Research in Transportation Economics 52 (2015) 46–55

Contents lists available at ScienceDirect

Research in Transportation Economics

journal homepage: www.elsevier.com/locate/retrec

The effect of carsharing on vehicle holdings and travel behavior: A propensity score and causal mediation analysis of the San Francisco Bay Area

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ARTICLE INFO

Article history:
Available online 14 November 2015

Keywords:
Self-selection bias
Carsharing
Shared use mobility
Propensity score matching
Vehicle ownership
Alternative modes

ABSTRACT

We examine the impacts of carsharing on travel behavior utilizing a San Francisco Area subsample of the 2010–2012 California Household Travel Survey. We control for self-selection bias due to differences in observed characteristics of the respondents using propensity-score based matching. We find that vehicle holdings of carsharing members are substantially and significantly lower than for non-members with similar characteristics in terms of individual and household demographics and built environment features of both residential and job location. These differences increase as the propensity to enroll in carsharing programs increases. A latent construct, which measures the propensity to own or utility from owning vehicles and rises with numbers of vehicles owned, is lower for members by 0.3–1.3 standard deviations relative to non-members. Members are also likely to walk, bike, and use transit more frequently than non-members. However, these differences are relatively minor and tend to be statistically non-significant. Future research should control for self-selection bias arising from differences in unobserved characteristics of respondents, as well as simultaneity bias whereby decisions concerning vehicle ownership both influence and are influenced by the decision to join carsharing programs.

1. Introduction

The significant growth in shared use mobility alternatives (e.g., carsharing, on-demand ride services) has prompted policymakers and the automotive industry to consider how these services impact travel behavior, vehicle ownership, and associated energy and greenhouse gas (GHG) emissions of the transportation sector. In recent decades, the availability of carsharing services such as Zipcar™ has spread throughout many cities, providing as-needed access to vehicles, typically on an hourly basis. Previous carsharing research, based largely on member surveys, suggests that carsharing leads to vehicle shedding, reduced vehicle miles traveled (VMT), and increased use of public transit, walking, and biking (Cervero, Golub, & Nee, 2007; Martin & Shaheen, 2011a; Shaheen, Cohen, & Chung, 2009; Sioui, Morency, & Trépanier, 2013), although studies differ in terms of the magnitude of impact (Tal, 2009).

One of the key limitations of previous carsharing work is that the adoption of carsharing is likely coupled with the decision to live in a dense, urban area, which in itself is known to have a significant impact on travel behavior (Bhat & Eluru, 2009; Handy, Cao, & Mokhtarian, 2005). In addition, other factors that pre-dispose an individual to adopt carsharing may also shape her travel decisions, the primary one being limited access to household vehicles. Failure to account for these prior propensities may lead to overestimating the effect that carsharing would have on travel behavior if adopted by someone without those propensities, i.e. if policies promoting carsharing led to its adoption across a broader segment of society. This study presents the first attempt to account for self-selection

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http://dx.doi.org/10.1016/j.retrec.2015.10.010
0739-8859/

bias in carsharing – specifically, to account for the potential predisposition towards carsharing enrollment in order to identify more accurately the effect of carsharing on travel behavior.

This study utilizes data from the 2010–2012 California Household Travel Survey (CHTS). The CHTS collects detailed information about household demographics and travel activity for the purposes of modeling statewide and regional travel and GHG emissions (Caltrans, 2013). Sampling and weighting methods are employed to match statewide household population distributions on key demographic variables. In the 2010–2012 survey, respondents were asked whether they were members of a carsharing organization. Around 800 of the 84,000 individuals 18 years or older indicated they were members, and 80% of these carshare members were employed.

We adopt a non-parametric matched-sampling procedure to identify a control group that is statistically balanced on various observed socio-economic traits and residential location choices, and whose travel behavior may be compared with that of carsharing members (treatment group). Matched sampling is well established in diverse disciplines such as political and legal studies (Ho & Rubin, 2011), epidemiology and medical research (Weitzen, Lapane, Toledano, Hume, & Mor, 2004), and economics (Caliendo & Kopeinig, 2008), as a statistical method to make causal and counterfactual inferences from observational data. The goal of matched sampling (or simply matching) is to balance the distribution of observed confounding covariates between the control and treated groups so that the resulting differences in outcomes between the groups may be attributed to the treatment under study. Further, matching reduces model dependency in parametric analysis and improves the precision of estimated coefficients (Ho, Imai, King, & Stuart, 2007).

The remainder of this paper is structured as follows. In Section 2, we review key studies on carsharing. We discuss methods in Section 3 and results in Section 4. In Section 5, we discuss the limitations of this analysis, future work, and potential policy implications of this research.

2. Background

2.1. Carsharing

A number of studies have sought to examine the causal impact of carsharing membership on travel behavior. The first major such study involved multiple surveys, between 2001 and 2005, of City CarShare members, a non-profit carsharing organization based in the Bay Area (Cervero & Tsai, 2004; Cervero et al., 2007). The control group for the study consisted of respondents who demonstrated interest in joining City CarShare, but who did not join as members for various reasons, including service unavailability in their neighborhoods. Adopting a difference-in-difference (DID) of means evaluation method for summary statistics, the study found that between 2001 (a few weeks before membership or treatment) and 2005, carsharing membership led to a decline of weekday total travel and vehicle miles traveled (VMT) by 4.50 and 4.26 miles per day respectively. Both members and non-members reduced their VMT and fuel consumption over the 5-year period – potentially due to rising oil prices – but the reduction was steeper for members.

One of the largest studies involved a survey of 9000 + members across the U.S. and Canada in 2008 to assess the impact of carsharing (Martin & Shaheen, 2011a; Martin, Shaheen, & Lidicker, 2010). Members reported their travel behavior both currently and retrospectively prior to joining carsharing. The study found that at an aggregate level, members increased their use of public transit after joining carsharing; however there was significant variability in the results. An increase in walking, biking, and carpooling, compared to levels prior to enrollment in carsharing, was more definitive. Further, carsharing members reduced their household vehicle holdings – from an average of 0.47 to 0.24 vehicles. In the absence of comparison with a control group and statistical control of various confounding variables, including potential relocation to an urban area prior to joining carsharing (together with the lower reliability of retrospective reporting), it is not possible to determine whether the entirety of these observed behavioral shifts can be attributed to carsharing membership.

According to the research by Martin et al. (2010), demand for carsharing comes largely from households with limited access to cars, and carsharing constitutes the primary access to a car for most active members. Martin and Shaheen (2011b) found that most members they surveyed (62%) did not own a car at the time of enrollment in carsharing. To put this number in perspective, only 10% of households residing in urban regions, which includes cities and their suburbs, in the U.S. do not own a car (U.S. Census Bureau, 2014). Analyzing the household travel surveys in Montreal, Klincevicius, Morency, and Trépanier (2014) similarly found that household car ownership was negatively correlated with carsharing service availability in a neighborhood (number of shared cars in a 500-meter radius) after controlling for various socio-economic confounders. Stillwater, Mokhtarian, and Shaheen (2009) found a negative correlation between demand for carsharing at a pod location and average car ownership levels in the neighborhood.

A more recent paper by Sioui et al. (2013) compared members of Montreal-based Communauto with the larger Montreal population. The study was facilitated by a purpose-built survey of members and an independent large-scale household travel survey conducted around the same time. The study found that members are less likely to own vehicles – around 90% of member households did not own vehicles compared to 34% of the general population. In general, the share of non-motorized trips was higher among carsharing households than among the rest of the population. Comparing only those without vehicles, however, carsharing households drove more and used public transit less than non-member households, suggesting either that carsharing households differed in unobserved ways from their non-member counterparts, or that carsharing enabled them to shift some travel from public transit to automobile.

Whereas the above studies were all based on observed (or revealed) behavior, at least two studies assessed likely changes in behavior if respondents enrolled in a yet-to-be introduced carsharing service. Zhou and Kockelman (2011) and Firnkorn and Müller (2011) found that respondents would likely reduce their vehicle holdings if they enrolled in car2go in Austin, Texas and Ulm, Germany respectively.

This paper builds on previous research to assess the impact of carsharing on travel behavior in two specific ways. It uses a well-defined statistical method to control for selection bias (discussed in detail in the next section), and it undertakes a causal mediation analysis to decompose the pathways through which carsharing likely affects short-term travel behavior such as the frequency of transit, walk, and bike trips, as well as daily driving distance.

2.2. Self-selection bias

Borrowing notation from the Rubin Causal Model framework, the difference in average travel outcomes (Y) between members (CS = 1) and non-members (CS = 0) can be decomposed into a causal effect and a self-selection bias:

$$\Delta\mu = E\left[Y_{1,i} \middle| CS_i = 1\right] - E\left[Y_{0,i} \middle| CS_i = 0\right] \tag{1A}$$