Immigrants' language skills and carpooling as need-based social networking: Evidence from large-scale national survey data

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ABSTRACT

Individuals often join social networks when lacking skills or resources. We study the motivation behind need-based networking in the context of transportation: using American Community Survey data, we examine how English proficiency is related to immigrants' carpooling behaviors. To conduct causal inference, we follow the standard approach and employ an instrumental variable strategy, in which we use the interaction term between age at arrival and linguistic origin to instrument for English proficiency, in additional to controlling for individual and geographic variables. Results support the hypothesis of "need-based networking": lower degrees of English proficiency are associated with higher carpooling probabilities and larger carpooling networks. A mediating analysis further shows that while English proficiency might indirectly affect carpooling behaviors through socioeconomic channels, the direct effect of English proficiency explains the majority of the overall effect.

1. Introduction

Scholars find that immigrants have unique transportation patterns in the U.S. Immigrants drive less (Tal and Handy, 2010; Chatman and Klein, 2013) and take public transit more than natives (Blumenberg and Evans, 2007; Blumenberg, 2013; Xu, 2018). Even conditional on driving, immigrants are more likely to carpool than driving alone (Blumenberg, 2013). In this paper, we study immigrants' carpooling behaviors from social network perspectives. Specifically, we examine the causal relationship between language skills and carpooling by estimating the effect of English proficiency on immigrants' carpooling behaviors, based on the hypothesis that carpooling reflects *need-based* social networking. Earlier studies (Teal, 1987; Ferguson, 1997) discuss socioeconomic reasons (e.g., education, income) for carpooling; in recent years, scholars introduce socialization mechanisms (McPherson et al., 2001) to transportation research and argue that immigrants' carpooling behaviors are associated with resource sharing (Blumenberg and Shiki, 2008) and signal the dependence on networking (Blumenberg and Smart, 2010, 2013; Shin, 2016) that widely exists among immigrants (Liu and Painter, 2011). However, less is known about the *motivation* behind decisions of joining carpooling networks.

We discuss language needs as a possible rationale for forming carpooling networks. Immigrants are exposed to language problems when driving due to, e.g., reading traffic signs (Liu and Schachter, 2007), communicating with traffic police (Correia, 2010), and racial profiling (Nier et al., 2012). The likelihood of encountering language-related problems is higher for immigrants with lower English skills, and carpooling could be immigrants' solutions to these problems through collaboration and collective decision-making (Van Vugt et al., 1997) and the decrease in nervousness (Créno and Cahour, 2014).

This paper contributes to the literature on urban/regional policy along multiple dimensions. Following the research stream of socialization mechanisms behind carpooling (Blumenberg and Smart, 2010), this paper extends existing studies by introducing the concept of need-based networking to explain the formulation of such mechanisms. Relatedly, while socioeconomic characteristics are associated with language skills, we analyze whether language skills alone—controlling for income, education, etc.—still affect carpooling. Moreover, if language skills indeed directly cause carpooling networking, then this paper reflects immigrants' potential challenges in daily transportation life due to language barriers and suggests social equity issues in the U.S., which is primarily a car-centric society (Giuliano and Dargay, 2006).

The causal relationship between immigrants' English skills and carpooling behaviors further relates to long-term trends in vehicle-related

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pollution and traffic congestion, two important topics in transportation policy. Carpooling provides a solution to pollution (Shewmake, 2012) and congestion (Huang et al., 2000), but carpoolers disproportionately concentrate among immigrants. As scholars forecast declines in immigration (Passel and Suro, 2005; Warren and Kerwin, 2018), one could expect simultaneous declines in carpooling, especially in megacities which have large immigrant populations as well as serious issues of pollution and congestion (Mashayekh et al., 2011).

Finally, this paper links immigration studies to transportation policy within a broad analytical framework of assimilation (Gordon, 1964). The first step of assimilation is usually language acquisition, which leads to further assimilation outcomes measured by earnings (Dustmann and van Soest, 2002), intermarriage (Guven and Islam, 2015), health status (Aoki and Santiago, 2018), and residential patterns (Bleakley and Chin, 2010). This paper lies under the same topic by studying how language acquisition reduces immigrants' dependence on carpooling, which is part of "transportation assimilation" (Blumenberg and Shiki, 2007; Xu, 2018).

In this paper, we exploit 2014 5-year American Community Survey data that record (a) carpooling behaviors and the number of co-riders, and (b) self-reported English proficiency. However, simply regressing carpooling variables on English proficiency and other controls lead to endogeneity issues, including omitted variable bias (unobserved attitudes towards socialization), reversal causality (effects of carpooling on language acquisition), and measurement errors (inaccurate self-reported English skills). We follow the standard causal inference approach (Bleakley and Chin, 2004) and employ an instrumental variable strategy to identify the effect of English skills based on psychological findings that a non-English speaker can acquire native-like proficiency only if arriving in an English-speaking country during the "critical period" (Lenneberg, 1967), hence age at arrival is a robust predictor of English skills. We then construct a "comparison group" based on immigrants' language origin to separate out language and non-language effects of age at arrival. Technically, the interaction between an indicator of arriving during the critical period and an indicator of non-English-speaking origin instruments for English proficiency.

Results show that immigrants with lower English skills are more likely to carpool and tend to carpool with more co-riders than immigrants with higher English skills. This relationship is not only correlational but also arguably causal, supported by the instrumental variable analysis. A one-unit decrease in English proficiency increases the likelihood of carpooling by 5.7 percentage points (or 40%) and the number of co-riders by 0.125 (or 50%). Individual and geographic factors also contribute to the effect; however, only a small proportion of the effect can be explained by these factors. While English proficiency could indirectly affect carpooling outcomes through socioeconomic channels, a mediating analysis shows that the direct effect of English proficiency explains the majority of the overall effect. These results present empirical evidence that many immigrants' carpooling behaviors are motivated by language needs and can be modeled by the concept of "need-based social networking.".

In the rest of this paper, Section 2 introduces the background. Section 3 discusses data and methods. Section 4 reports empirical results. Section 5 concludes.

2. Background

In the U.S., carpooling behaviors are largely determined by local highway infrastructures and fares (e.g., Giuliano et al., 1990; Nyerges and Aguirre, 2011), the urban spatial structure (Huang et al., 2000), and population distributions (Teal, 1987). Individuals' socioeconomic characteristics are also associated with carpooling behaviors. Higher education attainment accounts for the decline in carpooling in past decades (Ferguson, 1997), although the effect of personal income is less clear (Brownstone and Golob, 1992; Ferguson, 1997). In the U.S., immigrants are more likely to carpool than natives (Blumenberg and

Smart, 2010). Recent population data (Ruggles et al., 2015) show that 10.11% of native-born drivers and 17.82% of immigrant drivers carpool. Even among childhood immigrants—who are more assimilated than average immigrants—the percentage of carpoolers is still 14.81%.

The general determinants of carpooling apply to immigrants and could explain native-immigrant differences in carpooling behaviors. A key reason is that socioeconomic gaps—indicated by income, occupations, educational attainment, etc.—exist among natives and immigrants and contribute to differences in carpooling (Ferguson, 1997). But a more obvious reason of immigrants' carpooling behaviors is their residential location that directly influences carpooling behaviors. As people live in neighborhoods that form social networks, immigrants' residential location could affect their carpooling behaviors through mechanisms of networking, specifically in two ways described as follows.

First, immigrants prefer ethnic neighborhood residence (Bartel, 1989) that leads to networking, and carpooling is one of the typical networking behaviors. Following this idea, Charles and Kline (2006) consider a model of neighborhood social capital and show the positive relationship between minority racial makeups and carpooling behaviors. Consistently, empirical studies find that living in ethnic enclaves increases the likelihood of carpooling (Painter and Liu, 2012; Blumenberg and Smart, 2014). While some drivers carpool with family members, many people carpool with friends, acquaintances, and random neighbors (Shannon, 2016).

Second, and more specifically, immigrants living in an ethnic neighborhood are more likely to develop networks of commuting than their counterparts living outside the ethnic neighborhood, which is mainly due to occupational segregation by location in the U.S. (Cutler et al., 2008). Carpooling for work is challenging as suburbanization in recent decades (Baum-Snow, 2007) leads to the spatial separation of commuters, but immigrants are generally less suburbanized (Waldinger, 2001) and are more likely to live in denser and ethnic neighborhoods than natives (Bartel, 1989). As a result, immigrants are thus more likely to form carpooling networks for commuting than native-born commuters.

This paper extends this research stream by exploring possible mechanisms behind immigrants' decisions of joining carpooling networks. Economic theories argue that networking is related to intrinsic values between individuals and the cost of network formation (Jackson and Wolinsky, 1996). Immigrant benefit from forming social networks (McPherson et al., 2001; Munshi, 2003; Liu and Painter, 2011) because networking provides a platform for resource sharing (Blumenberg and Shiki, 2008) and psychological support (Créno and Cahour, 2014), and, as we will discuss later, carpooling is a typical behavior of forming a transportation network.

For immigrants, language proficiency is an important determinant of networking behaviors. Gordon (1964) describes language assimilation as a crucial step of immigrants' overall assimilation, and language assimilation is associated with other socioeconomic outcomes. Immigrants' skills of speaking the language in the host country are correlated with civil participation (Boyd, 2009; Aleksynska, 2011), socialization (Cho, 1999), friendship formation (Li, 2017), and channels of information retrieval (Zhou and Cai, 2002). Immigrants with a higher level of language skills are generally more assimilated in terms of social activity participation (Canagarajah, 2017) that resembles to that of natives, including more networking with natives and less networking with other immigrants.

Transportation networks and particularly carpooling networks (Blumenberg and Smart, 2010, 2013; Shin, 2016), as introduced earlier, are typical social networks among immigrants in the U.S. Consistent with the general relationship between language skills and social activity participation, immigrant drivers with low English skills experience technical and psychological challenges related to difficulties of understanding traffic signs (Liu and Schachter, 2007) and racial profiling (Horace and Rohlin, 2016), and carpooling could potentially tackle

these issues through collaboration with other co-riders and collective decision-making (Van Vugt et al., 1997).[1]

Although carpooling provides various types of benefits, forming a carpooling network is costly, and thus there is a trade-off between carpooling and driving alone. Carpoolers face lower degrees of flexibility: forming a carpooling network involves coordination problems between carpoolers (e.g., pick-up/drop-off delay), and a carpooler who shares the same origin and destination with a solo-driver usually needs to cover significantly longer traveling distance and spend more traveling time in commuting (Rietveld et al., 1999). This is particularly true for long-distance carpoolers, but carpooling could take substantially more time than driving alone even within a small neighborhood due to pick-up/drop-off delays (Levinson and Kumar, 1994). Therefore, carpooling should be more common among drivers with stronger needs for networking, such as immigrants with lower English skills.

3. Data and methods

3.1. Data

The American Community Survey (ACS, Ruggles et al., 2015) is the data source used in this paper. ACS is an annual nationwide representative micro-level survey that asks questions about demographic, socioeconomic, and geographic information. ACS also surveys regular means of commuting to work, including driving alone versus carpooling. We only study "childhood immigrants" who were not above 15 years old upon arrival. The main reason of only studying childhood immigrants is because that reasons of migration of adult immigrants are closely related to English skills (e.g., occupational migration) but are not observable. However, most childhood immigrants arrive in the U.S. with parents, and migration is unlikely to be a choice variable for them (Bleakley and Chin, 2004). We further restrict the sample to individuals who need to travel to the workplace. We only study drivers (including those who drive alone or carpool) in the main analysis; however, we consider other types of commuters (walkers, cyclists, etc.) in robustness checks.

Table 1's Panel A shows variables of English proficiency and carpooling behaviors. ACS provides five options for English proficiency: (a) does not speak English; (b) speaks English, but not well; (c) speaks English well; (d) speaks English very well; (e) speaks only English. Kominski (1989) constructs an ordinal measure of English proficiency ranging from 1 to 5, in which scoring 4 or 5 usually reflects native-like proficiency.[2] A simpler measure is a binary indicator of English proficiency: an immigrant is considered to have native-like proficiency if s/he selects (d) or (e) in the ACS.

In Table 1, we split the immigrant sample into two parts: immigrants from English-speaking countries (e.g., Australia) and non-English-speaking countries (e.g., Japan). We further split immigrants by their ages at arrival with the threshold being 9 years old: psychologists find that childhood immigrants can only acquire native-like language proficiency when arriving within the "critical period" (Lenneberg, 1967), which is traditionally considered to be 9 years old and younger (Johnson and Newport, 1989). Panel A shows that childhood immigrants who arrive before 9, regardless of linguistic origins, generally have high English proficiency; however, non-English-speaking immigrants who arrive after 9 have substantially lower English proficiency.

Panel A also reports immigrants' carpooling behaviors.

Approximately 15% of childhood immigrants are carpoolers, and age at arrival is positively correlated with carpooling propensity and the number of riders, and non-English-speaking immigrants generally have larger carpooling networks. Immigrants of non-English-speaking origins are more likely to carpool and have more co-riders than English-speaking immigrants, but differences in carpooling between immigrants from the two types of origins are smaller for those arriving before 9.

Panel B presents demographic variables. The average family size is approximately 3.5, and immigrants from non-English countries and immigrants arriving in the U.S. at older ages generally have larger families. Nearly 46% of individuals in the sample are female. Immigrants' average age is approximately 38 years old, which is close to the national average age of the workforce. English-speaking immigrants arrive in the U.S. at slightly younger ages, which is mainly because that many of them are infant immigrants. In robustness checks, we conduct additional tests that exclude immigrants arriving at very young ages.

Immigrants from non-English speaking countries, particularly those who arrive in the U.S. at older ages, tend to live in counties with more immigrants. This is consistent with earlier findings that English proficiency is negatively associated with ethnic enclave residence (Bleakley and Chin, 2010). Nearly 45% of individuals in the sample are Hispanics, and most of them are from non-English-speaking countries; nearly 28% of individuals are non–Hispanic White; 5.9% are Black. Nearly 20% of immigrants are Asian, and many Asian immigrants are from countries or regions where English serves as *lingua franca*, the language used in official administration, business, and education, and the *de jure* official language, but is not necessarily the major language (e.g., India and Singapore). This is similar in some African countries (e.g., Nigeria) that were previously British colonies. We will revisit this issue in robustness checks.

Panel C presents statistics of education and occupational outcomes. On average, childhood immigrants receive 13.6 years of education, which is close to the national average. Immigrants arriving at younger ages generally have more years of schooling. The traveling time to work is approximately 27 min, and the difference in the time cost of commuting appears to be small across immigrant groups. The average personal income is 50,018 USD. Age at arrival is negatively correlated with personal income, and immigrants from English-speaking countries have higher income. This pattern highlights the importance of discussing potential socioeconomic channels as confounding factors through which English proficiency might indirectly influence carpooling behaviors.

The statistical tests (Column 8) shows that immigrants from English and non-English speaking origins are different in many characteristics. Given the large sample size, however, it is worth noting that a number of key variables present similar patterns among the two groups immigrants: for children arriving between 0 and 9, both groups of immigrants have relatively small differences in carpooling propensity, the number of co-riders (conditional on carpooling), and commuting time. As this age group is associated with fairly small differences in English skills, these descriptive statistics naturally lead to the empirical question of the effects of English proficiency on carpooling behaviors.

3.2. Methods

For an individual i, denote p_i as the carpooling indicator that $p_i = 1$ if i carpools, and n_i is the number of riders ($n_i = 1$ if driving alone, and $n_i > 1$ if carpooling). We run the baseline OLS regression:

$$p_i = \beta_0 + \beta_1 E_i + \mathbf{X}_i \beta_2 + \varepsilon_i \tag{1}$$

where E_i is the ordinal or binary measure of English proficiency. $\mathbf{X}_i$ is the vector of individual characteristics (age, gender, etc.). β_1 reflects the effect of English proficiency on the propensity to carpool. In a similar regression, n_i is the dependent variable and β_1 reflects the effect of En-

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[1] For example, LA LA Times (1992) records immigrants' language problems in driving, including reading road signs and explaining situations to traffic police, which could be partially solved by networking; Yu (2016) documents Chinatown residents' reliance on networking when facing discrimination in transportation.

[2] Scoring 4 in English proficiency might still reflect native-like proficiency, as multilingual speakers have native-like English proficiency but cannot choose "speaks only English."

Table 1
Descriptive statistics: English proficiency and carpooling behaviors.

	(1) Total	(2) English-speaking immigrants	(3)	(4)	(5) Non-English-speaking immigrants	(6)	(7)	(8) Diff. (*p*-value)
		Total	Arr. 0–9	Arr. 10–15	Total	Arr. 0–9	Arr. 10–15	(3) - (6)
A. English Proficiency and Carpooling Behaviors								
English proficiency	2.721	2.922	2.949	2.869	2.663	2.842	2.412	< 0.001
(ordinal)	(0.634)	(0.314)	(0.264)	(0.390)	(0.688)	(0.497)	(0.828)	
English proficiency	0.805	0.934	0.956	0.923	0.768	0.900	0.599	< 0.001
(binary)	(0.396)	(0.248)	(0.205)	(0.267)	(0.422)	(0.300)	(0.490)	
Carpooling	0.148	0.124	0.118	0.137	0.155	0.139	0.179	0.003
(dummy)	(0.355)	(0.330)	(0.322)	(0.344)	(0.362)	(0.346)	(0.384)	
Number of co-riders	0.225	0.181	0.173	0.198	0.237	0.210	0.278	< 0.001
	(0.698)	(0.627)	(0.622)	(0.636)	(0.716)	(0.677)	(0.770)	
Number of co-riders,	1.517	1.460	1.470	1.442	1.530	1.512	1.552	0.001
among carpoolers	(1.152)	(1.140)	(1.176)	(1.076)	(1.154)	(1.155)	(1.153)	
B. Demographic Variables								
Family size	3.418	3.125	3.024	3.325	3.502	3.359	3.719	0.008
	(1.915)	(1.759)	(1.695)	(1.864)	(1.950)	(1.889)	(2.018)	
Female	0.455	0.483	0.482	0.484	0.446	0.470	0.411	< 0.001
	(0.498)	(0.500)	(0.500)	(0.500)	(0.497)	(0.499)	(0.492)	
Age	38.363	40.017	40.421	39.212	37.891	37.923	37.843	< 0.001
	(12.627)	(12.600)	(12.791)	(12.283)	(12.410)	(12.733)	(12.021)	
Age at arrival	7.304	6.738	3.796	12.600	7.467	3.929	12.813	0.001
	(5.021)	(4.897)	(2.938)	(1.719)	(5.044)	(2.978)	(1.728)	
# immigrants in the	426	311	293	348	459	429	504	< 0.001
county (in 100)	(647)	(522)	(493)	(567)	(675)	(652)	(504)	
Hispanic	0.448	0.168	0.180	0.146	0.528	0.463	0.627	< 0.001
	(0.497)	(0.131)	(0.138)	(0.119)	(0.498)	(0.498)	(0.481)	
Non–Hispanic white	0.277	0.323	0.396	0.179	0.264	0.334	0.158	< 0.001
	(0.448)	(0.468)	(0.489)	(0.383)	(0.441)	(0.472)	(0.363)	
Black	0.059	0.135	0.102	0.202	0.037	0.036	0.039	< 0.001
	(0.236)	(0.342)	(0.302)	(0.401)	(0.189)	(0.186)	(0.195)	
Asian	0.196	0.338	0.286	0.442	0.155	0.145	0.171	< 0.001
	(0.397)	(0.473)	(0.452)	(0.497)	(0.362)	(0.352)	(0.376)	
C. Socioeconomic (Education and Income) Variables								
Years of schooling	13.586	14.539	14.617	14.383	13.314	13.906	12.418	< 0.001
	(3.288)	(2.470)	(2.416)	(2.567)	(3.364)	(2.725)	(3.878)	
Traveling time to	26.588	26.843	26.531	27.463	26.515	26.182	27.018	0.006
work (minutes)	(20.620)	(20.680)	(20.806)	(20.414)	(20.602)	(20.526)	(20.707)	
Personal income	50.018	57.629	59.330	54.242	47.847	50.657	43.600	< 0.001
(in k. USD)	(59.888)	(64.890)	(67.750)	(58.634)	(58.200)	(61.225)	(52.970)	
Observations	246,576	54,743	36,446	18,297	191,833	115,451	76,382	

Standard deviations are in parentheses.

glish proficiency on the carpooling network size.

There are several important types of control variables that can be included in this baseline regression. First, controlling for geographic fixed effects $\tau_{i(g)}$ at the state or county level ($i(g)$ is i's state or county of residence) helps account for spatial heterogeneity in carpooling patterns. Second, it is useful to run a similar regression with socioeconomic controls (education, income, etc.). Comparing the change in the OLS estimate between the baseline regression and the regression with socioeconomic controls helps identify to what extent the overall effect of English proficiency includes the effect of socioeconomic status. Relatedly, a mediation analysis (MacKinnon, 2008) could separate out the *direct* effect of English proficiency on carpooling and the *indirect* effect of English proficiency through socioeconomic status as "mediators".

A crucial statistical issue of the above models is that English proficiency E_i is endogenous. One concern is measurement errors. It is usually difficult to accurately evaluate self English proficiency when there are only limited options (Dustmann and van Soest, 2002), which is similarly true in U.S. censuses and ACS (Kominski, 1989). The resulting measurement errors cause the downward bias of the OLS estimate. Another concern is omitted variable bias. Socialization preferences are not observable but could be related to both English proficiency and carpooling behaviors, which cause the upward bias of the OLS estimate.

Finally, reversal causality exists in the estimation, as English proficiency could be both the cause and consequence of carpooling. If English proficiency is indeed negatively related to carpooling, then reversal causality should cause the downward bias of the OLS estimate. As three sources of endogeneity lead to biases in different directions, it is theoretically impossible to predict the overall sign of the estimation bias.

To tackle the endogeneity issue, we employ an instrumental variable (IV) strategy designed based on two steps: first, we use age at arrival to predict English proficiency; second, We use the group of immigrants from English-speaking countries to separate out language and non-language effects of age at arrival. The essential idea of this IV is based on psychological findings that a child is most likely to acquire language proficiency during the "critical period" (Lenneberg, 1967) due to language learning activities in the cerebral cortex. However, age at arrival could generate non-language (e.g., cultural) effects. To partial out the non-language effect, We employ the standard econometric strategy developed by Bleakley and Chin (2004) to construct the IV using the interaction between age at arrival and linguistic origin. This is based on the idea that age at arrival has the language effect only among immigrants of non-English-speaking origins, but should have similar non-language effects among all immigrants regardless of linguistic origins. This IV strategy has been used in several related studies of the effect of

language proficiency on residential choices (Bleakley and Chin, 2010), intermarriage (Guven and Islam, 2015), and health status (Aoki and Santiago, 2018). Specifically, the IV is constructed by:

$$IV_{ija} = \mathbb{1}(\text{age at arrival} > 9) \times \mathbb{1}(j : \text{non English origin}) \quad (2)$$

where i indexes individual, j indexes country of origin, and a indexes age at arrival.

Following the literature, we define the critical period as 0 to 9 years old (Johnson and Newport, 1989). In robustness checks, we also redefine the critical period as 0 to 7 years old and conduct additional tests. Fig. 1 visualizes the relationship between age at arrival and English proficiency by linguistic origin. In general, immigrants who arrived in the U.S. during the critical period acquire native-like English proficiency, even for immigrants from non-English-speaking countries. However, there is a sharp decline in English proficiency by age at arrival after 9 among childhood immigrants of non-English-speaking origins.

In Table 2, we report first-stage regressions that quantify Fig. 1's findings that the age-origin indicator (i.e., the IV) serves as a robust predictor of English proficiency. While including control variables makes the magnitude of the correlation between the age-origin indicator and English proficiency smaller, the first-stage relationship is still statistically significant and strong (in terms of F-statistics).

Another assumption for the validity of the IV is the exclusion restriction: the age-origin indicator should affect carpooling behaviors only through its influences on English proficiency. This assumption is arguably reasonable because that compared with almost all other countries, the U.S. has a fairly unique driving (and carpooling) culture (Giuliano and Dargay, 2006). As a result, all childhood immigrants, regardless of linguistic origins, are similarly exposed to the U.S.' unique car-centric society and driving culture. Furthermore, systematic differences in immigrants of English-speaking and non-English-speaking origins should become smaller when further controlling for country-of-origin fixed effects, age at arrival, and individual characteristics.
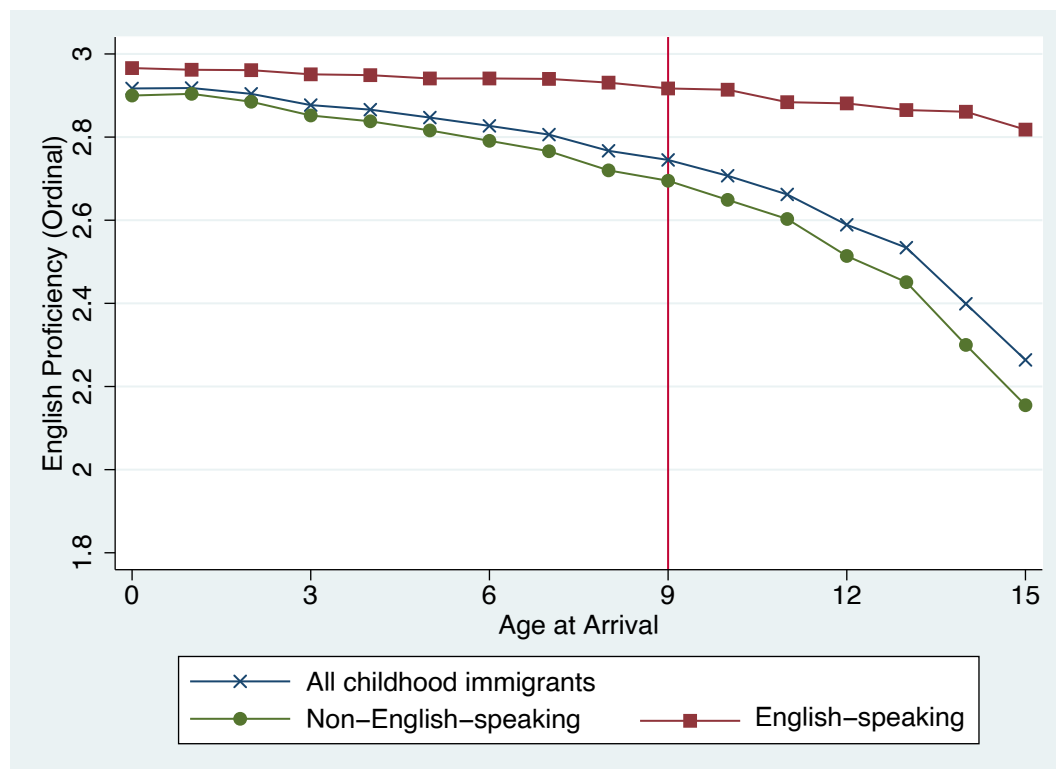
Table 2
First-stage regressions.

	English proficiency			
	Ordinal score		Binary measure	
	(1)	(2)	(3)	(4)
IV	−0.114***	−0.069***	−0.074***	−0.041***
(arr. age × origin)	(0.004)	(0.004)	(0.002)	(0.002)
Controls	No	Yes	No	Yes
R^2	0.130	0.224	0.140	0.265
F-statistic	727.38	352.20	1293.64	4847.97
Observations	246,576	246,576	246,576	246,576

Standard errors are in parentheses. Standard errors are clustered at county level.
*: $p < .05$; **: $p < .01$; ***: $p < .001$.

4. Results

4.1. Main results

Table 3 present the main results of this paper. In Panel A, we run OLS and IV regressions of the carpooling propensity on English proficiency. Columns 1 to 4 report results based on the ordinal measure of English proficiency, and columns 5 to 8 report results based on the binary measure of English proficiency (i.e., proficient or not). Results show that English proficiency is negatively related to the carpooling propensity. In particular, column 4 suggests that a one-unit decrease in English proficiency increases the likelihood of carpooling by 5.7 percentage points, which is nearly 40% of the proportion of carpoolers among drivers (see Table 1). Note that IV estimates are greater than OLS estimates, which is consistent with findings of Dustmann and van Soest (2002) that the effect of language skills is usually underestimated by the OLS, as measurement errors outweigh other endogeneity sources. The downward bias of the OLS estimate is similarly presented in other studies of the

Fig. 1. Age at arrival and English proficiency (ordinal measure).

Table 3

Main results: English proficiency and carpooling behaviors.

	OLS (1)	IV (2)	OLS (3)	IV (4)	OLS (5)	IV (6)	OLS (7)	IV (8)
A. Dependent Variable: Carpooling Propensity								
English proficiency (ordinal)	−0.067*** (0.004)	−0.096*** (0.007)	−0.048*** (0.003)	−0.057*** (0.013)				
English proficiency (binary)					−0.095*** (0.005)	−0.147*** (0.011)	−0.061*** (0.004)	−0.096*** (0.022)
R^2	0.015	—	0.029	—	0.011	—	0.027	—
B. Dependent Variable: Number of Co-Riders								
English proficiency (ordinal)	−0.130*** (0.012)	−0.166*** (0.017)	−0.100*** (0.010)	−0.125*** (0.025)				
English proficiency (binary)					−0.175*** (0.016)	−0.256*** (0.027)	−0.118*** (0.011)	−0.210*** (0.043)
R^2	0.014	—	0.025	—	0.010	—	0.022	—
Age at arrival	No	No	Yes	Yes	No	No	Yes	Yes
Country of origin	No	No	Yes	Yes	No	No	Yes	Yes
Demographic var.	No	No	Yes	Yes	No	No	Yes	Yes
C. Socioeconomic and Demographic Channels								
	Dependent Variables: Carpooling Propensity				Dependent Variables: Number of Co-Riders			
English proficiency (ordinal)	−0.038*** (0.002)	−0.055** (0.006)			−0.083*** (0.009)	−0.090*** (0.013)		
English proficiency (binary)			−0.045*** (0.003)	−0.080*** (0.014)			−0.091*** (0.009)	−0.129*** (0.018)
Log(income)	−0.019*** (0.001)	−0.019*** (0.001)	−0.019*** (0.001)	−0.026*** (0.002)	−0.025*** (0.002)	−0.025*** (0.002)	−0.025*** (0.002)	−0.025*** (0.002)
Years of schooling	−0.005*** (0.001)	−0.004*** (0.001)	−0.006*** (0.001)	−0.006*** (0.001)	−0.009*** (0.001)	−0.008*** (0.002)	−0.011*** (0.001)	−0.010*** (0.001)
Family size	0.007*** (0.001)	0.007*** (0.001)	0.007*** (0.001)	−0.008*** (0.002)	0.014*** (0.001)	0.014*** (0.002)	−0.014*** (0.001)	−0.013*** (0.001)
# immigrants in the county	1.400e-06*** (1.590e-07)	1.430e-06*** (1.570e-07)	1.390e-06*** (1.600e-07)	1.480e-06*** (1.600e-07)	3.090e-06*** (3.080e-07)	3.110e-06*** (3.750e-07)	3.060e-06*** (3.850e-07)	3.100e-06*** (3.840e-07)
Traveling time to work (minutes)	1.173e-03*** (0.006e-03)	1.168e-06*** (0.006e-03)	1.178e-06*** (0.006e-03)	1.157e-03*** (0.005e-03)	0.288e-03*** (0.015e-03)	0.288e-03 (0.016e-03)	2.890e-03*** (0.015e-03)	2.885e-03*** (0.014e-03)
# immigrants × traveling time	7.67e-09* (3.83e-09)	7.51e-09* (3.81e-09)	8.19e-09* (3.84e-09)	7.69e-09* (3.82e-09)	1.97e-08* (9.65e-09)	1.87e-08* (9.69e-09)	1.92e-08* (9.68e-09)	1.86e-08* (9.69e-09)
R^2	0.039	—	0.038	—	0.034	—	0.032	—
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Standard errors are in parentheses and are clustered at the county level. *: $p < .05$; **: $p < .01$; ***: $p < .001$. Observations: 246,576.

effect of English proficiency on social and economic outcomes (e.g., Bleakley and Chin, 2010; Guven and Islam, 2015). Panel B shows that English proficiency is negatively related to the number of co-riders, i.e., immigrants with lower English skills also have larger carpooling networks. The effects of English proficiency appear to be smaller after the inclusion of demographic controls, but are still statistically significant.

Is carpooling really for language needs? A main concern about the idea of modeling carpooling as need-based networking is that English proficiency could indirectly influence carpooling behaviors through its impacts on demographic and socioeconomic characteristics, in addition to the direct effect on carpooling, and the idea of need-based carpooling networking is valid only if the direct effect of English proficiency is statistically significant and sizable. Specifically, socioeconomic gaps—as indicated by income and education—account for differences in carpooling (Ferguson, 1977) and are simultaneously influenced by English skills. For immigrants in the U.S., English proficiency is also related to familial bonds and residential location (Bleakley and Chin, 2010) that jointly influence carpooling behaviors. A useful statistical approach to study these indirect channels is to include these variables in the analysis and compare the estimates among different regressions.

Panel C shows that socioeconomic characteristics are related to carpooling behaviors: both income and years of schooling are negatively correlated with carpooling behaviors. Immigrants' demographic

characteristics are also correlated with carpooling behaviors: an immigrant appears to be more likely to carpool than other immigrants if living in a larger family or in a county with more immigrants. Residential location also plays a role in determining carpooling behaviors: an immigrant appears to be more likely to carpool than other immigrants if living in a county with more immigrants and having a longer commuting time (as reflected by Panel C's last variable). These findings confirm the indirect demographic and socioeconomic channels through which English skills might influence carpooling behaviors.

In general, adding these demographic and socioeconomic controls makes OLS and IV estimates smaller (comparing columns 2/4 in Panel C with columns 4/8 in Panel A). We find similar results when using the number of co-riders as dependent variables (comparing columns 6/8 in Panel C with columns 4/8 in Panel B). However, the declines of coefficients are moderate, implying that English proficiency should still have strong direct effects on immigrants' carpooling behaviors.

To further study this, we conduct a mediating analysis based on IV regressions (Dippel et al., 2020), which identifies the proportion of the direct effect of English proficiency and the indirect effect of mediators (i. e., demographic and socioeconomic variables) in the overall effect on carpooling. Results of the mediating analysis show that these factors account for 45% of the overall effect of English proficiency on the carpooling propensity and 33% of the overall effect on the carpooling

network size when using the ordinal measure of English proficiency as the key independent variable; we find similar magnitudes using the binary measure of English proficiency. These results suggest while English proficiency indeed indirectly affects carpooling behaviors through other channels, the majority of the overall effect should still be explained by the direct effect of English proficiency.

4.2. Robustness checks

We conduct several additional tests to check the robustness of the main results. In Table 4, we study changes in specification and sample for regressions of the number of co-riders, i.e., the carpooling network size. Panel A reports regression results in the sub-sample of carpoolers: we study whether English proficiency still has significant effects on the carpooling network size conditional on carpooling. Results show that English proficiency plays an important role even among carpoolers: a one-unit decrease in English proficiency leads to 0.168 additional co-riders, which is more than 10% of the average carpooling network size among carpoolers (see Table 1).

In Panel B, we conduct a series of tests on changes in samples, using the number of co-riders (i.e., carpooling network size) as dependent variables. We first study areas where proportions of public transit commuters are less than 5%. These areas are more car-centric and have larger driving populations. As a result, there might be more solo-drivers. Results of columns 1 and 5 show that English proficiency is negatively related to the carpooling network size in these areas, with similar effect sizes. We then consider the spatial structure within the construction of the IV. First, we exclude immigrants from Canada and Mexico, which are adjacent to the U.S. and might have similar driving cultures with the U. S., compared to other countries. Second, we redefine English-speaking

origins and exclude immigrants from countries where English is the official language but is a minor language relative to local languages (e. g., India). In these regressions, we similarly find that immigrants with lower levels of English proficiency generally have larger carpooling networks, and the effect sizes are similar to the main results reported in Table 3.

As there are disproportionately many immigrants from English-speaking countries that are infant immigrants, we rerun the regression in the sub-sample of immigrants arriving after 5 years old. Columns 9 and 13 show that this adjustment of the sample does not alter the empirical results. We then extend the sample and include non-driving transportation modes (cycling, walking, public transit). The effect sizes reported in columns 10 and 14 appear to be smaller as, by definition, non-drivers do not have a carpooling network, but the qualitative pattern of the results remains unchanged. We finally test the gender heterogeneity in carpooling networking: we find that effects of English proficiency are significant and sizable among men, while effects among women (columns 12 and 16) appear to be substantially smaller and only marginally significant. In other words, carpooling networking for language needs tends to be more common among male drivers.

We finally conduct tests on alternative IVs. In Table 5, we change the definition of non-English-speaking origins and bounds of the critical period. In the first four columns, we reconstruct the control group in the new IV: all countries where English is not the major language are considered to be non-English-speaking (e.g., India and Singapore), as immigrants from these countries are not necessarily native speakers of English. Using either the ordinal or binary measure of English proficiency as the key independent variable, we observe that a decrease in English proficiency leads to both the higher carpooling propensity and larger carpooling network. In the last four columns, we use 7 years old to

Table 4
English proficiency and the number of co-riders, different tests.

	Dependent Variables: The Number of Co-Riders in the Carpooling Network							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
A. The Number of Co-Riders, Conditional on Carpooling								
	OLS	IV	OLS	IV	OLS	IV	OLS	IV
English proficiency (ordinal)	−0.114***	−0.092**	−0.100***	−0.168*				
	(0.025)	(0.031)	(0.020)	(0.086)				
English proficiency (binary)					−0.158***	−0.158***	−0.120***	−0.319
					(0.037)	(0.055)	(0.028)	(0.166)
Age at arrival	No	No	Yes	Yes	No	No	Yes	Yes
Country of origin	No	No	Yes	Yes	No	No	Yes	Yes
Control variables	No	No	Yes	Yes	No	No	Yes	Yes
R^2	0.006	—	0.017	—	0.004	—	0.015	—
Observations	36,516	36,516	36,516	36,516	36,516	36,516	36,516	36,516
B. Sample Changes (All Regressions are IV Regressions)								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
English proficiency (ordinal)	−0.132***	−0.121***	−0.133*	−0.143***				
	(0.030)	(0.027)	(0.069)	(0.027)				
English proficiency (binary)					−0.225***	−0.207***	−0.176	−0.218***
					(0.053)	(0.047)	(0.093)	(0.042)
Sample	Pub. tran. < 5% areas	Excl. Canada	Excl. Mexico	Excl. "Eng.-"minor"‡	Pub. tran. < 5% areas	Excl. Canada	Excl. Mexico	Excl. "Eng.-"minor"‡
Observations	179,601	238,691	179,253	214,601	179,601	238,691	179,253	214,601
	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
English proficiency (ordinal)	−0.097**	−0.067*	−0.165***	−0.054				
	(0.032)	(0.030)	(0.036)	(0.032)				
English proficiency (binary)					−0.169**	−0.116*	−0.282***	−0.089
					(0.058)	(0.052)	(0.063)	(0.053)
Sample	Arrival age > 5	Incl. all modes	Male	Female	Arrival age > 5	Incl. all modes	Male	Female
Observations	144,680	285,274	134,496	112,080	144,680	285,274	134,496	112,080
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Standard errors are in parentheses and are clustered at county level. *: $p < .05$; **: $p < .01$; ***: $p < .001$.

‡: "Eng.-minor" are countries where English is the official language, but is a minor language relative to local languages (e.g., India).

Table 5
English proficiency and carpooling behaviors: alternative IVs.

IV:	$\mathbb{1}$(age at arrival > 9) × $\mathbb{1}$(English is not the major local language)				$\mathbb{1}$(age at arrival > 7) × $\mathbb{1}$(non-English speaking country of origin)			
Dependent Variables:	Carpooling Dummy		Number of Co-iders		Carpooling Dummy		Number of Co-iders	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
English proficiency (ordinal)	−0.092*** (0.017)		−0.155*** (0.030)		−0.059*** (0.013)		−0.130*** (0.025)	
English proficiency (binary)		−0.138*** (0.026)		−0.233*** (0.045)		−0.097*** (0.021)		−0.216*** (0.042)
All controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	246,576	246,576	246,576	246,576	246,576	246,576	246,576	246,576

Standard errors are in parentheses and are clustered at county level.*: $p < .05$; **: $p < .01$; ***: $p < .001$.

define the critical period, as Fig. 1 suggests the "kink" of the relationship between English proficiency and age at arrival among immigrants from non-English-speaking countries could start as early as 7 years old. We find the same pattern that immigrants with lower levels of English proficiency are more likely to carpool and have larger carpooling networks than other immigrants with higher English proficiency, and the effect sizes are similar to the main results. In sum, Table 5 shows that the main empirical conclusion of this paper is not driven by the IV construction.

4.3. Revisiting other mechanisms

In the main analysis, we discuss demographic and socioeconomic characteristics as indirect channels through which English proficiency affects carpooling behaviors. We now revisit these mechanisms by focusing on the reasoning of the IV construction. Specifically, a natural question about these channels is: is the linguistic origin correlated with (a) family and social bonds, and (b) residential location?

To study this, we run a set of regressions of the variables of other mechanisms on English proficiency and English origins. Table 6 shows that immigrants with higher English proficiency generally have smaller families and shorter commuting times. Similarly, immigrants from non-English countries are often in larger families and spend more time on traveling to work. Demographers have long used traveling time to serve as a proxy for distance (e.g., Phibbs and Luft, 1995); in contexts of commuting between home and work, particularly for commuters, travel time may present an overestimate of traveling distance (Rietveld et al., 1999), which suggests that estimating the correlation between English proficiency and travel time to work leads to an upper bound of the relationship between English proficiency and residential location (distance to work) but should still represent the qualitative conclusion

regarding the geography of residence as a potential mechanism for the effects of English proficiency on carpooling. The findings shown in Table 6 are consistent with the main results that familial bonds and residential location might be indirect channels through which English proficiency influences carpooling behaviors. On the other hand, the size of the immigrant population in the place of residence (measured by either county or PUMA) appears to be uncorrelated with English proficiency or linguistic origin.

While statistically significant results are shown in the table, these regressions indicate the relationships between these variables are fairly small. Specifically, column 1 shows that a one-degree level of increase in English proficiency leads to a larger family size by 0.026. Compared with the average family size, which is close to 3.5 (see Table 1), the impact of English proficiency tends to be marginal. Column 2 shows that a one-degree level of increase in English proficiency leads to a longer commuting time by 0.236 min. Compared with the average commuting time, which is more than 25 min (see Table 1), the impact of English proficiency appears to be small as well. Similarly, columns 4 and 5 present fairly small impacts of linguistic origin on familial bonds and residential location. Overall, while Table 6 presents statistically significant patterns, the relationship between English proficiency and carpooling behaviors should still be dominated by the direct effect of English proficiency. This conclusion is consistent with results of the mediating analysis reported following the main results.

5. Conclusion

In the U.S., immigrant drivers are more likely to carpool than native-born drivers (Blumenberg, 2013). This is because of immigrants' socioeconomic patterns (Teal, 1987; Ferguson, 1997) and their tendency to form social networks for resource sharing and mutual support

Table 6
English proficiency/origins and other mechanisms.

	Family size (1)	Travel time to work (2)	# Immig. in the county (3)	# Immig. in the PUMA (4)	Family size (5)	Travel time to work (6)	# Immig. in the county (7)	# Immig. the PUMA (8)
English proficiency (ordinal)	−0.026* (0.012)	−0.236* (0.115)	−18.550 (11.458)	−20.339 (13.516)				
Non-English origin					0.073* (0.026)	−0.857* (0.031)	10.351 (12.481)	11.346 (13.681)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.217	0.049	0.082	0.090	0.217	0.050	0.084	0.092
Observations	246,576	246,576	246,576	246,576	246,576	246,576	246,576	246,576

Standard errors are in parentheses. Standard errors are clustered at county level when applicable. *: $p < .05$; **: $p < .01$; ***: $p < .001$.

(Blumenberg and Shiki, 2008; Shin, 2016). Following the research stream of carpooling networking, we extend the existing literature by exploring the motivation behind carpooling network formation among immigrants and propose the hypothesis that immigrants' carpooling behaviors are related to language needs.

Baseline regression results suggest immigrants with lower levels of English proficiency are more likely to carpool and have more co-riders (i.e., larger carpooling networks) than other immigrants with higher English proficiency. Using an instrumental variable strategy (Bleakley and Chin, 2004), we find the causal link between English proficiency and the carpooling propensity (and carpooling network size), and effects of English proficiency are not only statistically significant but also sizable. The results are robust to changes in samples and specifications. While language skills could indirectly affect carpooling through socio-economic channels, we find strong *direct* effects of English proficiency on the carpooling propensity and carpooling network size. A mediating analysis show that more than half of the overall effect on carpooling outcomes can be explained by the direct effect of English proficiency. The empirical results of this paper support the hypothesis that language needs could be a major driver of immigrants' carpooling behaviors, and carpooling is essentially for need-based social networking.

This paper points out several avenues for future research. First, a potential research direction is to investigate policy implications of carpooling from environmental perspectives. Vehicle-related pollution and traffic congestion are common in U.S. megacities, which are also usually home to many immigrants. With possible declines in new immigration (Warren and Kerwin, 2018) and old immigrants' improved English skills through language assimilation (Gordon, 1964), it is likely that trends in immigrants' carpooling behaviors will also change, and further affect pollution and congestion patterns. Second, immigrant networks play a pivotal role in shaping immigrants' labor market outcomes (Munshi, 2003; Liu and Painter, 2012) through, e.g., job referrals and word-of-mouth communications. A future research topic involves the estimation of the effect of carpooling on immigrants' earnings, occupational choices, and other socioeconomic outcomes.

CRediT authorship contribution statement

Dafeng Xu: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Visualization, Writing – original draft. **Yuxin Zhang:** Validation, Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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