Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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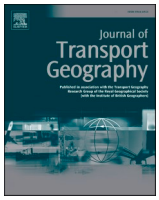

An empirical study on consumer automobile purchase intentions influenced by the COVID-19 outbreak

Yingying Yan [a,b], Shiquan Zhong [a,b], Junfang Tian [a,b,*], Ning Jia [a,b]

[a] College of Management and Economics, Tianjin University, Tianjin 300072, China
[b] Laboratory of Computation and Analytics of Complex Management Systems (CACMS), Tianjin University, Tianjin 300072, China

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ABSTRACT

The sudden onset of the coronavirus disease 2019 (COVID-19) may influence individuals' automobile purchase decisions, thus bringing great uncertainty to the automobile industry. To this end, the current study investigates individuals' behaviors regarding the purchase of automobiles, both before and after the outbreak of COVID-19. An ICLV (integrated choice and latent variable) model that integrates the socio-demographics, epidemic-related variables and psychological latent variables is applied. A survey of 960 respondents was conducted in China during the epidemic. The results suggest that there was an increase in the demand for automobiles after the COVID-19 outbreak. Firstly, demand was especially high in the groups of females, citizens, high-income earners, and people who own a driving license or who live in high epidemic risk areas. Secondly, although the severity of the epidemic for residences has a positive effect on automobile demand, travelers' perceived vulnerability is the key factor motivating purchases. Thirdly, the epidemic's negative income effects reduced the purchase propensity. Several dynamic policies are proposed to automobile consumption of the special time of the COVID-19 pandemic.

1. Introduction

With the rapid growth of its economy, China was the world's largest automobile market during the past decade (Zhili et al., 2019). However, the outbreak of an unexpected large-scale public health emergency, i.e. coronavirus disease 2019 (COVID-19), poses a huge crisis in the automobile industry. COVID-19 causes severe respiratory illness and is spread mainly by droplets that can be transmitted directly among humans (Munster et al., 2020). To wrestle with the pandemic, the Chinese government launched the first-level response mechanism for epidemic prevention and control, which included travel restrictions, free healthcare, and closures of schools and factories. These measures have achieved remarkable results for virus prevention and control (Cohen and Kupferschmidt, 2020; Tian et al., 2020). Consequently, as a kind of discretionary consumption, automobile sales in China have been significantly affected, decreasing by 42% when compared with the sales in January and February of 2019 (MIITPRC (Ministry of Industry and Information Technology of the People's Republic of China), 2020).

On the one hand, the slowdown in automobile consumption and travel might be beneficial for the environment. Previous studies have reported that restricting automobile consumption and travel through policies have reduced the growth rate of automobile ownership, and slowed down the increase of air pollution (Yang et al., 2017; He and Jiang, 2021). However, other research also has found that decreased automobile consumption and travel have not significantly increased public transport passenger volume and might not reduce fuel consumption as much as expected (Yang et al., 2014; Zhang et al., 2019).

On the other hand, the decline of automobile sales might trigger negative impacts on the economy and society. Since the automobile industry has played a vital role in China's real economy and is related to people's livelihoods in the industrial chain, a deteriorating automobile market might cause problems, such as unemployment and an economic downturn. In the past, the Chinese government implemented diverse measures to help the automobile industry through several tough periods. The focuses and intensities of the implemented favorable measures differed according to the special circumstances of those periods and had positive effects. For instance, the global financial crisis caused a negative growth rate for automobile sales in China for two consecutive quarters in 2008, but grew by 52.9% in 2009. The growth occurred after the government had set up a series of stimulus policies, such as vehicle purchase tax reductions. As the current crisis is more serious and challenging, policy makers are expected to adopt some rescue measures to curb the

* Corresponding author at: College of Management and Economics, Tianjin University, Tianjin 300072, China.
E-mail address: jftian@tju.edu.cn (J. Tian).

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escalating demand gap in automobiles and reboot the automobile industry. The required types of measures are a pressing issue.

There are relatively scant works about the effects of epidemics on the automobile industry, and most of the existing studies focus on the supply side and industrial chain of the automobile industry (Thun and Hoenig, 2011). Nevertheless, there are still some gaps in the research on the emergency responses of the demand side. In fact, the impacts of the disease's outbreak include individuals who may adapt their consumer behaviors to lower the perceived threat of infection. People have now begun to resume work and production as the epidemic has come under control, and they have to face the risk of COVID-19 infection from daily commutes and increasing mobility. Compared with public transport modes, such as taxis, buses and subways, the threat of infection while a person uses a private automobile is smaller, due to the lower probability of making contact with other people. Hence, would consumer automobile purchase decisions be affected by this epidemic? If so, then why? The answers are crucial issues for stakeholders, such as policy makers, with regard to future economic recovery plans and strategic layouts. Therefore, an investigation of the effects of an epidemic on the perceptions and potential automobile purchase intentions is necessary.

Several studies on behavioral decision making have examined the factors influencing automobile purchase intentions (Prieto and Caemmerer, 2013; Gao et al., 2014). Consumer purchase decisions and behaviors are complex processes that are affected by both internal and external factors (Azjen, 1980). External factors act through outside contextual factors, such as unexpected public health emergencies. Internal factors involve personal life experiences, attitudes, socio-demographic features and travel risk perceptions during epidemics. Therefore, apart from observed factors, subjective factors that cannot be directly observed also play indispensable roles in final decisions when consumers face multiple choices (Choo and Mokhtarian, 2004). Accordingly, an ICLV (integrated choice and latent variable) model that includes both latent variables and observed variables is an appropriate approach to solving this problem (Ben-Akiva et al., 1999; Ben-Akiva et al., 2002). In practice, ICLV models have been applied in the research of transportation issues, such as route selection, travel time selection, transportation mode selection, and consumer automobile purchase decisions (Varotto et al., 2017; Soto et al., 2018; Lavieri and Bhat, 2019; Malik et al., 2021). Such models can explore the relationships between heterogeneous variables and their effects on selection results (Bhat, 2015). Moreover, these models have been proved to improve explanatory powers and obtain estimated results closer to real situations (Soto et al., 2018). Hence, we adopted the approach to explore individuals' logic behind their automobile purchase decisions.

Given the limitations of research into how automobile purchase decisions are affected by an epidemic, the purpose of the current study was to investigate the influence of the epidemic on potential consumer automobile purchases. Specifically, from the perspective of the demand side, the present study focuses on consumer automobile purchase decisions affected by the COVID-19 outbreak and establishes an ICLV model that consists of socio-demographic attributes, epidemic-related factors, and travel risk perceptions. We analyzed the consumer automobile purchase decisions before and after the COVID-19 outbreak to reveal the influence mechanism of automobile consumption during the epidemic. Our findings provide policy implications for policy makers to help improve the policy effectiveness.

The remainder of this paper is structured as follows: Section 2 provides the theoretical model framework, Section 3 describes the data and model formulation, Section 4 presents the results of parameter estimation, Section 5 discusses the findings and policy implications of this study.

2. Conceptual framework

The current study establishes an ICLV model that considers both the internal and external factors of consumer automobile purchase decisions affected by the specific circumstances of COVID-19. A detailed description of this theoretical model is provided below.

2.1. Explanatory variable

We consider a set of socio-demographic and epidemic-related variables as explanatory variables. The socio-demographic variables refer to an individual's traits, such as natural and social attributes. We chose several socio-demographics related to automobile purchase scenarios: age, gender, household income, residential location (characterized as urban or non-urban), vehicle availability (if a household owns at least one private automobile), and driving licenses (if an individual has a driving license) (Lavieri and Bhat, 2019).

Epidemic-related variables imply the influence of the external environment on individual decisions, which involves the degrees of epidemic severity in the participants' current residences and the epidemic's negative impacts on household incomes. On the one hand, local epidemic severity, i.e. the severity of the epidemic in regions where participants currently live, would influence commuters' perceptions of travel risk. It can be reasoned that the greater the degree of local epidemic severity, the higher is the tendency of a person to use private transportation as a means of avoiding contact with other people. We characterized the degree of the epidemic severity in each province of China according to the cumulative number of confirmed cases: (1) slight (1–99 cases), (2) moderate (100–999 cases), and (3) severe (>1000 cases). Every participant was placed into a category according to their reported place of residence. On the other hand, the outbreak also had economic impacts on household income. Some studies have suggested that automobile purchase decisions were related to the economic situations of households, so a consideration of the epidemic's negative impacts on income at the household level was necessary (Lam et al., 2000; Dargay, 2001). Considering the percentage of decrease in participants' household income due to the epidemic, we divided the degree of the negative impacts on household income into four levels: (1) none (<10% decrease in household income), (2) slight (10%–40% decrease in household income), (3) moderate (40%–70% decrease in household income), and (4) severe (equal to or more than a 70% decrease in household income).

2.2. Latent variables

The present study introduces latent variables into the model to describe the influences of psychological factors on consumer automobile purchase intentions. The external environment stimulates the arousal of internal perceptions while perceived risks are regarded as important factors in consumer decisions (Tsiros and Heilman, 2005; Azjen, 1980). In public health emergencies, received external information affects individuals' psychological expectations of health risks and protective responses to the environment (Li et al., 2020; Maddux and Rogers, 1983; Wang et al., 2018). The COVID-19 epidemic involves a potential threat to both physical health and life, so now people have greatly increased their requirements for healthy and germ-free means of transportation. The infectivity of COVID-19 poses a potential danger of virus transmission in public transport and increases commuters' fear of public transport, whereas the relatively independent spaces of private automobiles allow people to feel safer and healthier, possibly leading to an increase in the demand for private automobiles. Hence, the present study incorporates travel risk perceptions into its model.

Perceived risks are the subjective evaluation of the severity of a threat (perceived severity (PS)) and the probability of encountering a threat (perceived vulnerability (PV)) (Dowling and Staelin, 1994). If commuters feel that the risk is higher, then they may take protective actions to lower the threat (Lee, 2011; Herath et al., 2014; Liu et al., 2017). Therefore, we assume that an individual's subjective perceptions of their travel risks affect their automobile purchase decisions.

In addition to perceived risks, an epidemic may induce a negative

mental health status (Xiong et al., 2020). The COVID-19 pandemic has been proven to increase the negative mental outcomes, such as depression, anxiety, and fear (Liao et al., 2021). Surveys from China have reported that more than half of the participants had experienced a moderate-to-severe psychological impact, and one-third had moderate-to-severe anxiety in the initial phase of the epidemic's outbreak (Wang et al., 2020). After returning to work, 10.8% of participants in China expressed feelings of post-traumatic stress disorder (Tan et al., 2020). In reality, a study from eight countries found that participants from China had the highest perceived impact of the pandemic; this variable was also positively associated with adverse mental health (Wang et al., 2021). Besides, other research found that being worried about becoming infected was associated with negative mental health (Lei et al., 2020). Therefore, we assume that an individual's perceptions of risks, both about being infected and the severity of the epidemic, affect their mental status. Also, the adverse mental status sequentially affects their intention to purchase vehicles.

2.3. Outcome variables

Individuals may change their automobile purchase decisions to reduce their travel risks. Thus, automobile purchase decisions made after the epidemic outbreak are the outcome variable in our proposed model. In the questionnaire, we asked participants if they had planned or intended to purchase private automobiles before or after the COVID-19 outbreak. Moreover, we used different descriptive statements for these two questions to avoid confusion and placed them separately at the beginning and end of the questionnaire. According to their answers about their automobile purchase plans prior to the epidemic, we placed each participant into one of two groups: those who had not planned to purchase before the outbreak (Group 1) and those who had planned to do so (Group 2). The participants in Group 1 still had no plans to buy automobiles or said they would wait to purchase until after the outbreak, whereas those in Group 2 would have canceled their plans or still intend to purchase after the outbreak. By grouping, we can better compare and understand the reasons and decision mechanism behind the changes in automobile purchase decisions before and after the COVID-19 outbreak. The results of Group 1 can help to answer the question "Why did the individual decide to purchase a private automobile after the public health emergency?" The results of Group 2 would answer the other question "Why did the individual cancel their automobile purchase plans after the public health emergency?"

3. Methodology

3.1. Data collection

An anonymous online questionnaire was used to collect empirical data, and the respondents were rewarded 5 RMB for completing their questionnaires. First, participants were asked if they had automobile purchase plans before the epidemic at the beginning of our survey. The second part of the survey was about the socio-demographic information. Then, participants would indicate their current residence (which implied the epidemic severity of their locations), any negative impact on their household income, as well as answering questions about perceived severity and perceived vulnerability. In addition, the mental status of each participant was rated by asking the question: "To what extent does COVID-19 evoke the following feelings in you?" There were three indicators for this question: anxiety, fear, and stress (Midden and Huijts, 2009), and a higher score implied a more negative mental status. All indicators of psychological latent variables were taken from the existing literatures but adapted to the specific circumstances of COVID-19 and rated on a 5-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree) (Johnston et al., 2015). At the end of survey was the question about participants' automobile purchase intentions after the COVID-19 outbreak.

The survey was conducted after a large number of workers were able to resume work. At that time, the intercity mobility in China went into recovery period (Li et al., 2021). However, doing so meant having to face the probability of becoming infected while commuting, thereby providing us with a suitable time to conduct our survey as mobility was increasing.

3.2. Data analysis

We conducted a data cleaning process of deleting samples with overly short or long response times, and overly low variances across the questions. At last, a total of 960 valid samples were collected, which is enough for further analysis. Previous research found that a sample above 500 is adequate to use maximum likelihood estimates and can provide only minimal improvements in the utility-difference precision of discrete choice models (Yang et al., 2015; Nemes et al., 2009). The distribution of the exogenous variables is summarized in Table 1.

Most of the participants (86.8%) were aged between 26 and 45 years old and lived primarily in urban areas (70.4%). Females and males were present in similar proportions. About 30.2% of the participants had monthly incomes of less than CNY 3000. More than three-fourths (75.3%) of the participants had driving licenses, but the families of just more than half of the participants (54.5%) had at least one private automobile. The data collected by the survey covered all the provinces of China. Most participants (73.4%) lived in areas where the epidemic had spread with moderate severity consistent with the distribution of the confirmed COVID-19 cases. Furthermore, >80% had suffered negative impacts on their incomes, and about 16.1% had serious income losses.

The participants' choices are presented in Fig. 1. There were 612 people who had no plans to purchase automobiles pre-COVID19 (Group 1), whereas 348 did have purchase plans (Group 2). In Group 1, nearly one-fifth ($n = 189$) had the intention to purchase an automobile after the outbreak. In Group 2, the majority ($n = 279$) had chosen to maintain their previous plan, whereas the remainder ($n = 69$) had abandoned or postponed their automobile purchase decisions.

We conducted a binary logit analysis to explore the relationship between socio-demographic variables and purchase plans before the epidemic. The dependent variable is the participants' choice of whether or not they planned to purchase automobiles before the epidemic. Respondents were labelled 1 for people who had plans to purchase automobiles before the epidemic and 0 for those who had no plans. The

Table 1
Descriptive statistics of respondents ($N = 960$).

Variable	Value	Frequency	Percentage
Age	18–25	24	2.5%
	26–35	502	52.3%
	36–45	331	34.5%
	46–55	74	7.7%
	>55	29	3%
Gender	Male	527	54.9%
	Female	433	45.1%
Household income	<3000	290	30.2%
	3000–5000	287	29.9%
	5000–10,000	251	26.1%
	>10,000	132	13.8%
Residential location	Urban	676	70.4%
	Non-urban	284	29.6%
Vehicle availability	Yes	523	54.5%
	No	437	45.5%
Driving license	Yes	723	75.3%
	No	237	24.7%
Local epidemic severity	Slight	30	3.1%
	Moderate	705	73.4%
	Serious	225	23.4%
Income impact	None	110	11.5%
	Slight	325	33.9%
	Moderate	370	38.5%
	Serious	155	16.1%

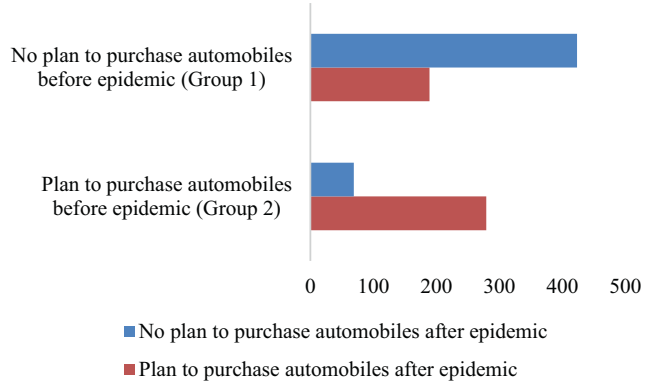

Fig. 1. Results of participants' choices.

socio-demographics are considered as independent variables. Table 2 shows that gender, household income, and vehicle availability were significant variables before the epidemic outbreak. Specifically, females were more reluctant to purchase automobiles, i.e. the probability of females' purchasing automobiles was less than that of males. As we had expected, individuals who already owned automobiles were less willing to purchase new ones, whereas higher-income individuals had stronger purchase intentions.

Next, we used the data of all respondents to preliminarily test the relationships between explanatory variables and latent variables; we also tried to explore whether or not the perceived risks had the negative impact on mental status (Fig. 2). The results show that all the paths of social-demographic variables on perceived risks were not significant, with the exception that females were associated with higher perceived severity (B = 0.087; $P < 0.01$). Furthermore, both perceived severity and perceived vulnerability had significant impacts on mental status (respectively, B = 0.340, $p < 0.001$, and B = 0.354, $p < 0.001$). These findings indicate that higher perceived risks are associated with higher levels of anxiety, fear, and stress.

When the structural model of Fig. 2 was incorporated into the ICLV model, the results shown that, although the paths of perceived severity and perceived vulnerability on mental status were both significant (P values were both below 0.001), the mental status had not significantly directly affected the final automobile purchase choices (B = -0.017; P = 0.647). This result indicates that the negative mental status caused by COVID-19 did not directly affect people's decisions to purchase automobiles. In addition, mental health did not have a mediating effect between the perceived risks and intention to purchase automobiles. Therefore, we did not incorporate mental health in the final ICLV model.

3.3. Model formulation

We employed an ICLV model to capture the effect of latent variables on the individuals' likelihood to purchase automobiles during the epidemic. The final structure of the selected model was shown in Fig. 3. There are two components in an ICLV model: SEM (including structural and measurement equations) and choice model (ordinal logit with latent variables).

Table 2
The effects of socio-demographics on purchase plans before the epidemic.

	Coef.	*P*-value	Likelihood Ratio (EXP(B))
Age	0.060	0.493	1.062
Gender	**−0.321**	**0.026**	**0.712**
Household income	**0.356**	**0.000**	**1.428**
Residential location	0.048	0.763	1.049
Vehicle availability	**−0.312**	**0.030**	**0.732**
Driving license	0.299	0.095	1.349
R^2	0.271		

Note: Estimates with p-values <0.05 are marked in bold.

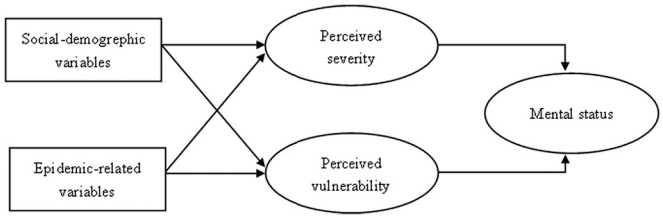

Fig. 2. Structural model that describes the relationships of explanatory variables, perceived risks, and mental health.

Eq. (1) is the structural equation that describes the relationship between the observed individual-related characteristics (s_n) and psychological latent variables (η_k), where k relates to the number of latent variables, n to the number of decision-makers, and r to the observed socio-demographics. λ_{rk} is the parameter to be estimated, and ξ_{kn} are error terms assumed to be independently and identically distributed (i.i.d.) normally distributed.

$$\eta_{kn} = \sum_r \lambda_{rk} s_{nkr} + \xi_{kn} \tag{1}$$

Eq. (2) and Eq. (3) are measurement equations that represent the measurement relationship between the latent variables and their corresponding indicators. Measurement equations are specified as ordinal logit models considering the indicators are Likert scale in the present study. In the equations, y_{tn}^* is the continuous variable represented by latent variables η_k, unknown parameters γ_{kt} and logistic distributed error term υ_{tn}.

$$y_{tn}^* = \sum_k \gamma_{kt} \eta_{kn} + \upsilon_{tn} \tag{2}$$

$$y_{tn} = \begin{cases} 1 \ if \ (-\infty) \langle y_{tn}^* \le \tau_{t1} \\ 2 \ if \ \ \tau_{t1} < y_{tn}^* \le \tau_{t2} \\ \quad \cdots \\ K \ if \ \tau_{t(K-1)} < y_{tn}^* \le \infty \end{cases} \tag{3}$$

In Eq. (3), the measurement of indicators (y_{tn}) takes the values of discrete response k, and y_{tn}^* is the continuous variable measured by a set of thresholds (τ) for each indicator; τ is the parameters to be estimated, and it is hypothesized that $\tau_1 \le \tau_2 \le \ldots \le \tau_{K-1}$ (Bierlaire, 2018).

Then turn to the choice model part, which explains the nonlinear relationships between the probabilities of discrete outcomes and potential influencing variables. The utility function U_{in} for each alternative i can be expressed as Eq. (4):

$$U_{in} = \sum_k a_{ik} \eta_{ikn} + \sum_q b_{iq} z_{iqn} + \varepsilon_{in} \tag{4}$$

where z_{iqn} are the epidemic-related variables, a_{il} and b_{iq} are unknown parameters, and ε_{in} is the error term following the i.i.d. Gumbel distribution with a mean zero (Márquez et al., 2014).

An individual is assumed to be rational and also assumed to choose d_{in} on the basis of utility maximization:

$$d_{in} = \begin{cases} 1, & if \ U_{in} > U_{jn}, i \ne j \\ 0, & otherwise. \end{cases} \tag{5}$$

There are two frequently-used methods for estimating the ICLV model, i.e., sequentially and simultaneously, which differ mainly in how to use the available information. The sequential estimation method consists of two separate stages, which is simple and costs less in estimation time. However, the sequential estimation method does not guarantee totally consistent results, due to the measurement errors of latent variables in the discrete choice model being excluded. Despite the simultaneous estimation method being quite difficult to solve, it can use

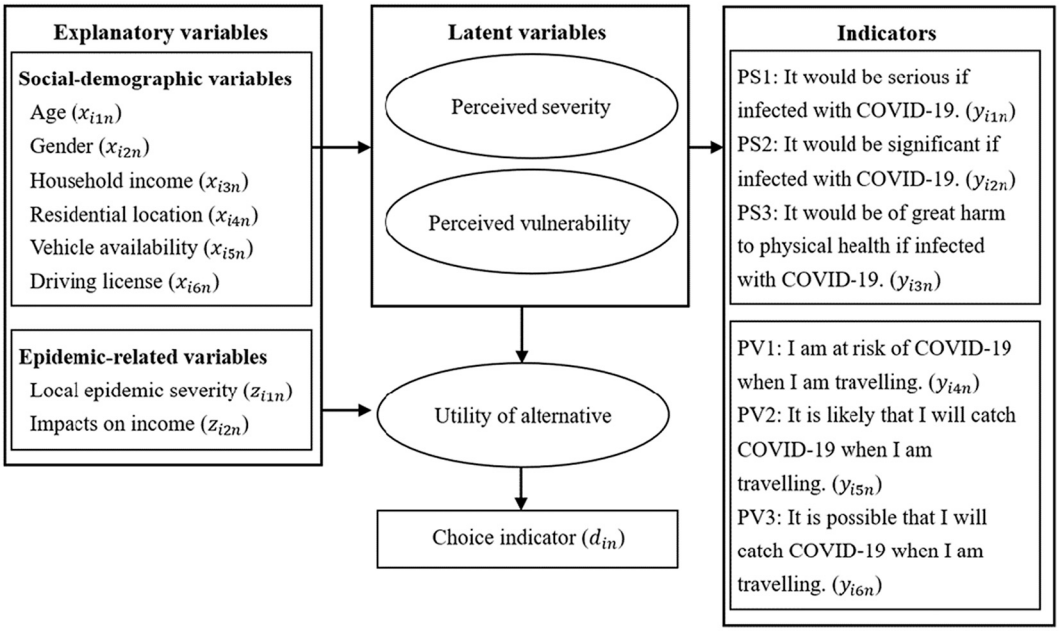

Fig. 3. Structure of model.

full information and offer unbiased estimators (Di Ciommo et al., 2013). Therefore, we applied the simultaneous estimation method to analyze the data of both groups. The joint probability using both choice and indicator data can be expressed as Eq. (6):

$$P\left(d_{in}, y_{in} \middle| z_{iqn}, x_{rn}; a, b, \tau, \gamma, \lambda, \Sigma_{\varepsilon}, \Sigma_{\nu}, \Sigma_{\xi}\right) = \int P\left(d_{in} \middle| \eta_n, z_{qn}, a, b, \Sigma_{\varepsilon}\right) f\left(y_n \middle| \eta_n, \gamma, \tau, \Sigma_{\nu}\right) g\left(\eta_n \middle| s_n, \lambda, \Sigma_{\xi}\right) d_{\eta_n} \quad (6)$$

4. Model estimation results

4.1. Structural equation model

The python-based package Biogeme was used to estimate the ICLV model, where we first used the sequential estimation method to obtain the final model specification and then estimated the final model simultaneously (Bierlaire, 2018).

The estimated results of the measurement equation and structural equation are shown in Table 3 and Table 4 respectively. Table 3 exhibits the estimated values and robust t-values of the measurement model, which demonstrates the measurement relationship between latent variables and corresponding indicators. For model identification consideration, the parameters for the first indicator of each latent variable are fixed as 1. These results conformed to our expectations that all measurement parameters are significantly and positively associated with the two latent variables.

With regard to the structural equations, Table 4 shows the statistically significant results associated with two latent attitudes, which reflect the structural relationship between observed variables and latent variables. In Group 1, gender and household income turn out to be the significant factors in the structural equation, which means that females and lower-income people were more likely to have greater perceptions of travel risks. The results also show that young people have perceptions of higher travel risks than older people do. In addition, people who had no private automobiles or resided in non-urban areas tend to be more concerned about travel risks. In Group 2, females and young people also revealed greater perceptions of travel risks.

Table 3
Results of measurement model.

Latent variables	Indicators	Group 1		Group 2	
		Coef.	Rob. *t*-test	Coef.	Rob. t-test
Perceived severity	PS1	1.000	–	1.000	–
	PS2	0.582	2.200	1.21	2.010
	PS3	0.663	2.310	1.41	1.990
Perceived vulnerability	PV1	1.000	–	1.000	–
	PV2	0.918	1.09	1.69	5.110
	PV3	0.993	1.82	1.55	1.806

Table 4
Results of structural model.

	Perceived severity		Perceived vulnerability	
Group 1	Coef.	Rob. t-test	Coef.	Rob. t-test
Age	–	–	−0.191	−3.16
Gender	0.288	3.780	0.185	6.37
Household income	−0.102	−2.270	−0.047	−2.78
Residential location	–	–	0.359	9.500
Vehicle availability	–	–	0. 23	7.49
Group 2				
Age	−0.19	−2.980	−0.200	−8.600
Gender	0.274	3.010	–	–

"–" = not statistically significant at 95% level of confidence.

4.2. Choice model

The estimation results of the ICLV model are displayed in Table 5. The positive estimates reflect the higher level (more likely), and inversely, the negative sign shows the lower level (less likely). In Group 1, household income played a significant role in the automobile purchase decisions, indicating that higher household incomes were correlated with higher tendencies to purchase automobiles and that income was important in automobile purchase decisions. These indications confirmed the findings of other studies (Lam et al., 2000). Surprisingly, the coefficient for gender was positively related, which means that the females were more likely than males to purchase automobiles. The positive value of local epidemic severity suggests that, as expected, individuals had greater inclinations to purchase automobiles when the local epidemic situation was more serious. The negative coefficient of residential location in the model indicates that the people living in urban

Table 5
Results of ICLV model.

Variables	Group 1		Group 2	
	Coef.	Rob. t-test	Coef.	Rob. t-test
Age	0.051	0.279	−0.22	−1.59
Gender	**0.849**	**8.04**	0.34	1.03
Household income	**0.125**	**2.25**	−0.039	−0.276
Residential location	**−0.449**	**−5.38**	−0.227	−1.56
Vehicle availability	**0.620**	**6.48**	**0.550**	**2.001**
Driving license	**−0.391**	**−3.23**	**−1.001**	**−3.02**
Local epidemic severity	**0.667**	**3.200**	**0.819**	**2.54**
Income impact	−0.373	−1.56	**0.344**	**3.26**
Perceived severity	−0.446	−1.309	0.128	1.160
Perceived vulnerability	**−1.170**	**−2.64**	**0.351**	**4.66**
Number of parameters	35		35	
Number of observations	612		348	
log likelihood	−5314.615		−2161.53	
Rho square	0.662		0.789	

Note: Estimates which are statistically significant at 95% level of confidence are marked in bold.

areas were more inclined than non-urban people to purchase automobiles. As we expected, individuals with a driving license or who did not have at least one automobile in the family were more likely to own their automobiles. In terms of latent variables, perceived vulnerability significantly affected final automobile purchase choices, but perceived severity did not. Stated equivalently, when people perceived the subjective probability of infection as higher, they were more likely to purchase automobiles.

In Group 2, similarly people who own driving licenses or who have no automobiles were more willing to maintain their prior automobile purchase plans. Likewise, the value of local epidemic severity was significantly positive and would have had similar impacts on Group 1, indicating that people living in areas with higher epidemic severity were more inclined to purchase automobiles. Meanwhile, it should be noted that the impact of income significantly influenced some people. The negative parameters suggested that higher income impacts might have led to some people changing their minds and abandoning their previous automobile purchase plans. As for psychological influence, individuals with higher perceived vulnerability still intended to purchase automobiles after the disease's outbreak, while perceived severity did not reach the standard of significance at 95% level.

Overall, the epidemic affected automobile purchase intentions. As mentioned before, local epidemic severity influenced both groups' automobile purchase decisions similarly, implying the influence of external surroundings. Usually, areas more severely affected by the epidemic will suffer more negative impacts on their incomes, but this was only significant in Group 2. Therefore, it can be deduced that people in areas with higher epidemic severity were more likely to purchase automobiles, but some had abandoned their plans because of economic losses. Also, the desire to own an automobile was aroused in two types of populations, those with either a driving license or without any automobiles. Meanwhile, perceived vulnerability was statistically significant for both groups, but perceived severity was not. The results are reasonable because COVID-19 is seen as a terrible and perilous virus by almost all kinds of people. Those with subjective perceptions of higher possibilities of becoming infected would have been more likely to have a sense of insecurity and more willing to purchase automobiles in order to avoid high probability events, i.e. perceived vulnerability is one of the most critical motivations for automobile purchase decision-making after the outbreak.

5. Discussion and conclusions

The present study aims to explore consumer automobile purchase decision-making, as well as the corresponding factors that influence consumers during an epidemic. We analyze the changes in the intentions before and after the COVID-19 outbreak and explore the influence mechanisms from the consumers' perspective. Our study constructs an ICLV model to examine the effects of socio-demographics, epidemic-related variables, and latent variables on automobile consumption intentions. Moreover, we designed and conducted a survey to obtain empirical data.

Several findings can be discussed. Firstly, both the perceived severity and the perceived vulnerability of traveling could induce a negative mental status, i.e. anxiety, fear, and stress. This result was consistent with the findings in other countries, which found that the perceived impact of the pandemic was associated with the mental health status across three continents (Wang et al., 2021). However, contrary to our expectations, the mental status was not associated with automobile purchase intentions and did not mediate the effect between perceived risks and the outcome variable. Secondly, we identified the population segments that increased automobile demand after the epidemic outbreak. Specially, in the group of individuals who had not planned to purchase automobiles before the outbreak (Group 1), the females, citizens, high-income earners, and people who own a driving license or live in areas with high epidemic risk are more likely to purchase automobiles. In the other group, comprised of consumers who had planned to purchase automobiles before the outbreak (Group 2), people with driving licenses or from higher epidemic severity areas are more likely to retain their consumption plan. Thirdly, the results of both groups reveal that perceived travel vulnerability was the major psychological latent variable motivating purchases. Fourthly, apart from the demand growth, a portion of original automobile plans have disappeared. We found that the earnings of some people in Group 2 had actually been negatively affected by the epidemic. This forced them to cancel their prior consumption plans, signifying the importance of household income to automobile purchases (Nolan, 2010).

In general, the present paper finds that the pandemic has resulted in an increase in the demand for private automobiles, specifically to alleviate the perceived travel vulnerability. In reality, non-automobile-owning individuals or families have been affected negatively by the lack of automobile ownership. For example, this paper reports that people without private automobiles tend to be more concerned about travel risks. An automobile with independent space is a better transportation tool to maintain social distance, avoid virus infection, and slow the spread of COVID-19, thus can help to relieve their concerns. In addition, some districts with cases of COVID-19 may suspend or limit the use of the transport system, which might negatively affect the commuting needs of non-automobile-owning families in this district, such as commuting to work or school. However, the current policies on automobile consumption do not apply to the current situation of the epidemic. On the one hand, to relieve traffic congestion, several cities in China had imposed automobile purchase restrictions before the epidemic outbreak, which only offer a fixed number of license plates for automobile consumers. As shown in Table 6, there are three modes that can be used to access license plates for internal combustion engine vehicles (ICEV): license-plate lottery, license-plate auction, and the combination of these two modes (Xian et al., 2022). It is noted that, in Beijing, the plates for new energy vehicles (NEV) are also limited to fixed numbers, and consumers need to queue up. Considering the increasing automobile purchase intentions, the demands of potential consumers

Table 6
The control modes of license plate in cities with purchase restrictions.

Cities	Control modes of ICEV license plate	Control modes of NEV license plate
Beijing	lottery	queueing
Shanghai	auction	directly licensing
Shenzhen	lottery, auction	directly licensing
Tianjin	lottery, auction	directly licensing
Guangzhou	lottery, auction	directly licensing
Hangzhou	lottery, auction	directly licensing

living in cities with purchase restrictions may be limited by the control policies. Meanwhile, for cities without purchase restrictions, policymakers must urgently consider how to induce people to transfer their increased automobile purchase intention to NEV, thus avoiding the environmental issues caused by the increasing number of automobiles. On the other hand, for the people who had canceled or postponed their automobile consumption plans, their demands have been squashed by the economic difficulties.

Therefore, we propose some dynamic policy recommendations, which mean that the policies related to automobile purchases could be eased during the epidemic and then be tightened after this special time. First, in cities with purchase restrictions, policymakers could dynamically adjust the number of license plates. They could increase the number of license plates allocated during the severe epidemic and then decrease the number of license plates after the special time, which ensure that total number of new automobiles is the same as originally planned in these periods. Furthermore, the number of license plates for both ICEV and NEV in Beijing is limited. As such, we suggest that policymakers in Beijing could assign more planned license plates normally provided for ICEV to NEV. This would not only ensure that the total number of license plates remains unchanged, but would also improve the percentage of NEV in the vehicle structure. Second, for cities without purchase restrictions, the irrepressible increased demand for automobiles might induce an increase in energy consumption and pollution. This will require the policymakers in such cities to propose policies that would switch the increased demand for ICEV to a demand for NEV. Two strategies are possible. On the one hand, several cities in China (such as Fuzhou, Zhengzhou, etc.) had already provided subsidies for NEV before the epidemic outbreak and planned to stop the subsidies at the end of 2022. Considering the effects of new energy vehicle subsidies on the structural adjustment of the private automobiles market, we suggest that policymakers could postpone ending this project. On the other hand, other cities without subsidies for NEV could provide purchase tax reductions or subsidies on NEV.

The present study makes contributions to both theory and practice. From a theoretical point of view, it contributes to the body of literature on automobile purchase decisions. From our use of an ICLV model, our findings offer novel insights into automobile purchase decision-making. In addition, this study also contributes to the literature about public health emergencies, as well as to an understanding of travel psychology and behavior changes during epidemics. From a practical point of view, our findings are helpful to policy makers for proposals of more effective macro policies to relieve the current crisis.

There are some directions for future research that could overcome the limitations of the present study. First, our study evaluates the epidemic's short-term effects on the automobile market, but a future study on the long-term influence could be conducted. Second, future studies could use system dynamic simulation to evaluate the impacts of dynamic policies on the economic, environment, society, and health. Third, the current study lacked the measurement of actual demand and perceived demand for a private automobile. This is an interesting issue for future research to explore.

Credit author statement

Yingying Yan: Conceptualization, Formal analysis, Writing – review & editing. **Shiquan Zhong:** Supervision, Funding acquisition. **Junfang Tian:** Investigation, Resources, Funding acquisition. **Ning Jia:** Investigation, Validation.

Declaration of Competing Interest

None.

Data availability

Data will be made available on request.

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