THE INFLUENCE OF PEER EFFECTS ON ADOPTION OF CONNECTED AND AUTONOMOUS VEHICLES

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ABSTRACT

As technologies enabling connected and autonomous vehicles (CAV) are rapidly advancing, a question remains not fully answered is that how peer effects influence users' adoption of CAVs. The answer is especially unclear for less-developed regions and residents not keen on new technology adoption. This paper designed a stated preference (SP) survey and collected opinions from five medium cities in China. Among all the determinants, peer effects showed significant influence. 87% of respondents confirmed the effects of peer effects on their adoption of CAVs at different levels. Ordered Probit model was then used to further analyze the impacts of peer effects. Results indicated that those who are experienced in driving or know CAV tend to be less dependent on peer effects in choosing CAV. This study offers valuable insights for understanding CAV adoption, especially for less developed regions.

Keywords: Peer effects, Connected and autonomous vehicles, Stated preference survey, Ordered probit models

INTRODUCTION

With the advent of technologies advance, transportation system is witnessing a revolution. Nowadays, people can get easy access to autos with semi-autonomous functionality. Connected and autonomous vehicles (CAVs) is not a completely new concept either. As a new alternative for traveling, CAVs are expected provide solutions to a series of transportation problems. However, as for other new technologies, users always have their concerns regarding the potential benefits and costs of CAVs, and adoption of CAVs will not happen overnight. It is expected that non-autonomous vehicles and CAVs will co-exist for a long period, and many studies are built on this assumption when studying the future traffic problems. Thus it is necessary to understand how potential users perceive CAV, and what factors may influence the adoption of this technology.

Recently many researchers have looked into public opinions on CAVs. Some of them focused on the willingness to pay for CAVs (*1*), some studied the latent variables describing the individual's attitudes (*2*), and others forecasted long term adoption (*3*). However, most of these studies only focused on individuals in developed regions with better readiness for technology adoption. In addition, as an important factor, peer effects hadn't been included into studies of influence factors. It is important to supplement the existing literature with studies on peer effects in less developed areas with different demographic features.

This study focused on China for several reasons: First, it is estimated that by 2035 there will be around 8.6 million autonomous vehicles in China, with about 3.4 million fully autonomous, and the others semi-autonomous (*4*). The market for autonomous vehicles in China is large and the potential impacts are enormous. Second, in recent years, China distinguishes itself from other countries with its overall high tendency for adopting new technologies and heavy reliance on social media. It is interesting to investigate how peer effects influence user behavior in China. Third, the unbalanced economic development in China enables information acquisition on potential CAV users from currently less-developed regions, who are largely neglected in existing literature.

This study conducted a Stated Preference (SP) survey on new vehicle buyers in five medium-level cities of China. An ordered probit model was adopted to estimate the data, with peer effects as the main focus.

LITERATURE REVIEW

CAVs are the most important technological advances of transportation systems in this century. Recently, many researchers have looked into public opinions about CAVs.

Among all the factors giving rise to the adoption of CAVs, social interactions cannot be neglected. This contains two parts: social effects and peer effects. Social effects refers to the overall influence of the society, often measured by market penetration rate. Peers effects refers to the effects coming from peers who are either socially or economically connected with the respondents. Although not specifically on CAV adoption, previous literature has also extensively discussed impacts of peer effects on people's behavior. As a concept in economics, peer effects have been widely studied on school participation (*5*), worker productivity (*6*), choice of medical school specialty (*7*), prenatal care (*8*), and retirement savings behavior (*9*) among others. Narayan et al. (*10*) studied three behavioral mechanisms to analyze the effect of peer influence on choice decisions. A generalization of the Bayesian updating mechanism was used. According to their study, the consumer's posterior preference for an attribute was a weighted average of her or prior preference and the preferences of her peers. Oster and Thornton (*11*) used probit model to estimate peer effects. Two types of data are collected: total number of friends, the strength of friendships and weak friendships. Based on model estimation, marginal effects are reported. Vardardottir (*12*)

analyzed the peer effects on educational performances using regression discontinuity approach. They found that assigning students to classes with good academic performance peers increased their own academic ability. Furthermore, the result showed that a 1 standard deviation increased in the average ability of peers would increase one's own seasonal exam outcomes by approximately 0.85 standard deviations and annual grade by 0.58 standard deviations. Bursztyn et al. (*13*) showed that when someone purchases an asset, his peers may also want to purchase it, both because they learn from his choice ("social learning") and because his possession of the asset directly affects others' utility of owning the same asset ("social utility").

Given the importance of peer effects on human behavior, this paper specifically focuses on the impacts of peer effects on people's opinions towards CAVs, adding great value to existing literature.

DATA

Stated Preference Survey

The data were collected via a SP survey to estimate people's opinion on CAVs in China. The survey was conducted in five small to medium level cities in China.

The respondents are new vehicle buyers who just made decisions on vehicle purchase. They were interviewed when they registered their vehicle licenses. The survey was distributed from December 2017 to March 2018. A total of 1243 respondents were investigated. After data cleaning, 4251 valid observations from 1132 respondents remained.

Data Statistics

TABLE 1 summarizes statistics of the key variables used for peer effects analysis. Besides, the SP survey also includes personal characteristics like gender, education level, income, accident history etc; technology related information like willingness for CAVs, incentives for using CAVs, tasks while riding CAVs; traffic conditions; market penetrations for CAVs; vehicle price and maintainance price.

TABLE 1 Descriptive Statistics for Key Response Variables

	Influential factor	Variable	Description	Mean	SD	Min	Max
Personal characteristics	Age	AGE_N	Age of respondent (year)	35.80	10.83	22.00	70.00
	Occupation	*JOB_1*	Indicator for work as a specialist	0.12	0.33	0.00	1.00
		JOB_2	Indicator for working in service industry	0.35	0.48	0.00	1.00
		JOB_3	Indicator for self-employed	0.19	0.39	0.00	1.00
		JOB_4	Indicator for worker	0.18	0.38	0.00	1.00
		JOB_5	Indicator for company employee	0.04	0.20	0.00	1.00
		JOB_6	Indicator for student	0.10	0.30	0.00	1.00
		JOB_7	Indicator for government staff	0.08	0.26	0.00	1.00
		JOB_8	Indicator for housewife	0.02	0.14	0.00	1.00
		JOB_9	Indicator for farmer	0.07	0.26	0.00	1.00
		JOB_10	Indicator for unemployed	0.03	0.17	0.00	1.00
		JOB_11	Indicator for other types	0.05	0.22	0.00	1.00
	Driving age	DRIAN	Numeric variable for respondent driving age (year)	0.14	0.34	0.00	1.00
	Household	HH_1	Indicator for having no child	0.40	0.49	0.00	1.00

	type	HH_2	Indicator for having children over 18 years old	0.11	0.31	0.00	1.00
		HH_3	Indicator for having children under 6 years old	0.49	0.50	0.00	1.00
	Elderly	ELD_1	Indicator for living with elderly(>65)	0.45	0.50	0.00	1.00
		ELD_2	Indicator for living with no elderly(>65)	0.53	0.50	0.00	1.00
	Time to work	TIME2W	Numeric variable for commute time (minute)	25.16	14.03	0.00	100
Technology Related	Information	*INF_1*	Indicator for not having heard of CAVs	0.28	0.45	0.00	1.00
		INF_2	Indicator for having heard of CAVs	0.70	0.46	0.00	1.00
	Equipment	*EQUI_1*	Indicator for not equipping with any AV technology	0.31	0.46	0.00	1.00
		EQUI_2	Indicator for equipping with one or more AV technologies	0.47	0.50	0.00	1.00
		EQUI_3	Indicator for not sure	0.22	0.42	0.00	1.00

Table 2 gives a brief summary for all opinion-based questions. Respondents' choices among the three alternatives indicate that Semis are favored by nearly half of the respondents. This may be because that Semis are much more convenient than regular vehicles yet still give drivers the sense of control. 72% of respondents have heard of CAVs and 27.5% want to try it while half of the respondents indicated to wait and see. Over half of them already owned a vehicle equipped with some AV technologies. As shown in Table 2, peer effect is an influential factor for the adoption of CAVs, as 87% of them think peer effects have impact on the preference about CAVs, and 37% think peer effects are essential for the preference.

TABLE 2 Survey Results Summary

Choice for Nons, Semis and CAVs	**Percentage**
Nons	36
Semis	45
CAVs	19
General Opinions towards CAVs	**Percentage**
Having heard of CAVs	
No	28.1
Yes, but not know it	62.4
Yes and know it well	9.5
Interested in trying CAVs	
No	28.6
It depends	43.9
Yes	27.5
New vehicle equipped with any AV technology	
None or not sure	42.4
Have one or more than one	57.6
Opinions towards Peer Effects	**Percentage**
No impact	13.1
A litter impact	14.0
Some impact	35.6
Large impact	22.6
Determining impact	14.7

MODEL

Methodology

To further identify study the SP survey, Ordered Probit (OP) model is used to analyze the impact of peer effect on people's adoption of CAV.

Ordered Probit Model

Ordered probability models are derived by defining an unobserved variable *z*, which is used as a basis for modeling the ordinally ranked data. The model formulation is as follows:

$$z = \beta X + \varepsilon \quad (1)$$

where X is a vector of variables determining the discrete ordering for observation n, β is a vector of estimable parameters, and ε is a random disturbance. This study uses an OP model to analyze the impact of peer effect. The dependent variable is the importance level of peer effect indicated by respondents, ranking from level 1 to level 5. Therefore, μ_1 is the threshold between "no impact" and "slight impact", μ_2 is the threshold between "slight impact" and "medium impact", μ_3 is the threshold between "medium impact" and "a lot impact" and μ_4 is the threshold between "a lot impact" and "determinant impact".

$$\begin{aligned}
&\Pr(\text{no impact}) = \Pr(z \le \mu_1)\\
&\Pr(\text{slight impact}) = \Pr(\mu_1 \le z \le \mu_2)\\
&\Pr(\text{medium impact}) = \Pr(\mu_2 \le z \le \mu_3)\\
&\Pr(\text{a lot impact}) = \Pr(\mu_3 \le z \le \mu_4)\\
&\Pr(\text{determinant impact}) = \Pr(z \ge \mu_4) \quad (2)
\end{aligned}$$

Results Analysis

Model is estimated using Limdep (*14*). The estimation results are presented and discussed as follows. A random parameter OP model is used to analyze the Importance of Peer Effects. The dependent variable is the rating of importance reported by each respondent. Independent variables contain all the respondents' characteristics. The random parameter variables are age, driving age and time to work. The final model estimation results are summarized in TABLE , marginal effects are shown in TABLE .

TABLE 3 Results from the Random Parameter Ordered Probit Model

Category	Variable		Coefficient	t-stat
Constant	**Constant**		1.173***	**4.98**
Personal characteristics	**Age**	**Mean**	0.009*	1.66
		STD	0.004***	3.44
	JOB_2		0.116	1.28
	DRIAN	**Mean**	-0.033	-1.39
		STD	0.063***	6.27
	HH_1		-0.271**	**2.51**
	ELD_1		0.157*	1.78
	TIME2W	**Mean**	-0.005	-1.57
		STD	0.012***	7.93
Technology related	**EQUI_2**		-0.222**	**-2.44**

	INF_2	-0.128	-1.21
Threshold parameters for probabilities		Threshold	t-stat
μ_2		0.575***	10.00
μ_3		1.569***	20.49
μ_4		2.294***	26.11

TABLE 4 Marginal Effects of Ordered Probit Model

Variable	Marginal effects				
	No impact	A litter impact	Some impact	Large impact	Determining impact
***ELD_1**	-0.029*	-0.021*	-0.009	0.023*	0.036*
***JOB_2**	-0.021	-0.016	-0.007	0.017	0.027
***EQUI_2**	0.042**	0.030**	0.012**	-0.033**	-0.050**
***HT_1**	-0.049**	-0.036**	-0.018*	0.040**	0.064**
***INF_2**	0.023	0.017	0.009	-0.019	-0.03
DRIAN	0.006	0.004	0.002	-0.005	-0.007
TIME2W	0.001	0.001	0	-0.001	-0.001
AGE_N	-0.002	-0.001*	-0.001	0.001	0.002*

As shown in TABLE , with 1 year's increase of respondent age, the probability of selecting no impact decreases by 0.2% while selecting determinant impact increases by 0.2%. For individuals who have AV technologies in car tend to have 4.2% more probability to select no impact for peer effects while have 5% less chance to choose determinant impact. By analyzing all variables, this study shows that peer effects have different levels of influence depending on the respondent's characteristics. Respondents who are older, and who live with elderly, work in service industry, and have no children are more likely to be influenced by suggestions from their friends or social media. Respondents who travel longer to work or have more driving experience are less influenced by peers. Respondents with knowledge of CAVs or having cars equipped with AV technologies also take less account of peer effects.

CONCLUSIONS

This study designed and implemented a survey in five less-developed cities in China. Results from the model show that peer effects play an important role on people's adoption of CAVs. In general, younger people with higher education level, higher income, having heard of CAV, living in developed area with high GDP are more likely to adopt CAVs than average individuals. The low maintenance price of CAVs will also attract more people. In addition, those who are experienced in driving or know CAV tend to be less dependent on peers. In short, CAV adoption will be a gradual process, and different regions and people will adopt CAV at different rates. However, this study still has some limitations. The survey was distributed to people who already decided to buy autos. The dataset thus cannot represent the overall population when predicting CAV adoption by a whole region.

Nevertheless, the study offers valuable insights for developing countries, especially on the aspect of CAV popularization. In addition, this study also introduces peer effects factor into the model. Social and peer influences are important, suggesting a potentially exponential curve in CAV adoption.

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