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Analyzing the transition from a public bicycle system to bicycle ownership: A complex relationship

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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.

Introduction

Rising motorization rates in developed countries since the second half of the 20th century have helped to improve citizens' quality of life, but at the same time have caused negative externalities, such as energy dependency, traffic congestion, and harm to the environment and public health (Rietveld, 2001). On the other hand, 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), non-motorized means of transport, such as the bicycle, have come to be regarded as synonymous with health and energy savings and efficiency.

In their reviews of actions implemented by governments around the world to promote bicycle use Pucher et al. (2010) and Yang et al. (2010) highlighted the *Public Bicycle-Sharing Systems* (PBSS). Originating in northern European countries, such as the Netherlands and Denmark, PBSSs have become very popular in recent years around the European fringe, and have acquired the status of an integrated urban mode of transport (Anaya and Castro, 2012).

According to Shaheen et al. (2010), the PBSS represents a successful transportation policy not only as it encourages cycle usage, but also due to its great potential, its adaptability to different sized cities, and its ability to provide emission-free

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transportation (Vogel et al., 2011), although, to date there has been limited research into its environmental benefits. PBSS also alleviate the high costs of new transportation systems efficiently, e.g., the subway, tram and light rail, especially in medium sized cities (Castillo-Manzano and López-Valpuesta, 2009), where bike sharing can fill a possible market niche in urban transportation relatively inexpensively and quickly: short journeys.

Nevertheless, some research restricts the benefits of PBSS in the short term; as authors such as Bouf and Hensher (2007), Castillo-Manzano and Sánchez-Braza (2013a, 2013b), Fishman et al. (2012, 2013), Lin and Yang (2011) state, once the investment has been made and initial expansion starts to wane, demand can stagnate, resulting in major drawbacks. The most important of these are: poor quality of service due to a lack of comfort and units in a poor state of repair; docking stations inappropriately located for intermodality; non-competitive cost; an inflexible schedule; 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 docking 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 (e.g. compulsory helmet use).

Authors such as Lin and Yang (2011), Lin et al. (2013) and Nakamura and Abe (2014) analyze other drawbacks of PBSS linked to urban planning (especially in city centers), the need for sufficient available space to install the number of docking points required to cover the demand for bicycles, and other disadvantages that they might have in preventing or obstructing other leisure activities.

According to Anaya and Castro (2012), all these circumstances shroud PBSSs in uncertainty, especially in the current framework of budgetary constraints. So, although public bicycle use may boast many advantages over private bicycle ownership (users do not need to worry about their own bicycles being stolen or vandalized, the lack of a place to park their bikes at the point of origin or destination, or bicycle maintenance; see Fishman et al., 2012 and Rietveld and Koetse, 2003), they alone are not sufficient for the bicycle to be unreservedly called an urban transportation system. In fact, previous studies such as Aldred and Jungnickel (2013) and Maness (2012) provide evidence that bicycle ownership could be a proxy indicator of a trend towards journeys being made by bicycle more frequently, meaning that the private bicycle could be regarded as a complementary tool for promoting a "bike-culture".

A literature review shows that the topic of bicycle ownership has only been studied to a limited extent and that research has usually focused on bicycle use (Xing et al., 2010) rather than the widespread interest aroused by PBSS (Fishman et al., 2013; Pucher et al., 2010; Shaheen et al., 2010; Yang et al. 2010).

Handy et al. (2010) find links between the 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 and income level by Emond et al. (2009), Owen et al. (2010) and Pinjari et al. (2009), and to a lesser extent, personal preferences and attitudes, such as lifestyle, health- and environment-related issues or economic aspects have been studied by authors such as Geus et al. (2008) and Moudon et al. (2005).
(2) social structure, 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 bicycle use; Beck and Immers (1994) consider the issue of bicycle theft; McCarthy (2011) examines the "*anti-bike culture*"; and Delbosc and Currie (2013) analyze the falling numbers of young people taking out their driving licenses in developed countries.
(3) infrastructure and the physical environment: from the obstacles that the urban area presents and the correct adaptation of the PBSS to the area (by Heinen et al., 2010; Larsen et al. 2013; Sallis et al., 2013; Snizek et al., 2013) to the installation of facilities for cyclists at journey origin/destination (lockers, changing rooms, showers) considered by, e.g., Hunt and Abraham (2007) and, above all, safe bike-parking and storage (Salleh et al., 2014) in public/private places (Aldred and Jungnickel, 2013) and facilitating intermodality with other means of urban transportation (Rietveld, 2001).

Although the cited studies 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 relatively new topic with major drawbacks. One of these is clearly the interaction between PBSS and private bicycles. In fact, the only precedent found is the analysis by Buck et al. (2013) of user profiles for the two systems, although the study does not address the relationship between the two. Finally, Bouf and Hensher (2007) report on the possible *expansive effect* of the PBSS in the city of Lyon, which has resulted in higher sales and greater use of private bicycles.

The motivation for this paper is, therefore, to fill the knowledge gap surrounding users' (registered PBSS members') opinions and attitudes to the obstacles and facilitators that lead them to decide to purchase a bicycle or not. User perception may determine this trend according to Damant-Sirois et al. (2014) and Handy et al. (2014). We therefore believe that specific field study-based analyses using interviews to collect data on demographics, mobility patterns and journey preferences could shed some light on the possible indirect impact of PBSSs on the bicycle purchase decision.

In short, our paper takes a new approach to analyzing the relationship between public and private bicycle use; from the point of view of PBSS users. First, specific data are provided as to Seville PBSS users' preferences regarding the use of private bicycles. Second, the factors are addressed that influence the decision of PBSS users who do not own private bicycles to purchase one. Subsequently, the barriers that deter public bicycle users from transferring to private bicycle ownership are

studied and the determinants that would explain the way that these users perceive the most important barriers are examined. The end goal is to arrive at an initial analysis of the relationship (substitution, complementarity or independence) between the use made of the two types of bicycle from the point of view of sustainable transportation policy, and to provide a set of practical recommendations for PBSS management in order, amongst other things, to prevent any congestion. The article is structured as follows: following this introduction, Section 'Empirical framework' sets out the empirical framework and the methodology for the case under study, the city of Seville (Spain); Section 'Results and discussion' includes the results of the estimations and the discussion, and Section 'Conclusions' presents the conclusions.

Empirical framework

Case study and sampling

The database was created from surveys of PBSS users in Seville, Spain. Recent years have seen a major transformation of the Seville (pop.704,980) urban area into a sustainable mobility model (see Castillo-Manzano et al., 2014 and Castillo-Manzano et al., 2015). Bicycle use has been vigorously promoted since 2007, with measures such as the construction of a 140 km bicycle lane network and the implementation of the *SEVici* PBSS managed by the JCDecaux company, with 260 docking stations, 2650 *smart-bikes* and 5,163 points. The success of Seville's public policies to promote bicycle use has been highlighted in previous research studies, including Castillo-Manzano and Sánchez-Braza (2013a) or Marqués et al. (2014), and proven by facts, such as an increase from 6,000 to 66,000 cyclists per day in the city between 2006 and 2010 according to the European Cyclists' Federation[1] – in fact, Seville is, as of today, the only city in the world where bicycle use is known to have risen from practically 0% to 6.6% of mechanized journeys in only 4 years, between 2006 and 2009 (see Castillo-Manzano and Sánchez-Braza, 2013b and Marqués et al., 2014) – and especially, the city's current fourth place ranking in the *Copenhagenize Index*[2] of the world's most bike-friendly cities, produced by the Copenhagenize Design Company (Copenhagenize, 2013), only behind Amsterdam, Copenhagen and Utrecht. These outcomes have prompted several organizations and prestigious international media to point to Seville as an example to emulate for cities that have no history of bicycle use at all and that have always regarded the cities of Copenhagen, Amsterdam and Utrecht as a model that could not be matched.[3]

This swift success of Seville's PBSS resulted in the system soon becoming highly congested (see Castillo-Manzano and Sánchez-Braza, 2013a), which seems to have also been the case in other areas of the world (see Pfrommer et al., 2013 or Kloimüllner et al., 2014).

Returning to the present research, the survey campaign was conducted in three successive waves, so as to prevent any distortion being caused by an unforeseen exogenous event (such as abnormal weather for the time of year, with unusually cold or hot temperatures, for example). Months with traditionally high (May and October) or low (December and January, July and August) numbers of Seville PBSS bicycle use have also been omitted.[4] The total size of the sample was 505 surveyees. Specific data regarding the survey campaign are given in Table 1.

The variables were generated from the 21 question items put to surveyees. As can be seen in Table 2, they were grouped into four categories. The items selected were based on previous research and, as commented in the Introduction Section, to a large extent related to factors affecting the perception of public bicycle uses, bicycle ownership and bicycle use:

(a) Individual demographic and socioeconomic user details: gender (variable a.1.) (Emond et al., 2009; Handy et al., 2010) and age (variable a.2.) (Owen et al., 2010; Xing et al., 2010); economic level (variables a.5. worker and a.6. student), residence (variable a.4.) and level of education (variable a.3.) have been included, as in Pinjari et al. (2009) and Pinjari et al. (2011); and, following Danyluk and Ley (2007) and Heinen et al. (2010), political and ideological preferences (our variable a.7., Franconstrs).

(b) Relationship with the PBSS: in line with a similar previous study (Buck et al., 2013), time factors have been considered, such as the user's experience (variable b.1.) and whether he/she is a short-term or annual registered PBSS member (variable b.2., type of pass), and his/her degree of satisfaction with the PBSS. In this last case, our purpose is to test for any drawbacks that the PBSS might have; so, as stated in the Introduction, certain variables have been considered that might help us to synthesize users' perceptions of the PBSS, including comfort (variable b.3., comfort SEVici), intermodality (variable c.7.), and ease of use (variable d.6.).

[1] See http://www.eurovelo.org/wp-content/uploads/2011/08/Economic-Benefits-of-Cycling-Paper.pdf.

[2] The Copenhagenize Index is a points-based ranking of cities around the world: cities are awarded from 0 to 4 points in 13 different categories to determine how bicycle friendly they are (advocacy, bicycle culture, bicycle facilities, bicycle infrastructure, bike share program, gender split, modal share for bicycles, model share increase since 2006, perception of safety, political climate, social acceptance, urban planning and traffic calming measures). Available at: http://www.copenhagenize.com/2013/04/copenhagenize-index-2013-bicycle.html.

[3] Such as the European Environment Agency (2013), Lonely Planet (2012) and Reuters (2012). The most positive include the US CNN TV channel, which in August 2014 ranked Seville second among the World's Best Cycling Cities (see http://edition.cnn.com/2014/08/17/travel/best-cycling-cities/), and the prestigious British daily newspaper, The Guardian, which in 2015 devoted an article to "how Seville transformed itself into the cycling capital of southern Europe" (see http://www.theguardian.com/cities/2015/jan/28/seville-cycling-capital-southern-europe-bike-lanes).

[4] Graphs and data on the monthly evolution of numbers of Seville PBSS bicycle hires are available from the authors on request.

Table 1
Technical data of the survey administered to Seville PBSS (SEVici) users.

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

Table 2
Explanatory variables and descriptive statistics.

Variable	Description	No. obsv.	Mean
a.1. Gender	1 if male; 0 if female.	294	0.582
a.2. Age	Age of person surveyed.	–	26.802
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
a.4. Resident	1 if resident in city of Seville; 0 otherwise.	410	0.812
a.5. Worker	1 if worker; 0 otherwise.	137	0.271
a.6. Student	1 if student; 0 otherwise.	276	0.547
a.7. Francostrs	1 if agrees that references to Franco Dictatorship (1939–1975) should be removed from street names; 0 otherwise.	242	0.479
b.1. Experience	If SEVici user: 1 for less than 6 months; 2 between 6 months and a year; 3 over a year.	-	2.412
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
b.3. comfortSEVici	Scoring of comfort of SEVici public bicycle, from 0 to 10.	-	6.844
c.1. Work/studies	1 if uses bicycle to commute to place of work or study; 0 otherwise.	413	0.824
c.2. shopping	1 if uses bicycle for shopping; 0 otherwise.	93	0.186
c.3. Sport	1 if uses bicycle for sport; 0 otherwise.	84	0.168
c.4. Leisure	1 if uses bicycle as a leisure activity or simply for enjoyment; 0 otherwise.	105	0.210
c.5. Usage	Number of times that uses bicycle per week.	-	6.053
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
c.7. Intermodality	1 if uses bicycle alone for journeys; 0 if combines bicycle with some other type of public or private transport.	276	0.547
c.8. Helmet	1 if thinks that helmet-use should not be compulsory for SEVici users; 0 otherwise	146	0.290
d.1. Healthy	To do exercise and for health reasons.	–	7.554
d.2. Environment	Benefits to the environment.	–	7.905
d.3. Avoidtraffconges	To avoid urban traffic congestion.	–	7.755
d.4. Cheap	It is a cheap mode of transportation.	–	8.487
d.5. Lifestyle	It is a lifestyle choice.	–	6.093
d.6. Ease of use	Easy to access and return bicycles.	–	7.126

(c) Purpose of journey and bicycle use: following prior research, such as Beck and Immers (1994) and Buck et al. (2013), shopping (variable c.2.), sport (variable c.3.) and recreational activities (variable c.4., leisure), work and school commuting (variable c.1., work/studies) were considered, and following Cheng and Liu (2012) and Pucher et al. (2011), among others, other use-related variables were included, such as intermodality-related issues (variable c.7), frequency of use (variable c.5. usage), substitutability patterns (variable c.6.) and helmet use (variable c.8.).
(d) Reasons for using a bicycle: as in Handy et al. (2010), Geus et al. (2008) and Moudon et al. (2005), aspects linked to lifestyle (variable d.5.), the environment (variable d.2. environment) and traffic congestion (variable d.3.), usability (variable d.6., ease of use), economics (variable d.4., cheap) and health awareness (variable d.1.) are examined.

Model

The models used in this study seek to analyze the relationship between public bicycle and private bicycle use from the point of view of PBSS users in Seville (SEVici) by analyzing two questions. First, a binary outcome model is used to study the

factors that influence the decision of PBSS users who do not own private bicycles to purchase one. A dichotomous-choice response question is examined; a binary dependent variable is given a value of 1 if a PBSS user that did not own a private bicycle before using SEVici has purchased a bicycle or is planning to purchase one in the near future, and 0 otherwise. We decided on a logit specification, as it maximized the log pseudolikelihood (−84.3616) compared to the probit (−84.4744).[5] In logit models, the conditional probability takes the form:

$$p_i \equiv P(y_i = 1|x) = F(x_i'\beta) = \frac{e^{x_i'\beta}}{1 + e^{x_i'\beta}} \tag{1}$$

Secondly, a bivariate probit model is applied to analyze the determinants of the responses that public bicycle users give to the question about why they are not contemplating purchasing their own bicycle. This second category of models is especially designed for cases like these, 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.

The bivariate probit formula is:

$$L = \sum w_i \ln \Phi_2(q_1(X_i\beta)^{\beta}, q_2(Z_i\gamma)^{\gamma}, \rho_i^*)$$

$$q_1 = \begin{cases} 1 & \text{if } y_1 \neq 0 \\ -1 & \text{if } y_1 = 0 \end{cases} \quad q_2 = \begin{cases} 1 & \text{if } y_2 \neq 0 \\ -1 & \text{if } y_2 = 0 \end{cases} \tag{2}$$

where Φ_2 is the accumulated distribution of a normal bivariate.[6] In our case, the sample's broad base means that we do not have to adopt any apriorism and thus $X_i = Z_i$, i.e., the 24 explanatory variables in Table 2.

As estimated coefficients in logit models, and in discrete demand models in general, cannot be interpreted directly, the odds ratio and marginal effects at the mean have been calculated at the mean. The first of these, the odds ratio, measures the absolute change in probability of the dependent variable following a unit change in one of the regressors. The second, the marginal effect, measures this change as a percentage, i.e., such a percentage increases or decreases the probability that the PBSS user wishes to purchase a private bicycle following a unit change in one of the regressors. The marginal effects of the bivariate probit estimation coefficients have also been calculated for the same reason.

Finally, a cluster-robust estimate of the variance–covariance matrix of the estimator is used in both the logit and bivariate probit, with PBSS users grouped by wave of survey.

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

Results and discussion

Table 3 shows the preferences of the Sevillian PBSS (SEVici) users surveyed in each of the three waves regarding the use of private bicycles.

Table 3 indicates 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 a bicycle. As was expected from previous studies (Fishman et al., 2012) the ability of PBSS to drive up use and frequency was confirmed, i.e., for expanding the market, with an expansive effect on demand similar to that recorded in other transportation sectors, such as the effect of low cost airlines on air transport (Castillo-Manzano et al., 2012), the high-speed train on rail passenger transport (Givoni, 2006), and container-carriers on maritime goods transport (Notteboom and Rodrigue, 2008).

Moreover, no clear evidence is found that the PBSS per se may act as a bridge towards the private bicycle in Seville (contrary to what has occurred, for example, in certain Japanese cities, as reported by Nakamura and Abe, 2014), which, logically, would contribute to relieving the PBSS congestion problem (as explained, for example, by authors such as Pfrommer et al., 2013 for the case of London's bike-sharing scheme, or Kloimüllner et al., 2014, for Vienna).

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.

To summarize, the relationship between the public bicycle and the self-owned bicycle can be seen to be complex. On the one hand, the use of the two may be simultaneous for approximately 41% of the sample (Table 3), with this percentage including both people who already owned a private bicycle previously and who continued use it, and others who have

[5] The results are fairly robust irrespective of whether a logit or a probit specification is used for the estimation. The results of the probit estimation are available from the authors on request.

[6] $[\varepsilon_1, \varepsilon_2] \sim (\text{BVN})[0, 0, v_{\text{icluster}}, v_{\text{icluster}}, \rho]$
$\rho_i^* = q_1 q_2 \rho \quad E(\varepsilon_1) = E(\varepsilon_2) = 0 \quad Var(\varepsilon_1) = Var(\varepsilon_2) = v_{icluster} \quad Cov(\varepsilon_1, \varepsilon_2) = \rho$

Table 3
Responses from SEVici users to the interview campaign questions.

User category		% of total		
		100%	100%	
1	Owned private bicycle before using SEVici	51.88%	–	
1.1	Used own bicycle before using SEVici		–	
1.1.1.	Continues to use own bicycle in conjunction with SEVici		32.87%	
1.1.2.	Has stopped using own bicycle and only uses SEVici		12.48%	
1.2.	Did not use own 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 a bicycle or is planning to purchase a bicycle in the near future		7.92%	16.46%
2.2.	Is not planning to purchase another bicycle		40.20%	83.54%

purchased a private bicycle or are planning to do so in the near future as a result of their use of the PBSS; all this confirms the hypothesis regarding an expansive effect, as analyzed by Bouf and Hensher (2007).

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%) and people who did not own a private bicycle but have decided to purchase one after using SEVici (8%).

Table 4 presents the logit and probit estimations for the factors that determine whether SEVici users who did not previously own 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.

According to Table 4, the explanations for the determinants that motivate a public bicycle user to purchase his/her own private bicycle include: first, the socio-demographic factors that facilitate the move 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 users who are forced to use the public bicycle in combination with other means of transport are less inclined to use private bicycles because they do not live in the Seville municipal area (but in the metropolitan area). To a certain extent, this finding coincides 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 journeys made by bicycle decreases.

The decision to purchase a private 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 the ideology variable (a.7.), PBSS users who declare themselves to be forward-looking state a more positive attitude towards combining usage of the public bicycle with usage of the private bicycle. This result is in line with prior evidence found by Danyluk and Ley (2007) and Heinen et al. (2010).

It was also proven that experienced bicycle users (b.1.) are more inclined to use private bicycles, especially people who give a lower score to the comfort of public bicycles (b.3). Meanwhile, it is precisely the people who have used the public bicycle more sporadically, those with a weekly pass (b.2.) (and who, therefore, 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 to the findings of Buck et al. (2013), who find that it is the short-term cyclists who most use PBSS, whilst it is the regular cyclists who state that they own their own bicycles.

In other respects, it seems that the need to possess a private bicycle depends on the specific use that is made of it. To be precise, the 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, among 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, as stated by Beck and Immers (1994) and Buck et al. (2013), private bicycles are mostly used for transportation rather than recreation.

In short, the purchase of a private bicycle seems to correlate with a number of reasons that determine its use for the user. Thus, people who award a higher score to the possibility of avoiding urban traffic congestion (d.3.) are less likely to want to own a private bicycle while, following Pinjari et al. (2011), people for whom the bicycle generally forms part of their "way of life" (d.5.) are more inclined to purchase their own private bicycles.

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, taking into account 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 confirms the reasons that explain why the majority of PBSS users without private bicycles have no need to purchase them, and alludes to two motives for this.

Table 4
Logit estimation of the marginal effects at the mean of SEVici users' decision to PURCHASE a bicycle.

Variables	Bicycle-purchasing decision Logit regression	
	Odds ratios	Marginal effects
a.1. Gender	1.066	Δ 0.593%
	(0.480)	(4.306)
a.2. Age	1.000	Δ 0.003%
	(0.041)	(0.385)
a.3. Education	1.341**	Δ 2.730%*
	(0.186)	(1.480)
a.4. Resident	3.350***	Δ 8.322%***
	(0.592)	(2.645)
a.5. Worker	0.995	∇ 0.044%
	(0.230)	(2.145)
a.6. Student	1.293	Δ 2.353%
	(0.708)	(5.287)
a.7. Francostrs	2.353**	Δ 8.111%***
	(0.820)	(1.947)
b.1. Experience	1.320***	Δ 2.581%***
	(0.089)	(0.954)
b.2. Type of pass	1.741*	Δ 6.243%*
	(0.523)	(3.295)
b.3. comfortSEVici	0.588***	∇ 4.940%***
	(0.059)	(0.818)
c.1. Work/study	2.645**	Δ 7.167%*
	(1.045)	(3.655)
c.2. Shopping	0.916	∇ 0.801%
	(0.474)	(4.487)
c.3. Sport	3.511***	Δ 16.436%***
	(1.729)	(5.830)
c.4. Leisure	1.229	Δ 2.007%
	(0.230)	(2.021)
c.5. Usage	0.962	∇ 0.356%
	(0.045)	(0.397)
c.6. Substitutability	0.881	∇ 1.124%
	(0.457)	(4.188)
c.7. Intermodality	0.789	∇ 2.367%
	(0.406)	(4.773)
c.8. Helmet	1.498	Δ 4.121%
	(1.119)	(8.690)
d.1. Healthy	1.086	Δ 0.767%
	(0.150)	(1.271)
d.2. Environment	0.932	∇ 0.657%
	(0.081)	(0.936)
d.3. Avoidtraffconges	0.766**	∇ 2.485%***
	(0.096)	(0.677)
d.4. Cheap	1.056	Δ 0.510%
	(0.099)	(0.956)
d.5. Lifestyle	1.293***	Δ 2.391%***
	(0.038)	(0.715)
d.6. Easeofuse	1.146***	Δ 1.268%**
	(0.053)	(0.638)
No. observations	239	
Log. Pseudolikelihood	−84.361583	
Pseudo R2	0.2066	
Wald Chi2 (p-value without clustering)	43.94 (0.0077)	

Notes: standard errors in brackets robust to heteroscedasticity and clustered by survey wave.
* $p \leqslant 0.1$.
** $p \leqslant 0.05$.
*** $p \leqslant 0.01$.
Shaded values are representing statistically significant coefficients.

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 bicycles where they live and/or destinations	57.14%
3. Fear of private bicycle being stolen	45.81%
4. Ease of use of SEVici compared to the private bicycle	49.26%
5. SEVici covers the user's needs	48.77%

First, *security problems* (fear of theft), especially if users have nowhere to keep their bicycles at their points of journey origin (home) and/or the main destinations that they travel 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 undesired externalities arise from a lack of secure parking. For example, users on occasion voluntarily disfigure 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 to respond 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 fewer than 7% of people not planning to purchase private bicycles use their cost as justification.

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 users to move to private bicycle use 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 docking 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 in Table 5, it would seem that it would be of greater use to give aid or tax breaks for the installation 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 and Japan (where the bicycle is already an integrated transportation mode in urban transit) and in countries like the U.S. (where cycling is growing in popularity) have developed a bicycle parking policy that mandates (by law) the provision of proper bicycle storage in workplaces (Hamre and Buehler, 2014) and even in residential areas. For example, the experience of the Netherlands stands out with respect to the latter; the Dutch Government requires municipal, regional and provincial authorities to provide bicycle parking facilities, specifically in new buildings, to minimize theft (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).

Thus, our analysis will focus on motives 2 and 3 in Table 5 (*There is nowhere to park their bicycles at their homes and/or destinations; Fear of private bicycle being stolen)* given the little importance afforded to the first (price of bicycles) and as it would be illogical to act on the last two, which relate to the high quality of the PBSS, since it would not make sense to lower the price of the PBSS to make it easy to transfer to the private bicycle.

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 a priori that motives 2 and 3 are mutually related, as the need to have a place to keep the bicycle at both the point of journey origin and destination is at least in part aimed at preventing theft. This justifies the use of the bivariate probit.

As a consequence, 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 one at the point of journey origin and/or destination, or because they are afraid that it might be stolen.

Table 6 shows the determinants of the two main drawbacks preventing any growth of private bicycle ownership that can be acted on: the lack of parking at journey origin and/or destination and the fear of theft.

The first thing that can be observed is that the Wald test on Rho confirms the hypothesis regarding 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 and, on the other, that from the point of view of transportation policy, joint action can be taken on the two.

Table 6
Bivariate probit estimations of the factors that influence SEVici users' decision NOT TO PURCHASE a bicycle (marginal effects at the mean).

Variables	Motive for NOT PURCHASING a bicycle	
	Nowhere to park at journey origin or destination	Fear of theft
a.1. Gender	∇ 3.995%***	Δ 8.984%
	(1.243)	(5.584)
a.2. Age	∇ 0387%	∇ 0.550%***
	(0291)	(0.062)
a.3. Education	Δ 13.602%***	Δ 5.492%**
	(4.536)	(2.502)
a.4. Resident	∇ 20.667%***	∇ 4.056%
	(6.073)	(9.698)
a.5. Worker	∇ 9.215%	Δ 6.746%
	(7.136)	(8.542)
a.6. Student	Δ 13.326%**	Δ 12.809%
	(6.725)	(11.332)
a.7. Francostrs	∇ 0.341%	∇ 8.580%
	(5.031)	(7.178)
b.1. experience	Δ 5.478%	∇ 2.137%
	(4.660)	(2.710)
b.2. type of pass	Δ 3.923%	∇ 17.724%***
	(10.7779	(5.895)
b.3. comfort SEVici	∇ 2.161%	Δ 0.242%
	(2.227)	(3.079)
c.1. Work/study	Δ 5.669%	Δ 9.085%
	(8.478)	(9.387)
c.2. Shopping	∇ 8.290%	∇ 10.663%
	(5.233)	(6.680)
c.3. Sport	Δ 15.027%	Δ 22.552%
	(10.317)	(16.526)
c.4. Leisure	∇ 9.177%	∇ 4.598%
	(18.098)	(29.079)
c.5. Usage	Δ 0.342%	∇ 0.975%
	(0.924)	(0.903)
c.6. Substitutability	Δ 13.393%	∇ 9.237%
	(11.992)	(11.811)
c.7. Intermodality	Δ 15.669%***	Δ 10.010%***
	(5.745)	(1.136)
c.8. Helmet	Δ 1.264%	Δ 12.425%*
	(9.745)	(7.531)
d.1. Healthy	Δ 4.208%***	Δ 1.318%
	(1.276)	(2.018)
d.2. Environment	∇ 3.785%	∇ 3.400%*
	(3.410)	(1.312)
d.3. Avoidtraffconges	Δ 5.504%	Δ 3.120%
	(4.338)	(3.684)
d.4. Cheap	Δ 4.380%***	Δ 4.701%***
	(1.382)	(0.9649
d.5. Lifestyle	∇ 2.330%***	∇ 3.357%***
	(0.8919)	(0.176)
d.6. Easeofuse	∇ 1.182%***	∇ 6.044%
	(0.227)	(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 survey wave.
* $p \leqslant 0.1$.
** $p \leqslant 0.05$.
*** $p \leqslant 0.01$.

Secondly, the results show a significant gender difference (a.1.). As explained above, Table 4 showed that gender was not a statistically significant variable for the decision to purchase a bicycle, but now, according to Table 6, females are more concerned with finding a proper place to keep their bicycles at journey origin or destination and so feel that this influences their decision not to purchase a bicycle. This might be due to the fact that the alternative to having somewhere to leave a bicycle at the journey origin might be carrying it up and down stairs while, in an extreme case, at the destination 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 provides major insights that might explain why some studies find gender differences in

bicycle usage in general (see Emond et al., 2009 or Heinen et al., 2010), while others find none in analyses 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 access and return 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 choice", (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 that cultural aspects may stimulate the use of bicycles even more than other typical policy variables.

On the other hand, the people who most appreciate the bicycle being an inexpensive mode of transport (d.4) are also those who most perceive the problems associated with theft and the lack of places to park. This is logical, as both these issues would result in private bicycle usage becoming more expensive.

Both these reasons are more sharply perceived by users who use the bicycle alone and do not combine 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 possessing a private bicycle (see Buehler, 2012; Chatterjee et al., 2013; Sallis et al., 2013; Sener et al., 2009).

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

Conclusions

Empirical evidence from around the world shows that Public Bicycle Sharing Systems (PBSS) are a successful transportation policy, especially in cities with little previous cycling activity (e.g., Southern European cities, such as Seville). As stated in the present article, PBSS have changed transport by significantly raising the demand for bicycle use in general, and, as such (except for the obvious differences), can be compared to the effect that the advent of Low Cost Carriers had on air transportation, or the High Speed Train on rail passenger transportation.

However, the success of PBSS has also exposed their main failing: congestion during the rush hour at docking stations in high traffic areas with high bicycle rotation. This shows the need for studies of the transition from PBSS 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, first, the great heterogeneity of the Sevillian PBSS user population's perceptions of the private bicycle. Second, unlike what could have been anticipated a priori, it is difficult to state that, on its own, the Seville PBSS can be considered 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 users declare that they alternate its use with the use of their own privately-owned bicycles. 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.

Some of the socio-demographic factors that stand out as favoring the move from the PBSS to the private bicycle are: having a higher level of education, being part of the ideologically more progressive segment of the population, and being a resident of the city itself, rather than the metropolitan area, while other aspects, such as gender and age, do not appear to be conclusive. The profile of users in the sample who state that they are already owners of private bicycles, or who would be willing to purchase one, is especially interesting: an experienced, frequent cyclist who makes the bicycle his/her daily and regular means of transport to his/her place of work or 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 the transition from the PBSS to the private bicycle difficult, users in Seville do not feel influenced by economic issues, but instead mention disincentives such as the high quality of the PBSS, which satisfies all the user's needs, and especially, the lack of proper parking at the point of journey origin/destination and the fear of theft. The factors that heighten concern for these last two issues include, amongst others: not residing on the city, being a student, being a frequent user of the PBSS, and having a higher level of education. Furthermore, even though females present similar behavior when making the decision to purchase a bicycle, the fact is, when asked to give a reason to justify why they do not purchase a bicycle, they mostly refer to the lack of proper parking at the points of journey origin/destination.

Our findings also show that these two reasons (lack of parking and fear of theft) are closely related, and this undoubtedly makes the implementation of an action plan for transfer from the PBSS to the private bicycle easier.

In short, any policy to promote private bicycle usage necessitates taking not only the typical measures, with the investment of large sums of public funds in the construction of bicycle lanes, but also requires other complementary measures to guarantee a minimum level of security to reduce the likelihood of a bicycle being stolen, with special attention paid to bicycle parks at journey origin and destination.

In countries like Spain, publicly funded subsidies have traditionally been provided for installing lifts in old apartment blocks, installing individual water meters and restoring building exteriors; in the future, when the economic situation allows, the co-funding of bicycle parks or storage areas in buildings should not be discounted.

As a future line of research to complement this study we propose the quantification of the environmental impacts of PBSSs, with the clear aim of improving PBSS management. This study already provides some relevant findings, as it offers empirical evidence that some users have transferred from private bicycle use.

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