to prevent any distortion that might be caused by an unforeseen exogenous event (such as a weather anomaly for the time of year, whether due to cold or heat, for example). The total size of the sample was 505 surveyees. Specific data regarding the survey campaign are given in Table 1.

Table 1. Technical data of survey given to users of Sevillian PBSS (SEVICI)

Field work	Place	Random selection of smart bicycle stations		
	Period	June-13	November-13	February-14
How information was obtained	Interview with closed questionnaire	21 questions		
	Universe	Users of 'SEVICI' PBSS		
Sampling	Sample size	95	222	188
	Sampling method	Random selection of users returning bicycles at the above-mentioned smart bicycle stations		

The variables were generated on the basis of the 21 items surveyees were asked and were grouped into four categories. These are shown in Table 2 together with their

corresponding descriptive statistics. The items selected are based on previous research and to a large degree relate to factors affecting both bicycle ownership and bicycle use already commented in the Introduction Section:

a) individual demographic and socioeconomic user details, e.g., gender (Emond et al., 2009; Handy et al., 2010) and age (Owen et al., 2010; Xing et al., 2010); economic level, residence and level of education (as in Pinjari et al., 2009; Pinjari et al., 2011); and political and ideological preferences (following Danyluk and Ley, 2007; Heinen et al., 2010).

b) Relationship with PBSS: in line with a similar previous study (Buck et al., 2013), temporal factors have been considered, such as the user's experience and whether he/she is a short-term or annual PBSS member, and the level of satisfaction assigned to the PBSS.

c) purpose of trip: following prior research, such as Beck and Immers (1994) and Buck et al. (2013), shopping, sport and recreational activities, work and school commuting are considered, as well as other intermodality-related issues (Cheng and Liu, 2012; Pucher et al., 2011).

d) reasons for riding a bicycle: as in Handy et al. (2010), Geus et al. (2008) and Moudon et al. (2005), aspects associated with lifestyle, ecology, economics and health awareness are examined (it is cheaper, healthy, better for the environment, to avoid traffic congestion, etc.).

Table 2. Explanatory variables and their descriptive statistics.

VARIABLE	*DESCRIPTION*	**No. obsv.**	**Mean**	**Std. Dev.**
a) Personal characteristics				
a.1. gender	1 if male; 0 if female.	294	0.582	0.494
a.2. age	Age of person surveyed.	-	26.802	10.748
a.3.education	1 if no formal education; 2 if school leaving certificate; 3 if high school diploma or professional training ; 4 if shorter graduate degree; 5 if longer licentiate degree; 6 if PhD.	-	3.352	0.899
a.4. resident	1 if resident in city of Seville; 0 otherwise.	410	0.812	0.391
a.5. worker	1 if worker; 0 otherwise.	137	0.271	0.445
a.6. student	1 if student; 0 otherwise.	276	0.547	0.498
a.7. Francostrs	1 if agrees that references to Franco Dictatorship (1939-	242	0.479	0.500

	1975) should be removed from street names; 0 otherwise.			
b) Relationship with SEVICI PBSS				
b.1. experience	if SEVICI user for 1 if less than 6 months; 2 if from 6 months to a year; 3 if for over a year.	-	2.412	0.834
b.2. type of pass	1 if has a short-term pass (7 days); 0 if has a long-term pass (yearly).	39	0.077	0.267
b.3. comfortSEVICI	Scoring of comfort of SEVICI public bicycle, from 0 to 10.	-	6.844	1.738
c) Bicycle use				
c.1. work/studies	1 if uses bicycle to commute to place of work or study; 0 otherwise.	413	0.824	0.381
c.2. shopping	1 if uses bicycle for shopping; 0 otherwise.	93	0.186	0.389
c.3. sport	1 if uses bicycle for sport; 0 otherwise.	84	0.168	0.374
c.4. leisure	1 if uses bicycle as a leisure activity or simply for enjoyment; 0 otherwise.	105	0.210	0.407
c.5. usage	Number of times that uses bicycle per week.	-	6.053	3.446
c.6. substitutability	1 if continues to use bicycle in bad weather; 0 if on such occasions changes to other type of public or private transport.	44	0.087	0.283
c.7. intermodality	1 if only uses bicycle for trips; 0 if combines bicycle with some other type of public or private transport.	276	0.547	0.498
c.8. helmet	1 if thinks that helmet-use should not be compulsory for SEVICI users; 0 otherwise	146	0.290	0.454
d) Reasons for using the bicycle: scoring of reasons for choosing the bicycle as mode of transportation in Seville (from 0 to 10).				
d.1. healthy	To do exercise and for health reasons.	-	7.554	2.226
d.2. environment	Benefits to the environment.	-	7.905	4.318
d.3. avoidtraffconges	To avoid urban traffic congestion.	-	7.755	2.320
d.4. cheap	It is a cheap mode of transportation.	-	8.487	1.560
d.5. lifestyle	It is a lifestyle choice.	-	6.093	2.601

d.6. ease of use	Easy to take out and return bicycles.	-	7.126	2.229

2.2. Model.

The models used in this study seek to analyze the substitution or complementarity relationship that exists between public and private bicycles from the point of view of PBSS users in Seville (SEVICI) by analyzing two questions. Firstly, logit and probit estimations are used to study the factors that influence the decision of PBSS users who do not own private bicycles to buy one. Secondly, a bivariate probit model is applied to analyze the determinants of the responses that public bicycle users give to the question as to why they are not contemplating buying their own bicycle. This second category of models is especially designed for cases like ours where two questions with very closely linked binary answers need to be answered, that is, when everything seems to point to their being influenced by the same factors and, therefore, both dependent variables vary as one.

Discrete choice models have been used in recent studies on the bicycle, including Castillo-Manzano and Sánchez-Braza (2013a, 2013b), Maness (2012), Moudon et al. (2005), and Zhang et al. (2014), among others.

3. Results and discussion.

Table 3 shows the preferences of PBSS users in Seville (SEVICI) surveyed during the three waves commented regarding the use of private bicycles.

Table 3. Responses from SEVICI users to the questions in the interview campaign.

User Category			% of Total		
			100%	**100%**	
1	**Owned private bicycle before using SEVICI**		51.88%	-	
1.1	Used own private bicycle before using SEVICI			-	
1.1.1.	Continues to use own private bicycle in conjunction with SEVICI			32.87%	
1.1.2.	Has stopped using own private bicycle and only uses SEVICI			12.48%	
1.2.	Did not use own private bicycle before using SEVICI			6.53%	**% of Category 2**
2	**Did not own private bicycle before using SEVICI**		48.12%	-	**100%**
2.1.	Has purchased bicycle or planning to buy one soon			7.92%	16.46%
2.2.	Is not planning to buy another bicycle			40.20%	83.54%

Table 4 presents the logit and probit estimations for the factors that would determine whether SEVICI users who did not previously own private bicycles (category 2 in Table 3) decide to purchase one. As estimated coefficients in logit and probit

models, and in discrete demand models in general, cannot be interpreted directly, the marginal effects have been calculated at the mean.

Table 4. Logit / Probit estimations of the marginal effects at the mean of SEVICI users' decision to PURCHASE a bicycle.

Variables	Bicycle-purchasing decision	
	Logit Regression	Probit Regression
a.1. gender	Δ 0.593% (4.306)	Δ 0.420% (4.885)
a.2. age	Δ 0.003% (0.385)	∇ 0.029% (0.392)
a.3.education	Δ 2.730%* (1.480)	Δ 3.608%*** (0.885)
a.4. resident	Δ 8.322%*** (2.645)	Δ 9.040%*** (2.846)
a.5. worker	∇ 0.044% (2.145)	∇ 0.039% (1.619)
a.6. student	Δ 2.353% (5.287)	Δ 1.983% (4.728)
a.7. Francostrs	Δ 8.111%*** (1.947)	Δ 9.086%*** (2.355)
b.1. experience	Δ 2.581%*** (0.954)	Δ 2.449%** (1.079)
b.2. type of pass	Δ 6.243%* (3.295)	Δ 4.978%* (2.568)
b.3. comfortSEVICI	∇ 4.940%*** (0.818)	∇ 5.388%*** (0.820)
c.1. work/study	Δ 7.167%* (3.655)	Δ 8.465%** (3.367)
c.2. shopping	∇ 0.801% (4.487)	∇ 1.076% (5.035)
c.3. sport	Δ 16.436%*** (5.830)	Δ 17.504%*** (6.294)
c.4. leisure	Δ 2.007% (2.021)	Δ 2.303% (2.137)
c.5. usage	∇ 0.356% (0.397)	∇ 0.424% (0.459)
c.6. substitutability	∇ 1.124% (4.188)	∇ 2.277% (5.437)
c.7 intermodality	∇ 2.367% (4.773)	∇ 2.097% (4.901)
c.8 helmet	Δ 4.121% (8.690)	Δ 4.560% (8.365)
d.1. healthy	Δ 0.767% (1.271)	Δ 0.989% (1.240)
d.2. environment	∇ 0.657% (0.936)	∇ 1.030% (1.095)
d.3. avoidtraffconges	∇ 2.485%*** (0.677)	∇ 2.717%*** (0.778)

d.4. cheap	Δ 0.510% (0.956)	Δ 0.654% (1.131)
d.5. lifestyle	Δ 2.391%*** (0.715)	Δ 2.500%*** (0.737)
d.6. easeofuse	Δ 1.268%** (0.638)	Δ 1.280%** (0.494)
No. observations	239	239
Log. Pseudolikelihood	-84.361583	-84.474408
Pseudo R2	0.2066	0.2056
Wald Chi2 (*p-value without clustering*)	43.94 (0.0077)	43.72 (0.0082)

Notes: standard errors in brackets robust to heteroscedasticity and clustered by waves of survey.
*p≤0.1; **p≤0.05; ***p≤0.01.

Table 5 shows non-exclusive reasons (i.e., the surveyees may have chosen more than one option) given by SEVICI users who do not own private bicycles for not wanting to purchase one, bearing in mind the findings in the previous literature commented in the Introduction section for both bicycle ownership and usage (Handy et al., 2010; Van Lierop et al., 2014; Xing et al., 2010).

Table 5. Responses of non private bicycle-owning SEVICI users as to motives for not purchasing one

Non exclusive motives for NOT PURCHASING a bicycle (Category 2.2)	**% of Category 2.2**
1. The bicycle that they wish to purchase is very expensive	6.90%
2. There is nowhere to park their bicycle at home and/or at their destination	57.14%
3. Fear of private bicycle being stolen	45.81%
4. Ease of use of SEVICI compared to private bicycle	49.26%
5. SEVICI covers the user's needs	48.77%

Our analysis will focus on motives 2 and 3 in Table 5 (*There is nowhere to park their bicycle at home and/or at their destination; Fear of private bicycle being stolen)* given the little importance of the first (price of bicycles) and as it would be illogical to act on the last two relating to the good quality of the PBSS, since it would not make sense to lower the price of the PBSS to facilitate transfer to the private bicycle.

A priori, according to the literature (e.g., Handy et al., 2010; Nielsen et al., 2013; Rietveld and Daniel, 2004; Van Lierop et al., 2014; Xing et al., 2010) it can be assumed that motives 2 and 3 are foreseeably mutually related, as the need to have a place to keep the bicycle both at trip origin and destination is at least in part aimed at preventing theft. This justifies using the bivariate probit.

Thus, Table 6 presents the bivariate probit estimations of the factors that would justify public bicycle users not wishing to own a private bicycle, either because they

have nowhere to keep it at the place of trip origin and/or destination, or because they are afraid that it might be stolen.

TABLE 6. Bivariate probit estimations of the elasticity of SEVICI users' decision NOT TO PURCHASE a bicycle

Variables	Motive for NOT PURCHASING a bicycle	
	Nowhere to park at trip origin or destination	Fear of theft
a.1. gender	∇ 3.995%*** (1.243)	Δ 8.984% (5.584)
a.2. age	∇ 0387% (0291)	∇ 0.550%*** (0.062)
a.3.education	Δ 13.602%*** (4.536)	Δ 5.492%** (2.502)
a.4. resident	∇ 20.667%*** (6.073)	∇ 4.056% (9.698)
a.5. worker	∇ 9.215% (7.136)	Δ 6.746% (8.542)
a.6. student	Δ 13.326%** (6.725)	Δ 12.809% (11.332)
a.7. Francostrs	∇ 0.341% (5.031)	∇ 8.580% (7.178)
b.1. experience	Δ 5.478% (4.660)	∇ 2.137% (2.710)
b.2. type of pass	Δ 3.923% (10.7779	∇ 17.724%*** (5.895)
b.3. comfortSEVICI	∇ 2.161% (2.227)	Δ 0.242% (3.079)
c.1. work/study	Δ 5.669% (8.478)	Δ 9.085% (9.387)
c.2. shopping	∇ 8.290% (5.233)	∇ 10.663% (6.680)
c.3. sport	Δ 15.027% (10.317)	Δ 22.552% (16.526)
c.4. leisure	∇ 9.177% (18.098)	∇ 4.598% (29.079)
c.5. usage	Δ 0.342% (0.924)	∇ 0.975% (0.903)
c.6. substitutability	Δ 13.393% (11.992)	∇ 9.237% (11.811)
c.7. intermodality	Δ 15.669%*** (5.745)	Δ 10.010%*** (1.136)
c.8. helmet	Δ 1.264% (9.745)	Δ 12.425%* (7.531)
d.1. healthy	Δ 4.208%*** (1.276)	Δ 1.318% (2.018)

d.2. environment	∇ 3.785% (3.410)	∇ 3.400%* (1.312)
d.3. avoidtraffconges	Δ 5.504% (4.338)	Δ 3.120% (3.684)
d.4. cheap	Δ 4.380%*** (1.382)	Δ 4.701%*** (0.9649
d.5. lifestyle	∇ 2.330%*** (0.8919)	∇ 3.357%*** (0.176)
d.6. easeofuse	∇ 1.182%*** (0.227)	∇ 6.044% (2.456)
No observations	200	
Log. Pseudolikelihood	-239.90658	
Rho (Wald test of Rho =0**)**	0.1715 (38.087***)	

Notes: standard errors in brackets robust to heteroscedasticity and clustered by waves of survey.
*p≤0.1; **p≤0.05; ***p≤0.01.

The following findings inferred from the preceding tables stand out:

1. Table 3 shows the broad heterogeneity of PBSS users with respect to the relationship between the private and the public bicycle, which means that it is difficult to make generalizations.

In general terms, it can be seen that over half the users surveyed (55%) had not used private bicycles previously; of these, the vast majority (48%) had not done so because they did not own one. As was expected on the basis of previous studies (Fishman et al., 2012) the natural strength of PBSSs for driving up use and frequency has been confirmed; i.e., for expanding the market, with a "*knock on effect*" on demand similar to that recorded in other transport sectors, such as low cost airlines on air transport (Castillo-Manzano et al., 2012), for example, the high-speed train on rail passenger transport (Givoni, 2006), and container-carriers on maritime goods transport (Notteboom and Rodrigue, 2008). To summarize, we are talking of a real revolution in non-motorized urban transport that manages to broaden demand for trips using a specific mode, the bicycle.

2. No clear evidence can be found that the PBSS acts as a bridge towards the private bicycle, which, logically, would contribute to relieving the PBSS congestion problem (as reported by Nakamura and Abe, 2014, for Japanese cities). In fact, according to Table 3, only 16.5% of SEVICI users that did not own a private bicycle (and that were therefore totally dependent on the public system) have purchased one or are planning to purchase one.

According to Table 4, among the explanations for the determinants that drive a public bicycle user to purchase a private bicycle are: firstly, the socio-demographic factors that facilitate the jump are having a higher level of education (a.3) (in keeping with Handy et al., 2014 and Maness, 2012) and being a resident of the city of Seville

itself (a.4). This latter would seem to indicate that there is a lower predisposition towards the use of a private bicycle among users who are forced to use the public bicycle in combination with other means of transport because they do not live in the Seville municipal area (but in the metropolitan area). To a certain extent this finding agrees with the findings of Beck and Immers (1994) and Nielsen et al. (2013) that, as the distance from the main urban centers grows, so the number of trips made by bicycle decreases.

The decision to purchase one's own bicycle does not seem to be influenced by factors such as gender (a.1) or age (a.2). These findings contradict those of other studies (Xing et al., 2010) which state that males are generally more likely to purchase a bicycle, and that differences in behavior also exist depending on the age bracket. Nonetheless, the findings of the present research corroborate other studies that find no causality between these two factors and bicycle ownership (e.g., Owen et al., 2010 for Australia and Belgium).

With respect to ideology (a.7), there are indications of possible bias, in the sense that users who declare themselves to be forward-looking are more likely to combine usage of the public bicycle with usage of the private bicycle. This idea could be underpinned by the evidence found by Danyluk and Ley (2007) and Heinen et al. (2010) regarding the trend towards the more general use of the bicycle as a means of transport among the population that is more left wing, ideologically-speaking.

It was also proven that experience (b.1) leans more towards the use of the private bicycle, especially among people who score the comfort of public bicycles lower (b.3). Meanwhile, it is precisely the people who have approached the public bicycle more sporadically, with a weekly pass (b.2) (and that may be less accustomed to its use) who are most likely to purchase a bicycle. This last point is clear evidence that the public bicycle, in small doses (weekly pass), is a test bench that could lead to the purchase of a private bicycle. The evidence provided by these findings is contrary the findings of Buck et al. (2013) that it is the short-term cyclists who most use PBSSs, whilst it is the regular cyclists who state that they own their own bicycles.

In other respects, it seems that the need to own one's own bicycle depends on the specific uses that are made of it. To be precise, purchase of a private bicycle seems to be more widespread among people who use it for reasons of work or to commute to their place of study (c.1) and, especially, by people who use it for sport (c.3). On the other hand, purchasing a private bicycle does not seem to be a necessity for users who use it for shopping (c.2) and leisure (c.4), where the public bicycle seems to be the best option. In other words, private bicycles are mostly used for reasons of transportation rather than recreation, according to Beck and Immers (1994) and Buck et al. (2013).

Finally, the purchase of a private bicycle seems to correlate with some reasons that determine its use for the user. Thus, people who score the chance of avoiding urban traffic congestion (d.3) more highly are less likely to want to own a private bicycle,

while, following Pinjari et al. (2011), those for whom the bicycle generally forms part of their 'way of life' (d.5) have a greater tendency towards purchasing their own private bicycles.

3. Table 5 corroborates the motives that explain why the majority of PBSS users without private bicycles have no need to purchase them, and alludes to two motives for this.

Firstly, *security problems* (fear of theft), especially if users have nowhere to keep their bicycles at their points of trip origin (home) and/or the main destinations that they go to (work, study, leisure or connection with other modes). In this regard, research such as Martens (2007) for the Dutch case finds a strong positive correlation between the availability of parking places suitable for private bicycles and their use.

This disincentive has been analyzed by other investigators in specific cities (Sidebottom et al., 2009 for London and Brighton; Pucher et al., 2011 for Portland; Van Lierop et al., 2014 for Montreal), proving that a series of unwanted externalities arise due to the lack of secure parking. For example, users on occasion voluntarily debase their own bicycles in order to make them less attractive, or adopt a passive attitude, even allowing them to be damaged (Van Lierop et al., 2014). One of the most conspicuous negative effects is the appearance of *illicit parking* or "*fly-parking*" (Gamman et al., 2014), improvised by users in response to the lack of specific bicycle parking lots and taking advantage of items of street furniture (sculptures, street lights, parking meters, traffic signs) or in areas near stations and public transport terminals, making use of underused areas of paths, sidewalks and roadways, as studied by Fukuda and Morichi (2007) for the case of Japan.

Secondly, the high quality offered by the PBSS appears to fully satisfy the needs of many users, and this is a factor that dissuades people from purchasing their own private bicycles or using them. According to Table 5, there appears to be no clear economic obstacle to changing from public to private bicycle use, as less than 7% of people not planning to purchase private bicycles justify this with their cost.

Therefore, according to our findings, implementing an economic stimulus plan for bicycle purchase should not be completely ruled out (see, for example, the successful case of direct deductions made by companies in Ireland examined by Caulfield and Leahy, 2011); and even indirectly encouraging the move of users to the private bicycle as a means of rationalizing excessive demand for the PBSS by introducing an incentives/penalty system in the PBSS for users to return their bicycles to the least congested stations (by way of price, see Ruch et al., 2014 for the case of London; or giving free time slots, as in Paris, Fricker and Gast, 2012). However, given the findings of Table 5, it would seem that it would be of greater use to give aid or tax breaks for the implementation of secure bicycle parks in apartment blocks and at places of work and leisure. For example, cities such as Toronto and Calgary offer support programs for companies, cafés and stores to install short-term bike-parking (Pucher et al., 2011).

Many levels of government in European countries, North America and Japan, where the bicycle is already a natural part of popular culture , have developed a current bicycle parking policy that mandates (by law) the provision of proper bicycle storage in workplaces (Hamre and Buehler, 2014) and even in residential areas. The experience of the Netherlands stands out with regard to the latter, for example; the Dutch Government requires municipal, regional and provincial authorities to provide bicycle parking facilities to minimize theft, specifically in new buildings (Heinen et al., 2013).

In our case study, the city of Seville, the regional government is proposing to make it compulsory to install bicycle parking in all new residential buildings (see http://www.juntadeandalucia.es/fomentoyvivienda/portal-web/web/noticias/4691ebbb-d9f-11e4-bad9-033248a5fe1a).

4. Table 6 shows the determinants of the two main limitations that would hinder any advances in private bicycle ownership and which can be impacted upon: the lack of parking at trip origin and/or destination and fear of theft.

The first thing that can be observed is that the Wald Test on Rho confirms the hypothesis as to the close relationship between the two motives, as had been formulated a priori in the previous section. On the one hand this implies that the bivariate probit is the right methodological choice, on the other, that from the point of view of transport policy, joint action can be taken on the two.

Secondly, the results show a significant gender difference (a.1). Females are more concerned with finding a proper place to keep their bicycles at their places of trip origin or destination. This might be due to the fact that the alternative to having a place to leave the bicycle at the trip origin might be carrying it up and down stairs; at the destination, meanwhile, in an extreme case it could mean taking the bicycle apart and carrying various pieces around to prevent their theft; in both cases this implies the need for greater physical strength. This finding evidences important nuances that could explain why some studies do find gender differences in bicycle usage in general (see Emond et al., 2009 or Heinen et al., 2010), while others find none in the analysis of the private bicycle, in particular, where these problems do not exist (see Castillo-Manzano and Sánchez-Braza, 2013a).

It can also be observed that the likelihood of showing a lack of interest in the private bicycle is greater among PBSS cyclists in both cases. PBSS users give a higher score to the ease with which they are able to pick up and drop off the bicycles provided by this system (d.6). However, both factors are less likely among people who consider the bicycle to be something more than just a mode of transport, in other words, a 'lifestyle' (d.5) as described by Handy et al., 2010 and Moudon et al., 2005. This last finding is compatible with the Goetzke and Rave (2011) hypothesis as to how cultural aspects may even stimulate the use of bicycles more than other typical policy variables.

On the other hand, the people who most appreciate the bicycle being a cheap mode of transport (d.4) are also those that most perceive the problems associated with theft

and the lack places to park. This is logical, as both these problems would result in private bicycle usage becoming more expensive.

Both these reasons are more sharply perceived by users who use the bicycle on its own, without combining it with any other mode of transport (c.7). This is in keeping with earlier studies that point to intermodality being one of the main obstacles to purchasing and having one's own bicycle (see Buehler, 2012; Chatterjee et al., 2013; Sallis et al., 2013; Sener et al., 2009).

Finally, Table 6 shows that non residents (a.4.), students (a.6.) and people with a higher level of education (a.3.) are the users who are most concerned with having somewhere to park their bicycles at the place of origin/destination. Similarly, the older people are (a.2.), the less fear of theft they have, although this does increase among those who have opted for a long-term SEVICI bicycle pass (b.2.).

5. In short, the relationship between the public bicycle and the self-owned bicycle is seen to be complex. On the one hand, according to Table 3 the use of the two is complementary for approximately 41% of the sample, with this percentage being made up of both people who already owned a private bicycle previously and who continued use it, and others who have purchased a private bicycle or are planning to do so in the near future as a result of their use of the PBSS; this all confirms the hypothesis as to a *knock on effect*, as analyzed by Bouf and Hensher (2007).

However, on the other hand, the sample distribution provides empirical evidence of a net substitution effect between the two, as shown by a 4.5% difference in the sample between private bicycle users that stop using the service and use the PBSS alone (12.5%) compared to people who did not own a private bicycle but have decided to purchase one after using SEVICI (8%).

4. Conclusions.

Empirical evidence on the international level shows that Public Bicycle Sharing Systems (PBSSs) have demonstrated themselves to be a successful transport policy, especially in countries with little previous cycling culture (e.g., Southern European cities, such as Seville). As stated in the present article, PBSSs have revolutionized transport by significantly raising the demand for bicycle use in general, and as such can be compared (except for the obvious differences) with Low Cost Carriers' bursting onto the air transport scene or the High Speed Train onto rail passenger transport.

The success of PBSSs has exposed their main Achilles Heel: congestion during the rush hour at stations in high traffic areas with high bicycle rotation. This shows the need for studies to be conducted of the transition from PBSSs towards privately-owned bicycles as a long-term solution.

This issue has been widely analyzed in the present study using a broad sample of PBSS users in Seville, one of the most highly acknowledged cities in the field at the present time.

The findings show, firstly, the great heterogeneity of the Sevillian PBSS user population as to the private bicycle and its relationship with the public bicycle. Secondly, unlike what could have been anticipated a priori, it is difficult to state that, on its own, the PBSS in Seville can be considered to be a tool for transitioning to the private bicycle. In reality, it has been found that for 59% of cyclists being, a PBSS user seems to have become a permanent state; even though 41% of these declare that they make joint use of their own private bicycle. Nevertheless, the results show a negative substitution effect between the PBSS bicycle and the private bicycle, which can be quantified as 4.5% of the total sample. As a result, the PBSS can be concluded to attract more users away from private bicycle usage than it transfers to it. This is not incompatible with the probable external *knock on effect* described by Bouf and Hensher (2007).

One of the socio-demographic factors that stands out as favoring the move from the PBSS to the private bicycle is having a higher level of education, being part of a segment of the population that is more progressive ideologically-speaking, and being a resident of the city itself, rather than the metropolitan area, while other aspects, such as age and gender do not appear to be conclusive. The profile of the user in the sample who states that he or she is already the owner of a private bicycle or who would be willing to purchase one is especially interesting: an experienced, not sporadic, cyclist who makes the bicycle his/her daily and regular means of transport to work, to his/her place of study, who regularly does sport and for whom the bicycle is just another part of his/her healthy lifestyle.

With respect to the obstacles that make it difficult to make the jump from the PBSS to the private bicycle, users in Seville do not feel influenced by economic issues, but rather cite obstacles related to the quality of the PBSS, which satisfies all the user's needs, and, especially, the lack of proper parking at the point of origin/destination, and fear of theft. The factors that heighten concern for these last two problems include, amongst others: not residing on the city, being a student, being a non-occasional user of the PBSS, having a higher level of education and, above all, gender differences, with a greater impact on women. These disadvantages do not seem to be evident with respect to bicycle usage in general, but with respect to private bicycle usage in particular.

The findings also show that these two reasons (lack of parking and fear of theft) are closely related, and this undoubtedly facilitates implementing any action plan for transfer from the PBSS to the private bicycle.

To summarize, any policy to promote private bicycle usage requires taking not only the typical measures based on investing a large sum of public funds in constructing bicycle lanes, but also requires other complementary measures to guarantee a minimum

level of security that reduces the likelihood of a bicycle being stolen, with special attention being paid to bicycle parking at the place of origin and destination.

In countries like Spain, where publically funded subsidies have traditionally been provided for installing lifts in old apartment blocks, installing individual water meters and restoring façades, in the future, when the economic situation allows, the co-funding of installing bicycle parks in buildings should not be rejected.

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