User Response to the Dynamic Pricing of Carsharing Services: A Stated-Choice Approach

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1. Introduction

Shared mobility services have developed rapidly and on a global scale in the last decade (Shaheen and Cohen, 2016). In parallel, researchers have sought to explore a number of challenges including predicting the future level of market prediction for different forms of shared mobility services, characterising new forms of user behaviour, and optimising the design and management of system operation (Jorge and Correia, 2013; Brendel and Kolbe, 2017).

In contrast to fixed schedule public transport services, in the case of shared mobility services, the short term spatio-temporal dynamics of user demand induce corresponding dynamics in supply, and managing this dynamic supply is a major challenge for shared mobility operators (Cepolina and Farina, 2012). As a result, research interest is growing into the question of how users might be encouraged to actively participate in the management of supply, through dynamic pricing and other forms of incentivisation schemes (Jorge *et al.,* 2015; Angelopoulos *et al.,* 2016). However, little is currently known about how users respond to such schemes, especially in the unique context of spatio-temporally volatile shared mobility networks.

In this paper, we address this gap by presenting the results of a stated-choice experiment undertaken with existing users of a free floating carsharing service on London. In the stated-choice experiment, various attributes of the carsharing service, including price, are subject to uncertainty. We then quantify respondents' behaviour using a variety of expected utility theory (EUT) models, including model formulations designed to detect specific response effects associated with the users' awareness of and response to the uncertainties in the carsharing system. The heterogeneity of attitude towards uncertainties is also tested.

2. Background

A major problem the operators of carsharing services is the imbalance of user demand and vehicle supply, leading to inefficient utilisation of the vehicle stock and, often costly, vehicle repositioning. These problems are particularly acute in so called 'free floating' carsharing schemes, in which users can pick-up and drop-off vehicles at any point in the network. The standard approach to vehicle repositioning, in both the industry and the academic literature, is to use dedicated repositioning staff to move vehicles from regions of low demand to regions of high demand (Kek *et al.,* 2009; Weikl and Bogenberger, 2015). Recently, however, there has been growing interest in the potential for the use of price signals to encourage users to actively participate in fleet distribution. For example, Jorge *et al.* (2015) propose a system in which trip-requests are priced on the basis of whether the journey would increase or decrease spatial imbalances in the carsharing system. They formulate the price setting problem as a mixed integer optimisation problem with a linear negative correlation between price and demand between any origin-destination pair.

In similar work, Angelopoulos *et al.,* (2016) generate all feasible trips for a single user request, orders these request by the level of imbalance of the pick-up and drop-off stations, and sets pricing for the trips on that basis. However, neither of these papers investigated empirically the response of users to these pricing strategies. In adjacent work, Chen and Sheldon (2014) investigated the impact of Uber's surge pricing scheme on the behaviour of Uber drivers. Using operational data, they demonstrated that, in keeping with intuition, Uber drivers work longer hours and provide more trips when the surge prices are high.

Beyond the domain shared-mobility, dynamic pricing has been explored empirically in a number of transport contexts including for example, city centre parking (Shoup, 2006), HOV lane operation (Jang *et al.,* 2014) and combined electric vehicle charging and parking (Latinopoulos *et al*., 2015, 2017). It is also widely used as a strategy for system optimisation in the airline industry (Williams, 2017), in grocery delivery (Yang *et al.,* 2016) and the hospitality sector (Zhang and Weatherford, 2017). However, to the authors' knowledge, consumer behaviour in response to dynamic pricing has not previously been empirically studied in the context of the uniquely volatile supply (in spatial and temporal terms) of carsharing.

Dynamic prices induce uncertainty in the user's strategic thinking, so one important aspect of the behavioural response to dynamic pricing is the response to this uncertainty. The recent work of Kim *et al*. (2017a,b) has explored the impact of uncertainty in certain attributes of a carsharing service, specifically whether a carsharing vehicle would be available when desired (Kim *et al.,* 2017a) and the experienced travel time to the desired destination *(Kim et al.,* 2017b). However, this work did not study response to uncertainty in the price of carsharing. There is evidence that consumers have distinctive responses to *pricing*-uncertainty (as opposed to uncertainty in non-price attributes) when price is modulated dynamically by a supplier (Courty and Pagliero, 2008; Bolton *et al.,* 2003). One explanation for this finding is that uncertainty is not the only relevant aspect of the behavioural response to dynamic pricing. Dynamic pricing can also be controversial, raising questions of equity and fairness (Bolton *et al.,* 2003). As a result, it is not applied universally, even in circumstances (e.g., internet retail) when a narrow application of economic theory would suggest efficiency gains are possible (Garbarino and Lee, 2003). This aspect of the behavioural response of users to dynamic pricing has also not been explored in the context of carsharing services.

3. Empirical data collection

The empirical dataset for this study is sourced from a bespoke stated-choice survey of customers of DriveNow, a free-floating carsharing service operational in parts of London. A D-efficient design process was undertaken, with 19 replications grouped into three sets. Respondents' attitudes towards various service attributes of carsharing are tested including preferences towards uncertain monetary and travel time attributes. Fieldwork was completed in Feb. 2018 (n=289; block design; CASI-administered).

Previous stated-choice experiments into attribute-uncertainty have generally introduced a single dimension of uncertainty in a choice task; the design we prepared for this study includes two interacting dimensions (uncertainty in waiting time and uncertainty in the price of the service). In order to evaluate respondent interaction with this aspect of the instrument, the survey includes both diagnostic replications and also debrief questions focused on information-processing of the uncertain attributes.

4. Modelling approach and expected results.

There are in general two approaches to modelling choice under uncertainty: the expected utility theory (EUT) and non-expected utility theory (non-EUT) (Starmer, 2000). Both are widely used, and multiple manifestations of each have been developed (Li and Hensher, 2011; de Moraes Ramos *et al.,* 2011). Using the stated-choice responses, paradata – i.e., data tracked passively by the CASI instrument (Campbell *et al.,* 2017) and responses to the debrief questions, we will focus on modelling respondent's behaviour with the general framework of EUT, applying a number of alternative specific formulations. The data-analysis task will focus in particular on respondents' interpretations and data-processing strategies regarding the uncertain-walking time and uncertain-price attributes.

We will formulate models that accommodate both generic responses to uncertainty and attribute-specific responses, and compare the respective performance of each. Further, we will quantify the extent to which respondents' risky choice behaviour is explainable by observable characteristics (gender, age, etc.) as opposed to residual (idiosyncratic) heterogeneity.

We anticipate that the findings will encompass:

1. Respondents' taste parameters, including parameters characterising the response to uncertainty, with respect to a number of attributes of free floating carsharing networks;
2. Impacts on parameter estimates of the stated-choice replications including two interacting dimensions of uncertainty (pricing and walking time);
3. Interpretation of attribute-specific versus aggregate attitudes-to-risk;
4. Quantification of explainable versus idiosyncratic heterogeneity of behaviour-under-uncertainty

Following the completion of the data-analysis task, the findings generated by this stated-choice experiment will be employed in a system-optimisation framework.

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