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Difference in Travel Behavior Between Immigrants in the U.S. and U.S. Born Residents: The Immigrant Effect for Car-Sharing, Ride-Sharing, and Bike-Sharing Services

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Difference in travel behavior between immigrants in the u.s. and us born residents: The immigrant effect for car-sharing, ride-sharing, and bike-sharing services

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ABSTRACT

Understanding immigrants' travel behavior is important to transportation planners and policymakers working to implement better transportation planning and public policies to serve those needs. The recent changes to the transportation system, specifically, the recent emergence of shared mobility services, such as car-sharing, ride-sharing, and bike-sharing, may have resulted in changes in how immigrants travel. Thus, we explored two research questions: (1) whether immigrants in the U.S. are more likely to rely on the three newly emerging transportation modes than US-born persons, and (2) whether the assimilation theory can be applied to the modes. To answer these questions, we used data from the 2017 National Household Travel Survey and employed Zero-Inflated Negative Binomial regression models to understand the specific behavior of immigrant travelers.

The models found the "immigrant effect" only for car-sharing services and bike-sharing programs; that is, relative to U.S. born residents, immigrants in the U.S. use car sharing and bike-sharing services more frequently, while we found an insignificant association in ride-sharing apps use. However, the negative binomial models suggested that immigrants use car sharing and ride sharing less frequently than expected. Immigrants who are in their first few years of living in the U.S. use smartphone rideshare app more frequently, confirming the "assimilation theory." The results of the predicted frequency of the use indicated that with all other independent variables held constant, U.S. born residents use car-sharing and ride-sharing services more frequently than immigrants, though the difference is marginal. However, immigrants would still tend to use bike share programs more frequently rather than U.S. born residents.

1. Introduction

Immigrants Face special mobility challenges and understanding immigrants' travel behavior allows transportation planners and policymakers implement better transportation planning and public policies. Existing literature has demonstrated that in most parts of the United States the use of a car has significant advantages for mobility in terms of increased access, higher speed, and higher quality of service (Blumenberg and Smart, 2011; Pyrialakou et al., 2016). Despite the advantages, the rate of car ownership of immigrants, particularly in their first few years of living in the U.S., is lower than non-immigrants (Blumenberg and Evans, 2010; Chatman and Klein, 2009; Klein and Smart, 2017; Smart, 2015). Previous literature has documented that most immigrants remain at least somewhat more likely to use alternative modes, including transit, walk, and bicycle, than US-born persons (Chatman and Klein, 2009; Blumenberg and Evans, 2010; Blumenberg and Smart, 2011; Smart, 2015).

Recent changes to the transportation system and the nature of immigration may have resulted in changes in how immigrants travel. On the transportation supply side, new modes have been introduced (car-share, ride-sharing, and bike-sharing services). The advances in transportation technology and modes can lead to the change in not only individual's lives, such as accessibility to educational and employment opportunities and residential location decision, but also their

travel behavior (Yago, 1983). At the same time, American homes and jobs have continued to sprawl at the national scale, while some cities have seen an urban resurgence, densification, and often gentrification (Newman and Wyly, 2006; Peiser, 1989; Smith and Williams, 2013; Squires, 2002), which might result in the travel behavior of the immigrant population. On the demand side, the nature of immigration has shifted: Asian immigrants have overtaken Hispanic immigrants as the largest population of newcomers, more foreign-born Americans have college degrees, and the foreign-born population is now characterized by longer stays in the United States ("Immigrants in America," 2019), characteristics of immigrants' travel behavior might differ from what previous literature suggested.

Arguably, a good share of the transportation literature has mainly focused on automobiles and conventional alternative transportation modes such as public transit (Blumenberg and Evans, 2010; Blumenberg and Smart, 2011; Chatman and Klein, 2009; Handy et al., 2008b; Klein and Smart, 2017; Liu and Painter, 2012; Smart, 2015; Tal and Handy, 2010). Although the recent changes on the demand and supply side require researchers to examine the travel behavior of immigrants in the U.S., few studies have so far examined immigrants' use of car-sharing, ride-sharing, and bike-sharing services, as the shared mobility services have recently been around. In light of not only the research gap but also recent changes on the demand and supply side, we examined two research questions: (1) whether immigrants in the U.S. are more likely to rely on the newly emerging transportation modes, which are car-sharing, ride-sharing, and bike-sharing services, than US-born persons, and (2) whether the assimilation theory can be applied to the three modes. To answer these questions, we developed Zero-Inflated Negative Binomial (ZINB) models by using the 2017 National Household Travel Survey.

Immigrants have been an essential part of American history and contemporary American society, e.g., the immigrant population is the main component of population growth, especially in the U.S. context (Chatman and Klein, 2009; Hirschman, 2005; Thomas, 2009). Therefore, we believe that the concrete understanding of immigrant's travel behavior contributes to providing improved transportation policies that can respond to the needs of immigrants, as public policies require more reliable information on travel behavior. The following section reviews previous literature on immigrants' travel behavior. The next section presents the details of the research design. Finally, the findings section and conclusion of this research follow.

2. Literature review

Previous literature on immigrant's travel behavior has primarily focused on two overarching themes: (1) difference in travel behavior between immigrants in the U.S. and U.S. born residents and (2) vehicle ownership. The studies on immigrants' travel behavior focus mostly on examining and explaining different travel patterns between immigrants and U.S.-born residents (Chatman and Klein, 2009). Much of the existing literature has mostly documented that most immigrants remain at least somewhat more likely to use alternative modes, including transit, walk, and bicycle, than US-born persons (Chatman and Klein, 2009; Blumenberg and Evans, 2010; Blumenberg and Smart, 2011; Smart, 2015). The mean commute distance among the U.S.-born residents is slightly higher than that among immigrants, and the difference declines according to the duration of residence in the U.S. (Bruce Newbold et al., 2017). Another interesting study shows that female immigrants are less likely to use public transit, and highly educated immigrants have a lower propensity toward carpooling (Kim, 2009). Moreover, some immigrant communities have used informal transportation modes, e.g., intercity Chinatown buses, Camionetas, and carpooling (Blumenberg et al., 2007). For instance, on the east costs in the U.S., Chinatown buses have transported Chinese workers to employment in nearby cities (Klein, 2009; Klein and Zitcer,

2012). "Camionetas," an informal van service, has served the Hispanic population for inter-regional travel (Valenzuela et al., 2005; Handy et al., 2008a). Carpooling is an important transportation mode for immigrants; interviews suggest that carpooling is often preferable for Mexican immigrants (Handy et al., 2008a).

Much of previous literature has examined automobile ownership among immigrants. The car ownership is important largely because having access to and using a car has significant advantages in terms of the increased access, high speed, and higher quality of services, to users in the U.S., where car-oriented land-use configuration and "forced" automobile ownership is prevalent (Blumenberg and Smart, 2011; Pyrialakou et al., 2016). Despite the advantages, the rate of car ownership of immigrants, particularly in their first few years of living in the U.S., is lower than non-immigrants (Blumenberg and Evans, 2010; Chatman and Klein, 2009; Klein and Smart, 2017; Smart, 2015). One important finding is that the travel behavior of immigrants is becoming that of non-immigrants, called "assimilation theory" (Chatman and Klein, 2009; Handy et al., 2008a; Smart, 2015; Blumenberg and Evans, 2010; Myers, 1997; Alba and Nee, 1997; Tal and Handy, 2010; Klein and Smart, 2017). Nonetheless, McGuckin and Srinivasan (2003) found that although immigrants who have lived in the U.S. for more than ten years likely own a vehicle, they are still more likely to continue to be without a car than U.S.-born residents. The different car ownership rates between the two population groups seem to be due to income, transportation expenditure, hardship on obtaining driver licenses, and immigrants' disproportionate residential location in central-city areas (Blumenberg et al., 2007; Handy et al., 2009). Interestingly, the recent immigrants who appear to have a stronger preference for car ownership and single-adult households are assimilating faster (Ma and Srinivasan, 2010).

Although considerable academic efforts have been dedicated to examining immigrants' travel behavior, there is a limitation. Much of the existing literature, to our understanding, has focused on automobiles and alternative transportation modes, such as walking, bicycling, public transit, informal transportation modes, and carpooling. Few studies have so far examined immigrants' use of car-sharing, ride-sharing, and bike-sharing services, as the shared mobility services have recently been around. Therefore, we examined two research questions: (1) whether immigrants in the U.S. are more likely to rely on the newly emerging transportation modes than US-born persons, and (2) whether the assimilation theory can be applied to the three modes. By answering the research questions, this study can fill the gap that we defined and add an understanding to existing literature on immigrants' travel behavior.

3. Research design

3.1. Data set

We used the 2017 National Household Travel Survey (NHTS) conducted by the U.S. Department of Transportation. The NHTS is a travel-diary survey, with respondents providing information on their trips in a 24-hour period, along with various other data on demographics, housing location, car ownership, frequency of the use of modes over longer periods, and so forth. We used the 2017 NHTS for three main reasons. It is the most recent national travel survey in the U.S., enabling us to examine travel patterns of recently emerging transportation modes such as bike-share programs that the 2001 and 2009 NHTS do not include. Also, since it contains information regarding not only travel behaviors and individual characteristics but also immigration status, it allows us to see if there is a difference in travel patterns between immigrants in the U.S. and the U.S. born residents. Lastly, it makes the results of this paper representative of the entire population in the U.S. due to its U.S.-scale address-based sampling.

3.2. Variable specification

In this research, we attempted to explore two research questions: (1) whether immigrants in the U.S. are more likely to rely on the three newly emerging transportation modes than US-born persons, and (2) whether the assimilation theory explains use of these three modes as the length of time in the United States changes. Therefore, we created two sets of models. The first set of models (models 1, 2, and 3) included our full sample to examine if there is a difference in travel behavior between immigrants and non-immigrants in the U.S. The second set of models (models 4, 5, and 6) examined a subgroup of immigrants and added the duration in the U.S. as an independent variable of interest. We presented the results and interpretations of six ZINB models in the next section.

The initial descriptive statistics indicated that the sample under-represents some populations, including immigrants in the U.S. Thus, the univariate analysis used NHTS-provided weights to adjust for the imbalances in the sampling (see Table 2). We conducted a multi-collinearity test (VIF test) test, and the result confirms that none of the explanatory variables covary strongly.

3.2.1. Dependent variables

We used the frequency of car-sharing service use, frequency of smartphone rideshare app use, and frequency of bike share program use as a dependent variable for each ZINB regression model (see Table 1). The NHTS survey instrument provided examples of service providers for each category, which likely reduced, but did not eliminate, confusion regarding the specific terms employed (i.e., reporting Zipcar, a traditional car-sharing service which can be booked using a smartphone application, as a smartphone rideshare service). While car-sharing services include Zipcar or Car2Go, smartphone rideshare applications include Uber, Lyft, or Sidecar. Because the travel patterns associated with car-sharing and ride-sharing are likely different, we examined both variables separately. We also explored the travel behavior of immigrants regarding bike-sharing programs (e.g., Zagster or CycleHop) in the third ZINB regression model. Table 2 shows that the percentage of respondents providing no answer (or not being asked) about bike-sharing systems is around 90%. Although the large proportion of the missing cases might influence the results, the sample size is still large (n = 28,426), the variable is essential in terms of examining the travel behavior of newly emerging transportation modes. We, thus, used the dependent variable in Model 3 and 6.

3.2.2. Independent variables

The variable of the interest in models 1, 2, and 3 is the immigrant status of the respondent. Table 2 shows that 13.62% of all respondents are immigrants, which is consistent with Census and American Community Survey (ACS) data; ACS estimates nearly 39 million immigrants in 2012 and nearly 45 million immigrants in 2018, comprising approximately 13.5 percent of the total population in the U.S. Another variable of interest in models 4, 5, and 6 regards log-transformed duration in the U.S. to examine the process of acculturation in the emerging transportation mode use.

Our models included three categories of control variables; (1) locational factors, (2) individual characteristics, and (3) neighborhood characteristics. Based on our literature review, we included the control variables about individual characteristics and neighborhood characteristics. These variables include age, income, population density, and others (see Table 1). This study also attempted to examine a vital hypothesis regarding the influence of locational factors on travel behaviors. Thus, we focused on three independent variables, such as log-transformed distance from home to work, whether the respondent lives in a highly populated Metropolitan Statistical Area with a heavy rail system, and whether the respondent lives in the New York Metropolitan area, a strong transportation outlier in the United States.

Table 1

Description of Variables used in Zero-Inflated Negative Binomial (ZINB) Regression Models 1, 2, 3, 4, 5, and 6.

Variable Name	Description	Used in Zero-Inflation Equation	Used in ZINB models
Dependent Variable			
Frequency of Car Sharing Service use	Frequency of Ride Share Services (e.g., Zipcar or Car2Go) use of the Respondent for 30 days	Yes	Model 1,4
Frequency of Smartphone Rideshare App Use	Frequency of Smartphone Rideshare Application (e.g., Uber, Lyft, or Sidecar) use of the Respondent for 30 days	Yes	Model 2,5
Frequency of Bike Share Program Use	Frequency of Bike Share Program (e.g., Bikeshare, Zagster, or CycleHop) use of the Respondent for 30 days	Yes	Model 3,6
Independent Variables			
Independent Variable of Interest			
Immigrant Status	Whether the Respondent is a Foreign-Born Resident in the U.S.	Yes	Model 1,2,3
ln (Duration in the U.S.)	Log Transformed Duration in the U.S. in 2017		Model 4,5,6
Control Variables			
Locational Factors			
ln (Distance from Home to Work)	Log Transformed Road Network Distance between the Respondent's Home and Respondent's Workplace		All models
Highly Populated MSA. with Heavy Rail Systems	Whether or not the Respondent lives in a Metropolitan Statistical Area (MSA) of 1 Million or More with Heavy Rail System	Yes	All models
New York-Newark-Jersey City	Whether or not Core Based Statistical Area (CBSA) for the Respondent's Home Address is New York-Newark-Jersey City	Yes	All models
Individual **Characteristics**			
Age	Age of the Respondent in 2017		All models
Female	Whether the Respondent is Female		All models
Race/Ethnicity	The Race/Ethnicity of the Respondent		All models
Education Attainment	The Education Attainment of the Respondent		All models
Household Income	The Household Income of the Respondent	Yes	All models
Commute to Work	Whether or not the Respondent Commutes to Work	Yes	All models
Neighborhood **Characteristics**			
Population Density	Population Density (Persons per Square Mile) of the Respondent's Residential Location at the Census Tract Level	Yes	All models
Employment Density	Employment Density (Workers per Square Mile) of the Respondent's Residential Location at the Census Tract Level	Yes	All models

We made some changes. Upon visual inspection of our data, we observed a logarithmic relationship between our dependent variables and two variables, which are the distance from home to work and duration in the U.S., we take the natural log of this variable. We

Table 2
Results of Univariate Analysis with Weighting of Variables.

Name of Continuous Variables	Total Number of Valid Cases	Mean	Standard Deviation
Frequency of Car Sharing Service use	236,076	0.03	0.5
Frequency of Smartphone Rideshare App use	236,089	0.43	2.1
Frequency of Bike Share Program use	28,426	0.62	4.2
ln (Distance from Home to Work)	264,234	0.39	0.6
ln (Duration in the U.S.)	25,132	1.18	0.4
Age	263,738	40.72	21.5
Name of Discrete Variables	**Categories**	**Frequency**	**Percent**
Immigrant Status	Total Number of Valid Cases	264,046	100.0
	Yes	35,959	13.6
	No	228,087	86.4
Highly Populated MSA.	Total Number of Valid Cases	264,234	100.0
with Heavy Rail Systems	Yes	73,129	27.7
	No	191,105	72.3
New York-Newark-Jersey City	Total Number of Valid Cases	264,234	100.0
	Yes	16,963	6.4
	No	247,271	93.6
Female	Total Number of Valid Cases	263,918	100.0
	Yes	134,408	50.9
	No	129,510	49.1
Race/Ethnicity	Total Number of Valid Cases	262,224	100.0
	Non-Hispanic White	161,991	61.8
	Non-Hispanic Black	31,699	12.1
	Hispanic	44,247	16.9
	Non-Hispanic Asian	13,732	5.2
	Other races	10,555	4.0
Education Attainment	Total Number of Valid Cases	231,488	100.0
	High School or Less	77,568	33.5
	Some College or Associate Degree	66,117	28.6
	Bachelor's Degree	48,676	21.0
	Graduate Degree	39,127	16.9
Household Income	Total Number of Valid Cases	257,328	100.0
	Less Than $49,999	102,907	40.0
	$50,000 to $99,999	76,703	29.8
	$100,000 or More	77,717	30.2
Commute to work	Total Number of Valid Cases	264,234	100.0
	Yes	116,080	43.9
	No	148,154	56.1
Population Density	Total Number of Valid Cases	264,135	100.0
	0 to 999	82,108	31.1
	1,000 to 3,999	79,605	30.1
	4,000 to 9,999	67,436	25.5
	10,000 or More	34,985	13.3
Employment Density	Total Number of Valid Cases	264,135	100.0
	0 to 99	47,179	17.9
	100 to 499	46,703	17.7
	500 to 1,999	84,122	31.9
	2,000 or More	86,130	32.6

-This analysis uses NHTS-provided weights.

recoded missing values as zeroes to account for those who do not commute, such as telecommuters, young people, retirees, the unemployed, and stay-at-home parents. We tried a second-degree equation of age and the natural log of the variable. Since we found that age without the transformation best fits in our models, however, we used age in the final models.

We initially controlled for car ownership, such as no car in the household and less than one car per worker in the household.

However, since car ownership is endogenous to alternative transportation mode choices, we omitted the variables in our final models.

3.3. Modeling approach

Since our three dependent variables, frequency of car-share program use, frequency of rideshare application use, and frequency of bike share program use, are count data, we attempted to develop the Negative Binomial regression and Poisson regression model, which have a wide range of applications in transportation field (Coxe et al., 2009; Hilbe, 2011). However, as Fig. 1 shows, the dependent variables showed an over-dispersed distribution with excess zeros; that is, most people report using these modes zero times, but among those who do use them, the frequency varies considerably. Therefore, we employed a Zero-Inflated Negative Binomial (ZINB) regression, which assumes that the data consists of two data generating process: (1) one with only zeros and (2) the other with a negative binomial data generation processes (Lambert, 1992; Garay et al., 2011; Erdman et al., 2008). The ZINB model is appropriate, as the results may be seriously biased if we use an ordinary least squares regression, a zero-inflated Poisson regression, or a negative binomial regression. More importantly, the results of model validation tests, the Likelihood-ratio test and the Vuong test, confirmed that ZINB is preferred (see Table 6).

4. Results

In our final models, we created two sets of models: (1) models with both immigrants in the U.S. and the U.S. born residents to examine the difference between the two population groups and (2) models only with immigrants to account for the process of acculturation in the emerging transportation mode use. The ZINB model estimates two separate but linked equations; (1) a logit model predicting whether the respondent reported using a certain emerging transportation mode at all (see Table 3) and (2) a negative binomial model predicting the respondent's frequency of using the alternative transportation mode for those respondents who used it (see Table 4). In this research, we used 7 independent variables to predict the use of each of our three modeled modes, including immigrant status (see Table 3), and used 12 independent variables to predict the frequency of use, given any use at all (see Table 4).

We also tried diverse specifications. Importantly, the results of ZINB regression models with these additional independent variables are similar to that of models that do not control for car ownership. We also created a zero-inflated Poisson regression model and a negative binomial regression model. The results of both models indicated that there is a marginal difference between the outcomes of ZINB regression models and those of these alternative regression models. However, given over-dispersed and zero-inflated of the dependent variables mentioned in the previous section, we presented and interpreted the ZINB models.

4.1. Zero-Inflated Negative Binomial regression Model 1: Car sharing service (e.g., Zipcar or Car2Go) use

Relative to U.S. born residents, immigrants are more likely to use car-sharing services, which support our hypothesis (see Table 3). Controlling for the variables, including residential location and individual characteristics, durations in the U.S. of immigrants is not a statistically significant predictor of car-sharing service use. However, the result in Table 4 shows that immigrants who report car-sharing service use at least once use them less often than non-immigrants (B = -0.740), controlling for other variables in the model.

Controlling for other variables in the model, income has no relationship to the use of car-sharing services, though education does (users of car-sharing services who have graduate degrees tend to
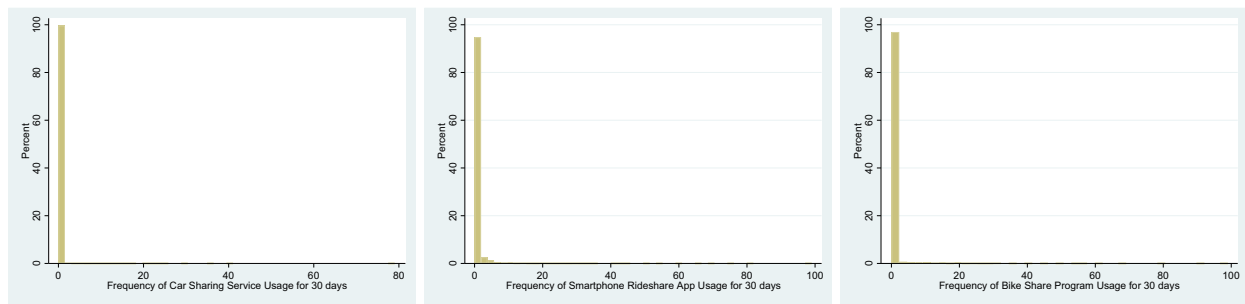
Fig. 1. Histograms of Each Dependent Variable in Three Zero-Inflated Negative Binomial Regression Models.

Table 3
Results of Zero-Inflated Equation for the Six Models Predicting Reported Ever Uses of Certain Modes of Transportation.

The Subject of Analysis	Total Population			Immigrants in the U.S.		
Models	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Dependent Variable	Frequency of Car Sharing Services Use	Frequency of Smartphone Rideshare App Use	Frequency of Bike Share Programs Use	Frequency of Car Sharing Services Use	Frequency of Smartphone Rideshare App Use	Frequency of Bike Share Programs Use
(Constant)	4.078***	3.968***	2.466***	2.653***	4.309***	2.999***
Immigrant Status	0.773**	0.078	0.388**	–	–	–
Highly Populated MSA with Heavy Rail Systems	0.295	0.516***	0.672***	−0.822	0.546**	1.778***
New York-Newark-Jersey City	1.032**	−0.538***	0.827***	0.271	−0.398	0.713
Household Income (Base: Less Than $49,999)						
$50,000 to $99,999	−0.213	0.513***	0.399**	0.014	0.518**	−0.517
$100,000 or More	0.053	1.300***	0.691***	−0.733	1.041***	−1.526***
Commutes to Work	0.287	0.512***	0.455**	0.877	0.216	0.884**
Population Density (Base: 0–999)						
1,000–3,999	0.052	0.566***	0.372	−0.297	1.553**	−1.432
4,000–9,999	0.235	0.622***	0.468	−0.349	1.339**	−1.383
10,000 or More	0.716	1.428***	0.151	21.179***	2.136***	−1.871
Employment Density (Base:0–99)						
100–499	0.115	0.949***	0.074	−1.287**	1.857***	1.643
500–1,999	0.855*	1.210***	0.434	2.106**	1.418**	1.987
2,000 or More	1.417**	1.785***	0.403	3.052	1.714**	1.632
Model Statistics						
Total Observations	226,750	226,763	18,803	23,025	23,030	1,987
Non-Zero Observations	1,435	17,043	1,022	306	2,492	174
Zero Observation	225,315	209,720	17,781	22,719	20,538	1,813
LR Chi^2	122.07	961.86	55.73	120.50	284.96	88.13
Prob > Chi^2	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

*Significant at $p < 0.10$; **Significant at $p < 0.05$; ** Significant at $p < 0.001$
-This analysis uses NHTS-provided weights.

use it more often than those who attain high school or less). Those in the New York metropolitan area are considerably more likely to use car-sharing (B = 1.032), but among those who do use it, people in New York use it less. The coefficients for commute and log-transformed distance from home to work are not statistically significant, suggesting that the frequency of car-sharing use is unrelated to employment status or distance to work (see Table 4). Relative to immigrants with non-Hispanic White, immigrants with non-Hispanic Black, Hispanic, and others take fewer trips, while Asian immigrants take more trips (see Table 4). Population density is a significant predictor of car-sharing service use, i.e., relative to immigrants in the census track with <999 persons per square footage, those in the census track with more than 10,000 persons use it more frequently (B = 21.179).

4.2. Zero-Inflated Negative Binomial regression Model 2: Smartphone rideshare App (e.g., Uber, Lyft, or Sidecar) use

A notable finding of our model regards immigrant status. Our model indicates that while controlling for other variables, relative to U.S. born residents, immigrants in the U.S. are less likely to use smartphone rideshare apps (i.e., they are less likely to report the trips; the coefficient of −0.139 suggests an e-0.139 = 0.87, or 13 percent smaller odds of reporting the use), which runs counter to our hypothesis (see Table 4). Yet, as Table 3 shows, immigrant status is not a statistically significant predictor of respondents using smartphone rideshare applications, including Uber. As the assimilation theory suggested, Fig. 2 shows again that the use of these services attenuates with duration in the United States. Regardless of the duration in the U.S., the

Table 4

Results of Negative Binomial Equation for the Six Models Predicting Frequency of Mode Use, Given Nonzero Use.

The Subject of Analysis	Total Population			Immigrants in the U.S.		
Models	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Dependent Variable	Frequency of Car Sharing Services Use	Frequency of Smartphone Rideshare App Use	Frequency of Bike Share Programs Use	Frequency of Car Sharing Services Use	Frequency of Smartphone Rideshare App Use	Frequency of Bike Share Programs Use
(Constant)	−0.037	1.286**	1.938***	−0.802	2.375***	3.976***
Immigrant Status	−0.740**	−0.139*	0.377	–	–	–
ln (Duration in the U.S.)	–	–	–	−0.353	−0.252**	−0.478
ln (Distance to Work)	−0.145	−0.133**	−0.273	0.005	−0.263**	−0.185
Highly Populated MSA with Heavy Rail Systems	−0.718**	0.193**	−0.103	0.298	−0.100	−0.731
New York-Newark-Jersey City	−0.865**	0.053	−0.380	−0.093	0.155	0.047
Age	−0.015**	−0.039***	−0.009**	−0.011	−0.041**	−0.013
Female	−0.119	−0.157**	−0.270**	−0.141	−0.152	−0.799**
Race/Ethnicity (Base: NH White)						
NH Black	0.601**	0.517***	0.191	−1.957***	−0.461**	0.714
Hispanic	0.078	−0.030	0.329	−0.630**	−0.386**	0.590
NH Asian	0.862***	−0.211**	−0.007	0.630**	−0.569***	0.657
Others	−0.148	0.193	−0.199	−0.960**	−0.600***	−0.174
Education Attainment (Base: High School or Less)						
Some College or Associates Degree	0.166	0.458***	0.270	0.011	0.715***	0.563
Bachelor's Degree	0.247	1.028***	−0.125	0.164	1.278***	0.247
Graduate Degree	0.708**	1.090***	−0.158	0.705**	1.338***	0.614
Household Income (Base: Less Than $49,999)						
$50,000 to $99,999	−0.103	−0.251**	−0.115	−0.429	0.018	−0.929**
$100,000 or More	0.013	−0.064	0.284	−0.354	0.303	−0.261
Commutes to Work	−0.270	−0.022	0.070	−0.254	0.089	−0.483
Population Density (Base: 0–999)						
1,000–3,999	0.453	−0.143	0.609	0.368	−0.951**	2.865***
4,000–9,999	0.482	0.067	0.268	0.012	−0.697**	2.001***
10,000 or More	1.365**	0.435**	1.195**	0.081	−0.576**	3.558***
Employment Density (Base:0–99)						
100–499	−0.104	−0.186	−0.220	2.670**	−0.826**	−2.463**
500–1,999	−0.612	−0.004	−0.369	−0.794	−0.180	−2.691**
2,000 or More	−1.115*	−0.021	−0.173	−1.169	0.037	−2.922**
Model Statistics						
Total Observations	226,750	226,763	18,803	23,025	23,030	1,987
Non-Zero Observations	1,435	17,043	1,022	306	2,492	174
Zero Observation	225,315	209,720	17,781	22,719	20,538	1,813
LR Chi^2	122.07	961.86	55.73	120.50	284.96	88.13
Prob > Chi^2	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

* Significant at $p < 0.10$; * * Significant at $p < 0.05$; * * Significant at $p < 0.001$

- This analysis uses NHTS-provided weights.

predicted frequency of its use is never more than one time for 30 days (see Fig. 2).

Again, the results regarding control variables largely support our hypotheses. Denser places and large MSAs with rail are home to more (and more frequent) rideshare app users; though, interestingly, the opposite is true for New York City (see Table 3). In addition, among those who do use rideshare apps, living in the New York Metropolitan Area appears to have no statistically significant effect on the frequency of the use, while a statistically significant impact was found in large MSAs with rail (see Table 4). Respondents with higher educational attainment are more likely to use smartphone rideshare applications, as are those with higher incomes and blacks, controlling for other variables in the model. Immigrants with non-Hispanic Black, Hispanic, non-Hispanic Asian, and others use ride-sharing less frequently, relative to non-Hispanic White immigrants (see Table 4). Among immigrants, education attainment, household income, population density, and employment density are statistically significant predictors.

4.3. Zero-Inflated Negative Binomial regression Model 3: Bike share program (e.g., Bikeshare, Zagster, or CycleHop) use

The results in Table 3 suggest that all else equal, immigrant status is a statistically significant predictor of bike share program use (B = 0.388) that confirms the "immigrant effects." It, however, is not a significant predictor of the emerging transportation mode among those who do use it (see Table 4). Among immigrants who use the bike share program, the duration in the U.S. is not correlated to its use.

As the two table shows, age, sex, race/ethnicity, household income, MSAs with heavy rail systems, and New York are significant predictors of public transportation use. The use of these services attenuates with age, suggesting that younger people use it more frequently than older people. Relative to men, female respondents who ride transit appear to take fewer trips (B = -0.157). Table 3 shows that while controlling for other variables, those who live in highly populated MSA with heavy rail systems or the New York metropolitan area show the higher
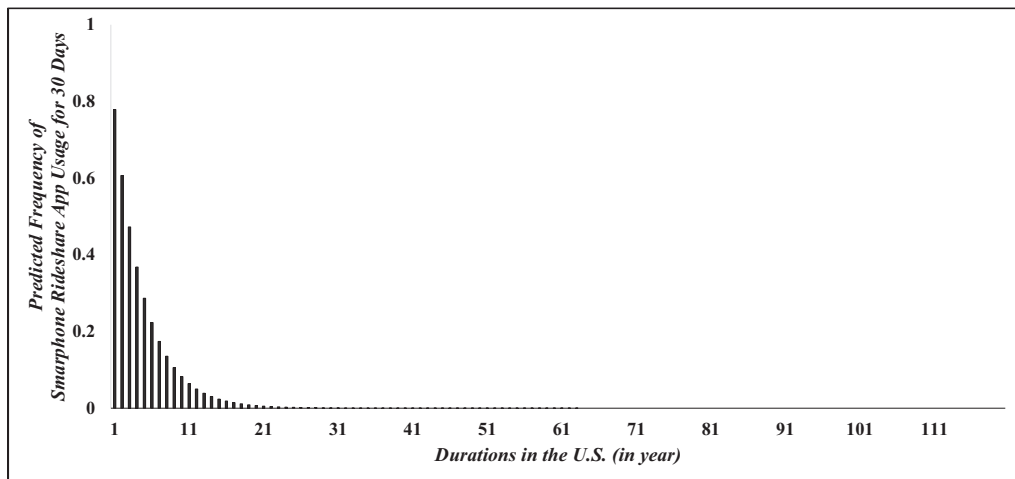
Fig. 2. Predicted Frequency of Smartphone Rideshare App Use for 30 Days among Immigrants who Use It.

Table 5
Results of the Predicted Use for 30 Days of a Certain Emerging Transportation Mode for Models 1, 2, and 3.

	Model 1	Model 2	Model 3
	Frequency of Car Sharing Services Use	Frequency of Smartphone Rideshare App Use	Frequency of Bike Share Programs Use
Total Sample			
U.S. Born Residents	0.018	0.183	0.499
Immigrants in the U.S.	0.018	0.169	1.029
Those who use an emerging transportation mode			
U.S. Born Residents	0.040	0.836	0.793
Immigrants in the U.S.	0.037	0.760	1.609

frequencies of bike share program use. Among those who do use a bike-share program, variable race/ethnicity is not statistically correlated with the bike share program use. Among immigrants who use it, the coefficients of population density are the highest (B = 2.806, 2.001, 3.558).

4.4. Predicted use of the three newly emerging transportation modes

Table 5 indicates that with all other independent variables are held constant at its sample mean value, and there are the differences between their predicted frequency of using rideshare apps and bike-share programs between the two population groups, while only a marginal difference was found in car-sharing service use. Interestingly, immigrants in the U.S. would use bike share programs more frequently and rideshare apps less frequently than U.S. born residents.

Among those who do use an emerging transportation mode, U.S. born residents show a slightly higher predicted frequency of its use of car-sharing services and rideshare apps than immigrants in the U. S. If immigrants were identical to non-immigrants in all variables other than immigrant status, immigrants would still tend to use bike share programs more frequently rather than U.S. born residents.

4.5. Model validation

To assess model selection and the goodness of model fit, we conducted the likelihood ratio chi-square test and Vuong test (Vuong, 1989). As shown in Table 6, the test results (p-values < 0.001) indicated that all six ZINB models outperformed the Zero-Inflated Poisson model. Moreover, given the outcomes of the Vuong test, the ZINB model was preferred to a standard Negative Binomial regression model.

5. Conclusion

Understanding immigrants' travel behavior is crucial because transportation planners and policymakers can understand the needs of the population group and implement better transportation planning and public policies. A growing volume of transportation literature has mainly focused on conventional alternative transportation modes such as public transit (Blumenberg and Evans, 2010; Blumenberg and Smart, 2011; Chatman and Klein, 2009; Handy et al., 2008b; Klein and Smart, 2017; Liu and Painter, 2012; Smart, 2015; Tal and Handy, 2010).

The recent changes, such as the emergence of shared mobility services and shifted nature of immigration, require further research on immigrants' travel behavior. However, few studies have so far examined immigrants' use of car-sharing, ride-sharing, and bike-sharing services, as the shared mobility services have recently been around. In light of not only the research gap but also recent changes on the demand and supply side, we examined two research questions: (1) whether immigrants in the U.S. are more likely to rely on the newly emerging transportation modes, which are car-sharing, ride-sharing, and bike-sharing services, than US-born persons, and (2) whether the assimilation theory can be applied to the three modes.

Therefore, we explored whether immigrants rely more on emerging transportation modes by examining the 2017 National Household Travel Survey. To answer the research question, we developed the Zero-Inflated Negative Binomial (ZINB) regression Models, which separate but linked equations; (1) a logit model predicting whether the respon-

Table 6
The Results on P-Value of Likelihood-Ratio Test and Vuong Test.

Models	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Likelihood-ratio test	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Vuong test	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

dent reported using a certain emerging transportation mode at all, and (2) a negative binomial model predicting the respondent's frequency of using the alternative transportation mode for those respondents who used it.

The logit models found the "immigrant effect" only for car-sharing services and bike-sharing programs; that is, relative to U.S. born residents, a higher share of immigrants in the U.S. use car sharing and bike-sharing services at least once, while we found an insignificant association in ride-sharing apps use. However, the negative binomial models suggested that those immigrants that use car sharing and ride sharing at all, do so less frequently than expected. Immigrants who are in their first few years of living in the U.S. use smartphone rideshare app more frequently, confirming the "assimilation theory" – that over time, immigrants will rely less on these emerging mobility systems (and likely transition to mainline transit or auto). The results of the predicted frequency of the use indicated that with all other independent variables held constant, U.S. born residents use car sharing and ride-sharing services more frequently than immigrants, though the difference is marginal. However, immigrants tended to use bike share programs more frequently rather than U.S. born residents.

We believe that this research fills the gaps of existing studies and adds to our understanding by examining the travel behavior of foreign-born residents in the U.S. We also think that the results of this research would be helpful for transportation planners and policymakers to make better decisions to meet the needs of the immigrant population. However, there is a limitation that further research needs to examine. The first limitation regards the limitation on the data set. Specifically, since there might be a difference between undocumented and documented immigrants, we did not examine it because the NHTS does not include the information. Department of Homeland Security estimates that 12.0 million undocumented immigrants in 2015, compared to 11.5 million in 2014 and 11.6 million in 2010, meaning that the population increased by 70,000 per year from 2010 to 2015 (Department of Homeland Security, 2018). Given the number of the population, further studies are needed to explore their travel patterns. Also, the 2017 NHTS conducts the survey between April 2016 and April 2017. The period is at a relatively early stage of some of these modes, which means that the examined travel behavior might change as time goes. Moreover, although features on the shared mobility services, such as the regulation, pricing, and service provision, might influence the travel behavior, we did not examine the detailed aspects. Lastly, since there might be a regional variation on immigrants' travel behavior, comparative case studies in different regions are needed.

CRediT authorship contribution statement

Sangwan Lee: Conceptualization, Methodology, Software, Investigation, Writing - original draft. **Michael J. Smart:** Conceptualization, Investigation, Writing - original draft, Supervision, Validation. **Aaron Golub:** Conceptualization, Validation.

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