



HAL
open science

Effects of numerical platforms and matching characteristics on individual choices and social welfare: the case of short-distance carpooling

Alix Le Goff, Guillaume Monchambert, Martin Koning

► **To cite this version:**

Alix Le Goff, Guillaume Monchambert, Martin Koning. Effects of numerical platforms and matching characteristics on individual choices and social welfare: the case of short-distance carpooling. 2023. halshs-04406375

HAL Id: halshs-04406375

<https://shs.hal.science/halshs-04406375v1>

Preprint submitted on 29 Jan 2024

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



LABORATOIRE
AMÉNAGEMENT
ÉCONOMIE
TRANSPORTS

TRANSPORT
URBAN PLANNING
ECONOMICS
LABORATORY

WORKING PAPERS DU LAET

NUMÉRO
2024/01

Effects of numerical platforms and matching characteristics on individual choices and social welfare: the case of short-distance carpooling

Alix LE GOFF
Guillaume MONCHAMBERT
Martin KONING

This paper investigates the effects of carpooling organization and individuals' idiosyncrasies on the propensity to carpool. We test whether pre-planning the trip, use of a platform, and socio-demographic similarities or differences between driver and passenger affect choices towards carpooling over solo-driving and public transportation. A stated choice experiment collected answers of 3,600 inhabitants from in the Lyon's urban area, France. Our results indicate platforms raise the individual willingness to carpool, and that this platform's effect is larger for passengers than for drivers. Other things being equal, we identify a clear gender effect: women are more easily accepted as carpoolers than men, and they also are more sensible than men to their carpooler's gender. By contrast, the age of the proposed carpooler does not affect carpooling choices. We illustrate these results with a stylized social welfare analysis which highlights a significant contradiction between what it would take to make carpooling beneficial from a welfare perspective – drivers should pay passengers – and what seems to be individually acceptable.

Keywords: Daily carpooling, Numerical platforms, Matching effects, Individual choices, Stated choice experiment

J.E.L. Classification: C35, R41, R42



LABORATOIRE
AMÉNAGEMENT
ÉCONOMIE
TRANSPORTS

TRANSPORT
URBAN PLANNING
ECONOMICS
LABORATORY

NUMÉRO
2024/01

Effects of numerical platforms and matching characteristics on individual choices and social welfare: the case of short-distance carpooling

Alix LE GOFF

Univ Lyon, Université Lyon 2, LAET, F-69007, LYON, France

Guillaume MONCHAMBERT

Univ Lyon, Université Lyon 2, LAET, F-69007, LYON, France

Martin KONING

UGE, SPLOTT, Bron, France

Décembre 2023

ISSN : 2741-8103

Laboratoire Aménagement Économie Transports
MSH Lyon St-Etienne
14, Avenue Berthelot
F-69363 Lyon Cedex 07 France

- Avertissement** | Les Working Papers du LAET n'ont pas vocation à être une revue. En conséquent, ils ne sont pas dotés d'un comité éditorial et les propos n'engagent que leur(s) auteur(s) avec ou sans review.
- Sans review** | Ce WP n'a pas fait l'objet d'une review par ses pairs. Les propos n'engagent que son ou ses auteur(s).
- Avec review** | Ce WP a fait l'objet d'une review par ses pairs en guise d'amélioration du contenu et non de contrôle éditorial. Les propos n'engagent que son ou ses auteur(s).

Effects of numerical platforms and matching characteristics on individual choices and social welfare: the case of short-distance carpooling

Alix Le Goff^{*†}, Guillaume Monchambert^{*} and Martin Koning[‡]

December 6, 2023

Abstract

This paper investigates the effects of carpooling organization and individuals' idiosyncrasies on the propensity to carpool. We test whether pre-planning the trip, use of a platform, and socio-demographic similarities or differences between driver and passenger affect choices towards carpooling over solo-driving and public transportation. A stated choice experiment collected answers of 3,600 inhabitants from in the Lyon's urban area, France. Our results indicate platforms raise the individual willingness to carpool, and that this platform's effect is larger for passengers than for drivers. Other things being equal, we identify a clear gender effect: women are more easily accepted as carpoolers than men, and they also are more sensible than men to their carpooler's gender. By contrast, the age of the proposed carpooler does not affect carpooling choices. We illustrate these results with a stylized social welfare analysis which highlights a significant contradiction between what it would take to make carpooling beneficial from a welfare perspective – drivers should pay passengers – and what seems to be individually acceptable.

JEL Codes: C35, R41, R42

Keywords: Daily carpooling, Numerical platforms, Matching effects, Individual choices, Stated choice experiment

^{*} LAET, University of Lyon, Université Lyon 2, Lyon F69007, France

[†] Corresponding author: a.legoff14@gmail.com

[‡] AME – SPLOTT, Gustave Eiffel University, Bron, France

Acknowledgements: This research was funded by the Auvergne-Rhône-Alpes region (Pack ambition recherche 2018: Projet Covoit'AURA). The authors acknowledge the support of IRT SystemX and the partners of the Lyon Carpooling Experimentation project (LCE): Métropole de Lyon, Vinci Autoroutes, APRR and Ecov who participated in the dissemination of the survey. We also thank participants of the ITEA 2021 and RFTM 2021 conferences for their valuable comments to improve this work and Charles Raux for initiated this research and its funding.

1 Introduction

The sharing economy and peer-to-peer services are experiencing strong growth in recent years (Yaraghi & Ravi, 2017). Many sectors of the economy are concerned. Airbnb is considered as a mainstream solution when looking for a place to rent, Ebay for a product of any kind, or Uber to have purchases delivered or to get around town. In addition to offering attractive costs, these sharing platforms could help to improve the market efficiency and reduce the environmental impact of consumption. Indeed, they allow to maintain the same level of service while reducing the quantity of goods produced and consumed.

Since the sharing economy is a recent and growing sector, there is a need to know more about the mechanisms that influence the use of services it offers. While sharing can be practiced with relatives, it becomes much more effective when practiced in a large network. The larger the number of users, the better the opportunities, creating more demand and a virtuous cycle (Montero, 2019). However, while the sharing economy may be more efficient, it may also require regulation. Some markets in which platforms operate need supervision to avoid a monopoly situation that could conflict the general interest (Montero, 2019). As an example, Airbnb seems to strongly affect housing market. Its activity could be negative for tenants who see rental prices increase, especially in touristic areas (Garcia-López et al., 2020).

Carpooling is a good example of the sharing economy. It is often seen as an efficient and low-cost way to alleviate negative externalities of car traffic. Indeed, it allows to increase the occupancy rate of cars by filling empty seats (Shaheen et al., 2018).¹ Thus, governments and local authorities are implementing measures to promote it. For example, the French government is offering a €100 subsidy to drivers who commit to carpooling, with the goal of tripling the modal share of carpooling for daily trips.² Similarly, several countries have recently opened dedicated carpooling lanes: in Belgium in 2019³, in Switzerland in 2018, Israel in 2023⁴.

¹ Note that this analysis is still debated. Carpooling reduces road traffic if carpool passengers use carpool instead of driving alone. However, a significant share of carpool passengers would have use public transport in the absence of carpool supply, and a non-negligible part of carpool drivers would have not made the trip in absence of the monetary reward earned when carpooling. The overall effect on traffic is not clearcut (see Wagner, 2016, or Finger et al., 2017).

²https://www.lemonde.fr/en/economy/article/2022/12/14/french-government-presents-updated-plan-to-encourage-carpooling_6007720_19.html

³ <https://www.brusselstimes.com/56328/new-e411-carpool-lanes-only-on-walloon-side-weyts-belgium-overijse-wavre-arlon>

⁴ <https://www.jpost.com/israel-news/article-730018>

Several determinants influence the adoption of collaborative practices. Most authors agree that trust is a key factor in the success of sharing economy (see e.g. Hawlitschek et al., 2016). This is why collaborative platforms have progressively emerged. They allow individuals to use their network and create a secure contracting environment. Lee & Kim (2019) and Ter Huurne et al. (2017) have shown that a platform considered to be of high quality has a positive effect on the trust that people place in it. In turn, this higher level of trust strongly influences the decision to use the service, as shown by Malardé & Penard (2019) in the case of carpooling. Carpooling also has its own specific determinants (Bulteau et al., 2019; Olsson et al., 2019; Bachmann et al., 2018; Gheorghiu & Delhomme, 2018). One of the most predominant features is the perceived risk – or lack of trust – towards the individual with whom the carpooling is done (Delcampe, 2018; Olson et al., 2019). Indeed, for the driver, carpooling implies sharing his private space with an unknown person, and for the passenger, entering the private space of an unknown person and letting her take control of trip parameters, like speed or safety. These beliefs being highly subjective, a key ingredient for a successful carpool is the quality of matching between driver and passenger.

In this article, we investigate the effects of carpooling organization and individuals' idiosyncrasies on the propensity to carpool. Specifically, we test whether pre-planning, use of a platform, and socio-demographic similarities or differences between driver and passenger affect the likelihood of choosing this mode of transportation over solo driving and public transportation.

We answer these questions by using a stated choice experiment collected over 3,000 people in the Lyon's urban area. Interviewees are confronted with choice experiments presenting different transport modes for a trip close to their usual journey, including carpooling alternatives. Two types of carpool organization are presented. Each respondent face one of it and several carpooler profiles are presented in different transport modes choice situations. We estimate the utility functions of each transportation model with multinomial logit calibrated on our sample.

Our results indicate that platforms raise the individual willingness to carpool. We also find platform's effect to be larger for passengers than for drivers. Other things being equal, we identify a clear gender effect: women are more easily accepted as carpoolers than men, and they also are more sensible than men to their carpooler's gender. By contrast, the age of the proposed carpooler does not affect carpooling choices. We illustrate these results with a stylized social welfare analysis which highlights a significant contradiction between what it would take to

make carpooling beneficial from a welfare perspective – drivers should pay passengers – and what seems to be individually acceptable.

This paper relates and contributes to three strands of the literature. First, we focus on short-distance carpool whereas a vast majority of the specific literature was interested with long-distance trips (Farajallah et al., 2019, Monchambert, 2020). Second, in line with recent development on platforms economics (Montero, 2019, Monchambert, 2023), we quantify the value of the platform for both sides of the market, i.e drivers and passengers. More specifically, our empirical strategy allows us to estimate willingness-to-pay measure for different types of carpool organization as well as different types of travelers. Third, we build on our estimate to propose a social welfare analysis of short-distance carpool schemes, consistently with a vast literature in transport economics which however has mostly focused on road or public transport pricing and infrastructure provision.

The rest of the paper is organized as follows. Section 2 presents the hypothesis tested in this paper. Section 3 presents the empirical material. Econometric specifications and results are displayed and discussed in Section 4. Welfare analysis is done in Section 5 before concluding in Section 6.

2 Hypotheses

Consider a situation in which an individual makes a choice between several available modes to make a trip. We are interested in the factors that may affect the probability of an individual choosing to carpool as a driver or as a passenger. Among these factors, we focus specifically on those related to the organization of carpooling and the characteristics of the matching between driver and passenger.

2.1 Trust and organization

We first detail the hypothesis about carpool “organization” which refers to the way carpooling is realized. The typology of carpooling organizations can be articulated around two distinctions: planned/real-time and with/without platform (ADEME, 2015). Planned carpooling consists of sharing a vehicle with people contacted beforehand. This is the usual carpooling organization, widely spread also by the Blablacar platform (Shaheen et al., 2017) for long-distance carpooling. It involves setting up a meeting place and time for passengers, which can lead to various time constraints such as scheduling, detour and waiting times and be quite restrictive on a daily basis. One way of overcoming this barrier is to organize carpooling in real-time, which consist of meeting the carpool partner during the trip. It can be made at predefined stops

like the “slugs” in Washington D.C. (Cui et al., 2022), or at the roadside, with or without a matching system. For the passenger, this type of carpooling is similar to a public transport service, or a cab. For the driver, this real-time station or matching system can also reduce potential time issues mentioned previously. Carpooling can also be organized with a platform that connects individuals with compatible journeys. When these two dimensions are crossed, four types of organizations arise:

- planned in advance with someone met through a platform.
- planned in advance with someone not met through a platform, i.e. with someone known before the trip that we consider here as a relative (family, friend, colleague).
- in real-time via a platform.
- in real-time without a platform, i.e. hitchhiking.

Platform is expected to increase individuals' level of trust for several reasons. It sends signals about the profile of carpoolers and their carpooling experience. When there are many carpooling opportunities on offer, it allows individuals to screen and choose their preferred option. Platforms often include a secure banking service that guarantees payment. In general, therefore, the platform should help to reduce uncertainty (Ter Huurne et al., 2017).

Hypothesis 1: The presence of a platform increases the probability of choosing carpooling.

Planned carpooling is by far the most common form of carpooling in France. Half of carpools are made intra-family (ADEME, 2015) and the market-leading long-distance carpooling platform, BlaBlaCar, also organises planned trips (Shaheen et al., 2017). Consequently, only a small minority of trips are organized in real-time. Real-time carpooling is something unusual for individuals, which could lead to a situation perceived as riskier⁵. Moreover, using focus groups, Deakin et al. (2010) showed real-time carpooling is perceived as less reliable than planned carpooling.

Hypothesis 2: Carpooling is preferred when planned ahead rather than organized in real time.

Sharing a car with an unknown person is perceived as a risk (Chan & Shaheen, 2012). Both drivers and passengers share this risk, but the driver knows the environment in which the carpooling takes place (his car), while the passenger does not. In addition to the risk previously

⁵ In this paper, we use the word “risk” although the situations shown to respondents are rather “ambiguity” situations according to the associated literature.

mentioned, passengers are also affected by their driver's driving style. They can have a feeling of absence of control on board which can also be stressful (see e.g. Dillen et al., 2020). If passengers are assumed to take more risks than drivers when carpooling and that platforms are ways to overcome perceived risks, then the platforms should have a larger effect on passengers.

Hypothesis 3: The positive effect of the presence of platform on carpooling choices is larger for passengers than for drivers.

As previously mentioned, carpooling may be perceived by individuals as a risk. Experimental economics have shown that males exhibit more confidence than females and that females appear more risk averse than males (Chaudhuri & Gangadharan, 2003; Borghans et al., 2009). If, as previously mentioned, platform effects are positively related to situations perceived as riskier, females should be more sensitive to them.

Hypothesis 4: The positive effect of the presence of platform on carpooling choice probability is larger for females than for males.

2.2 Matching

Whereas previous assumptions only focus on the characteristics of decision-makers, we should also acknowledge that carpooling choice is also affected by matching effects. It might thus be the case that idiosyncrasies of passengers and drivers interacts with each other and drive the decisional process. In this second part, we detail the hypothesis about the effects of the matching characteristics on the carpool choice. Matching during a carpooling trip is the proposed pairing between a driver and a passenger.

Chaube et al. (2010) have shown the relationship with the potential carpooler can highly change the willingness of individual to carpool for daily trips. A closer relationship leads to a higher probability to accept to carpool. If carpooling with a stranger is perceived as riskier and women are more risk averse – as mentioned in hypothesis 4 – then female respondents should be more willing to carpool with a relative than male respondents.

Hypothesis 5: Females are more willing to carpool with a relative than males.

Age, or more precisely the age difference between the two individuals, is also a characteristic that can have an effect on the attractiveness of carpooling. People tend to have a more natural affinity for people of the same age (Buunk et al., 2002). It is then assumed that a carpooler of the same age is more easily accepted than a carpooler with a wide age difference.

Hypothesis 6: The likelihood of participating in carpooling is higher when the driver and passenger are of the same age.

Another carpooler's characteristic that could influence willingness to carpool is the carpooler's gender. A recent study from Farajallah et al. (2019) observed that women sell more seats and for higher prices than males on the Blablacar platform. This may result from several factors such as the perceived security to travel with a female carpooler. Indeed, more than three out of four road death involve men according to the French National Interministerial Observatory for Road Safety (ONISR, 2021), a number that is consistent at the world's scale (Sengoelge et al., 2018). Carpooling with a male could also be perceived more dangerous as they tend to be more aggressive (see e.g. Björkqvist, 2018). Carpooling is therefore expected to be chosen more often when it is proposed with a woman.

Hypothesis 7: The likelihood of participating in carpooling is higher when a female is on the other side.

3 Data

We collected data from an online discrete choice experiment conducted in spring 2019 on inhabitants of the Lyon area. This experiment was built to understand how individuals would react to a new carpooling supply on their usual trip.

3.1 Survey design

On the first part of the questionnaire, we collect information on a usual trip of the respondent. They are asked to detail their most frequent trip made by car or public transport during the last 30 days. Respondents whose usual trip is susceptible to be carpoled are kept in the survey (see Le Goff et al., 2022 for more details on survey design). The time components of this trip are then used to create choice situations adapted to the respondent usual trip. This way, respondents face situations close to the reality of their daily life, the experiment seems more realistic and the hypothetical bias is reduced.

Before the choice situations start, respondents are randomly divided into two samples. The first one is assigned to a "planned ahead carpooling" experiment and the second one to a "real-time carpooling" experiment. For both samples, a screen detailing the carpooling organization is presented (see screens in Appendix 1). In the first sample, carpooling can be organized through dedicated platforms or informal with family, friends, or colleagues. This is the "classic" carpooling organization, where passengers and drivers contact each other before the trip. They

can then set a time and place for the pick-up, and discuss the drop-off location. The second sample faces choice tasks in which carpooling is done in real-time (or spontaneous), involving hitchhiking and so-called dynamic carpooling through digital apps. In this case, carpooling is organized spontaneously, during the journey. Passengers and drivers meet either at a predefined location, such as a carpooling station, or at the roadside.

Respondents then face six successive mode choice situations in which they choose their preferred alternative between four modes: solo driver, carpooling driver, carpooling passenger and public transport. These choice situations include different types of attributes. The first one is the time variables, in which the different stages of the trip are detailed. This includes departure time, access and egress time to a station for passenger modes, waiting time – which is also presented to carpooling drivers – as well as detour time and finally, the in-vehicle time in each mode (see Appendix 2 for an example of choice screen). Table 1 details attributes and levels used in the survey. The monetary cost of the alternative is also displayed. Finally, what we called carpooler profile – i.e. the way carpooler is met, its gender and age – is presented in both driver and passenger carpooling alternatives. The carpooler profile presented may vary depending on whether respondents were assigned to the planned or spontaneous carpooling experiment. If they are in the planned sample, the proposed carpooler may be a relative or a person met by a carpooling platform. In the case of a relative, we consider gender and age do not impact the choice and these characteristics are consequently not presented. In the other case, and in spontaneous carpooling where the proposed carpooler is either registered on a platform or a hitchhiker, the age and gender characteristics of the carpooler are presented.

Table 1: Trip attributes and levels in stated choice design

Attributes	Alternatives	Levels
Time variables		
Schedule early/late	Solo Driver	0, 30, 60 minutes (earlier or later)
Access time	Passenger modes*	5 minutes walking (ref), 10 minutes by car, 20 minutes by car
Detour time	Carpooling Driver	0, 5, 10 minutes
Waiting time	Passenger modes and Driver in Spont. Carpool	0, 5, 10 minutes
In-vehicle travel time	All	Solo Driver: $(0.8, 1.1, 1.5) \times \text{usual_tt}$ Other modes: $(0.6, 0.9, 1.2) \times \text{usual_tt}$
Travel time variability	All	$(0.1, 0.3, 0.5) \times \text{In-vehicle travel time}$
Egress time	Passenger modes	Carpooling passenger: 5 min walking (ref), 10/20 min by Public Transport Public transport: 5 min walking
Cost (in €)	Carpooling modes* and Public Transport	Carpooling Driver: receives $(0, 0.02, 0.05, 0.1) \times \text{usual_tt}$ Carpooling Passenger: pays $(0, 0.02, 0.05, 0.1) \times \text{usual_tt}$ Public transport: pays 0.8
Carpooler profile		
Carpooler matching		Planned (with a relative or by platform), Spontaneous (with a hitchhiker or by platform)
Carpooler Gender		Male, Female (not presented if relative)
Carpooler Age		25, 45, 65 years old (not presented if relative)

Notes: Passenger modes: Carpooling Passenger and Public Transport. Carpooling modes: Carpooling Driver and Carpooling Passenger. "usual_tt" is the usual travel time the respondent reports in the first part of the survey

3.2 Data collection and descriptive statistics

The survey's web-link was widely spread to many inhabitants of the Lyon area. Participation in the survey was financially encouraged by a chance to win vouchers. The call message did not mention carpooling to avoid strategic or selection bias (see more details in Le Goff et al., 2022). The initial database contains 4,845 respondents.

Table 2 : Sample characteristics

Variables	Mean	
	Sample	Population
Male	55.8%	54.8%
Age (years)	48.3 (13.6)	41.1 (11.6)
Income per month (€)	2361 (950)	
Occupation		
Self-employed	3.6%	3.2%
Senior Management	41.1%	14.7%
Middle Management	9.9%	12.2%
Clerical Staff	25.0%	23.7%
Blue collar workers	2.0%	9.6%
Farmers	0.1%	0.6%
Students	2.1%	11.5%
No activity	0.6%	\
Retired	15.7%	24.4%
Choices during the experiment		
Solo Driver	28%	
Carpooling Driver	34%	
Carpooling Passenger	15%	
Public Transport	23%	
Nb of individuals	3632	

Notes: Standard deviation in parentheses. Income variable is collected as categorical. Mean and standard deviation are calculated using the center of the classes selected by respondents. Income is not available in the census. Population in the area data are from SYTRAL (2016), enquête ménage-déplacements, a public mobility survey in the Lyon urban area.

Adhoc data filtering recommended by Hess et al. (2010) is then applied. As response time for each choice situation is available, 734 respondents who answered a choice situation in less than 6 seconds were excluded. This way, those who answered as fast as possible to try to win the voucher and did not examine the choice situations were removed. The 479 respondents who did not report their income were also excluded from the survey for a final sample of 3,632 respondents and 21,792 choice situations analyzed. Descriptive statistics of this sample are presented in Table 2 above. We compare our sample with the study population. Our sample is on average more male and older than the study population. We also observe that students and blue-collar workers are under-represented in our sample, while senior management is over-represented. The mode most often chosen during the discrete choice experiment is driver carpooling, followed by solo driver, public transport and then passenger carpooling. These choices depend on the screens that were offered to the sample and therefore do not reflect preferences on their own.

Table 3 : Reference trips characteristics

Variables	Mean
Length (min.)	43.2 (20.4)
Frequency	
Every working day	58%
Several times a week	27%
Several times a month	12%
Once a month	2%
Less	2%
Mode	
Driver (Alone)	69%
Carpool Driv.	12%
Carpool Pass.	2%
Pub. Transports	10%
Both car and PT	5%
Other	2%
Purpose	
Work	77%
Shopping	6%
Leisure	7%
Studies	2%
Accompaniment	2%
Other	6%

Notes: Standard deviation between parenthesis.

Table 3 displays the characteristics of the average reference trip of the sample. This average trip is around 43 minutes long. In more than half of our sample, this trip takes place every day, by a single person in a car, to get to work.

4 Econometric analysis

4.1 Empirical strategy

The usual methodology to estimate the effect of each variable in a stated preference survey considers that each alternative displayed has a specific utility function, composed with a systematic and a random part as in a random utility model (Walker & Ben Akiva, 2002)⁶. The

⁶ Even though this methodology is usual, stated preference data assume respondents make choices similar to what they would do in a real situation. This hypothetical bias generally leads to overestimated willingnesses-to-pay (Haghani et al., 2021).

respondent will then choose the alternative that provides the highest utility. Individual i using mode k with carpooler j experiments the following systematic utility:

$$V_{ijk} = ASC_k + \beta_C \times C_k + \beta_{T_k} \times Time_k + \beta_{orga_{ik}} \times Orga_{ik} + \beta_{match_{ijk}} \times Match_{ijk} + \beta_{Z_i} \times Z_i \quad (1)$$

Where k is a transport mode among solo driver, carpooling driver, carpooling passenger, and public transport.⁷ ASC is the alternative-specific constant of the mode (with solo driver as the reference, $ASC_{SoloDriver} = 0$). $Cost$ is the price (or gain in the case of e.g. carpool driver⁸). $Time$ is a vector of the different temporal characteristics of the mode presented in the survey, $Orga$ is a vector of carpool organization variables, $Match$ a vector of matching variables and Z a vector of individual characteristics. $Orga$ and $Match$ are null for solo driver and public transport. ASC , β_C , β_T , β_{orga} , β_{match} and β_Z are coefficients or vector of coefficients to estimate.

The $Orga$ vector in Equation 1 defines the carpooling organization presented to the respondent during the choice experiment. Four types of organization were presented: carpooling can be planned, with a relative or via a platform, or spontaneous with a hitchhiker or via a platform. This vector is hence as follows:

$$\beta_{orga_{ik}} \times Orga_{ik} = (\beta_{plat}, \beta_{spon}, \beta_{plat \times spon}) \times \begin{pmatrix} \parallel_{platform} \\ \parallel_{spontaneous} \\ \parallel_{platform} \times \parallel_{spontaneous} \end{pmatrix} \quad (2)$$

where \parallel_X is a dummy variable indicating that X is realized. β_{plat} and β_{spon} respectively allow to test Hypothesis 1 and Hypothesis 2. Adding the interaction effect measured by $\beta_{plat \times spon}$ allows to test Hypothesis 3. To test hypothesis 4, we interact the $orga$ vector with the respondents' gender.

$Match$ is a vector containing proposed carpooler's gender and age in both driver and passenger alternatives. These carpooler characteristics are crossed with the respondents' individual characteristics. It allows to distinguish the carpooler's gender effect depending on the respondent's gender (i.e. four types of gender matching are possible: male/male, male/female,

⁷ Complete utility functions are available in Appendix 3.

⁸ The cost can also be negative in the case of a subsidy, as is the case in the simulation performed in the welfare analysis section

female/male, and female/female). These utility functions are discussed in more detail in the Appendices. Taking into account both respondent individual variables and the proposed carpooler's profile, the *Match* vector is the following:

$$\begin{aligned} & \beta_{match_{ijk}} \times Match_{ijk} \\ &= \left(\beta_{Male_i}, \beta_{Male_i \times rel}, \beta_{Male_j}, \beta_{Male \times Male}, \beta_{AgeMatch} \right) \\ & \times \begin{pmatrix} \parallel_{Male_i} \\ \parallel_{Male_i} \times (1 - \parallel_{Platform}) \times (1 - \parallel_{Spontaneous}) \\ \parallel_{Male_j} \\ \parallel_{Male_i} \times \parallel_{Male_j} \\ AgeMatch \end{pmatrix} \end{aligned} \quad (3)$$

$\beta_{Male_i \times rel}$ allows to test Hypothesis 5 (carpooling with a relative is appreciated more by women than by men). Hypothesis 6 (a carpooler of about the same age is more easily accepted) is tested in Model 6 through $\beta_{AgeMatch}$. The *AgeMatch* variable is coded "1" when the age difference between respondent and its potential carpooler is under or equal to 15 years and "0" if this difference is over 15 years. β_{Male_j} allows to test Hypothesis 7.

4.2 Organization effects

Table 4 shows results of multinomial logit estimations of Equation (1) for the four modes (solo driver, carpooling driver, carpooling passenger, and public transport). We estimate five different specifications. The first specification in column (0) does not include organization effects. This model is the reference to compare other models with. In specification (1) we introduce a Platform dummy to estimate an average platform effect, and in Specification (2) a Spontaneous dummy to estimate a spontaneous effect. On top of that we include an interaction effect between these dummies in specification (3) to estimate average effect of the four organizations studied (planned with a relative, planned via a platform, spontaneous with a hitchhiker or spontaneous via a platform). Specification (3) corresponds to Equation (2). Organization effects are differentiated depending if the carpooling trip is made as a driver or as a passenger in specification (4). We also consider a differentiation by gender in specification (5). The reference mode is solo driver, so generally a negative (resp. positive) coefficient implies a negative (resp. positive) marginal effect of the variable on the probability of choosing carpool over solo.

The Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) confirm that using interaction effects and differentiated organizations coefficients in specification (5)

produces the best goodness of fit. We focus here on the organization effects and delegate the full table of results including alternative specific constants, time components differentiated by mode, time components diff. by stage of the trip and individual Characteristics to Appendix D.

Specification (1) allows to estimate an average platform effect for both drivers and passengers. The estimated coefficient is positive (0.102), meaning that other things being equal, respondents are more willing to accept carpooling trips when the carpooler's is met via a platform. This result reflects a globally positive effect of the platform, without consideration of the mode (driver or passenger) or the way carpooling is organized (planned or spontaneous). Hypothesis 1 is then verified.

An average spontaneous effect is estimated in specification (2). We find a significantly negative value (-0.0089). This means respondents will tend to accept more carpooling alternatives if its organization is planned ahead, all other things being equal. This result confirms Hypothesis 2.

Specification (3) combines the two previous effects, adding an interaction variable. The key result is that the platform effect becomes negative. In this model, the platform coefficient estimate measures the difference between the planned situation with and without platform (i.e. with a relative). The negative estimate (-0.107) shows that individuals, when taking a planned carpool, prefer carpool with a relative rather than with someone met through a platform. The difference between hitchhiking and carpooling with a relative is also directly observable through the spontaneous estimate (-0.301), indicating a large preference for carpooling with a relative over hitchhiking. To measure the effect of the platform in the spontaneous carpooling, we consider both the platform and the interaction between spontaneous and platform coefficients. With a high positive value (0.414), the interaction coefficient overcomes the negative value found previously. It confirms platform has a positive impact concerning spontaneous carpooling. The difference between hitchhiking and spontaneous carpooling organized via a platform is the sum of the two previously cited coefficient ($0.414 - 0.107 = 0.307$), which remains strongly significant after a test at a 99.9% confidence level. This highly positive impact also reflects how hitchhiking is depreciated compared to other forms of organization.

In specification (4) we differentiate these effects for drivers and for passengers. Estimates are of the same sign as those found previously showing consistency through the models (except the platform coefficient which is not significant for passengers). The platform coefficient estimate is significantly higher for passengers than for drivers (t-ratio: 2.31, 95% confidence level). This result, combined to similar estimates for the interaction coefficients (0.0406 and 0.442), shows

that platforms are more valuable to passengers than to drivers. The difference between the spontaneous effect for drivers and passengers is also significant, revealing an even higher depreciation for hitchhiking as passengers compared to drivers. Passengers are more sensitive to carpooling organization than drivers which confirms Hypothesis 3.

The last specification differentiates estimates between male and female respondents. The female respondent (i.e. the reference) estimates are consistent with results from specification (4). The results of interest are the “x Male” estimates, which are systematically of the opposite side of the female estimates (e. g. “platform” estimate for drivers is negative and “platform x male” estimate for drivers is positive). This means the organization effects are systematically lower for males (they even become insignificant for some estimates) than for females. This confirms Hypothesis 4 that females are more sensitive to the different forms of organization.

Table 4: Organization effects estimates

	(0)	(1)	(2)	(3)	(4)	(5)
	Base	Platform	Spontaneous	Pltfm + Spont.	Driver/pass	dri/pass + gend
Organization effects						
Platform		0.102 ***		-0.107 **		
Spont			-0.089 **	-0.301 ***		
Spont x Ptfm				0.414 ***		
Driver-specific organization effects						
Platform x Driver					-0.171 ***	-0.271 ***
Spont x Driver					-0.208 ***	-0.593 ***
Spont x Ptfm x Driver					0.406 ***	0.658 ***
Platform x Driver x Male						0.181 *
Spont x Driver x Male						0.677 ***
Spont x Ptfm x Driver x Male						-0.443 ***
Passenger-specific organization effects						
Platform x Passenger					-0.005	0.070
Spont x Passenger					-0.397 ***	-0.607 ***
Spont x Ptfm x Passenger					0.442 ***	0.577 ***
Platform x Passenger x Male						-0.134
Spont x Passenger x Male						0.386 **
Spont x Ptfm x Passenger x Male						-0.265 .
Cost	-0.068 ***	-0.070 ***	-0.067 ***	-0.064 ***	-0.063 ***	-0.063 ***
Alternative-specific constants	Y	Y	Y	Y	Y	Y
Time components differentiated by mode	Y	Y	Y	Y	Y	Y
Time components diff. by stage of trip	Y	Y	Y	Y	Y	Y
Individual Characteristics	Y	Y	Y	Y	Y	Y
# individuals	3632	3632	3632	3632	3632	3632
# observations	21792	21792	21792	21792	21792	21792
# parameters	29	30	30	32	35	41
LL(final)	-26561.8	-26553.5	-26557.9	-26516.2	-26503.8	-26464.3
Adj.Rho-square (0)	0.1198	0.1200	0.1199	0.1212	0.1215	0.1226
AIC	53181.5	53166.9	53175.9	53096.3	53077.6	53010.6
BIC	53413.2	53406.6	53415.5	53352.0	53357.2	53338.1

Notes: The organization reference level is carpool without platform in Model (1) and planned ahead carpool in Model (2). P-values: 1 () 0.1 () 0.05 (*) 0.01 (**) 0.001 (***) 0. See Appendices 4 for more detailed results

4.3 Matching effects

We present in Table 5 results of four new specifications to study matching. We start from specification (4) in Table 4, and add new variables. Specification (6) includes male and male x relative dummies, differentiated according to the distinction between carpool driver and carpool passenger. In specification (7) we add the age match variable and in specification (8) the gender of the proposed carpooler. Specification (9) allows the latter to be differentiate by the gender of the respondent. It corresponds to the utility function described by Equations (1), (2) and (3).

Again, AIC and BIC show the richest specification produces the best goodness of fit. We focus on the matching effects. Detailed results are available in Appendix 4.

Specification (6) shows a negative effect of the male x relative dummy for drivers (-0.390), indicating female respondents prefer carpooling with a relative when they are drivers. Surprisingly, the male x relative coefficient is not significant for the passenger mode. Hence, our Hypothesis 5 is only verified for drivers and not for passengers.

The age match coefficients in specification (7) are not statistically significant. Other variables remain consistent compared to the previous model. The age match between respondent and the proposed carpooler does not affect the decision to choose carpooling modes. Hypothesis 6 is consequently rejected.

The proposed carpooler gender coefficients added in specification (8) are significantly negative in both driver and passenger modes. It indicates that carpooling modes are chosen less often when the proposed carpooler is a male, other things being equal. Individuals are on average more willing to carpool with a female, which verifies Hypothesis 7.

Finally, specification (9) considers a gender match through the interaction between the respondent gender variable and the proposed carpooler's gender variable. This interaction is positive for both carpool driver and passenger modes (significant at a 10% threshold for passenger). The Carpooler Male coefficient measures the difference between the situation where a female is matched with a female (reference) versus the case where the female is matched with a male. These negative estimates indicate that females prefer carpooling with a female both in driver and passenger modes. Now to compare the male matched with a male situation and the male matched with a female situation, we consider both the Carpooler Male variable, and its interaction with the Male variable. Estimates of this interaction are such that they compensate the Carpooler Male estimates in both driver and passenger modes. It indicates that males are not significantly impacted by the carpooler's gender. This result is then consistent with our supposition that females are more impacted by their carpooler's gender than males.

Table 5: Matching effects estimates

	(6)	(7)	(8)	(9)
	Relative matching	Age matching	Carpooler's gender	Gender matching
Driver-specific organization effects				
Platform x Driver	-0.390 ***	-0.406 ***	-0.358 ***	-0.300 ***
Spont x Driver	-0.426 ***	-0.443 ***	-0.398 ***	-0.340 ***
Spont x Ptfm x Driver	0.625 ***	0.641 ***	0.592 ***	0.534 ***
Passenger-specific organization effects				
Platform x Passenger	-0.004	-0.010	-0.060	-0.094
Spont x Passenger	-0.400 ***	-0.383 ***	-0.320 ***	-0.286 **
Spont x Ptfm x Passenger	0.440 ***	0.427 ***	0.366 ***	0.331 **
Driver-specific matching effects				
Male	0.001	0.001	0.001	0.104 .
Male x Relative	-0.390 ***	-0.390 ***	-0.390 ***	-0.286 ***
Age Match		0.045	0.044	0.044
Carpooler Male			-0.102 **	-0.226 ***
Male x Carpooler Male				0.217 **
Passenger-specific matching effects				
Male	-0.408 ***	-0.407 ***	-0.408 ***	-0.477 ***
Male x Relative	0.003	0.002	0.004	0.070
Age Match		-0.037	-0.035	-0.033
Carpooler Male			-0.120 **	-0.195 **
Male x Carpooler Male				0.145 .
Cost	-0.064 ***	-0.064 ***	-0.063 ***	-0.063 ***
Alternative-specific constants	Y	Y	Y	Y
Time components differentiated by mode	Y	Y	Y	Y
Time components differentiated by stage of the trip	Y	Y	Y	Y
Individual Characteristics	Y	Y	Y	Y
# individuals	3632	3632	3632	3632
# observations	21792	21792	21792	21792
# parameters	37	39	41	43
LL(final)	-26516.2	-26487.0	-26479.7	-26473.8
Adj.Rho-square (0)	0.1220	0.1220	0.1221	0.1223
AIC	53050.2	53051.9	53041.9	53033.7
BIC	53345.8	53363.5	53368.6	53377.2

Notes: P-values: 1 () 0.1 (°) 0.05 (*) 0.01 (**) 0.001 (***) 0. See Appendices 4 for more detailed results

4.4 Willingness to pay

In the frame of stated preferences study, it is usual to translate the varying utility impacts of varying situations into monetary equivalents. To do so, we here use the results from specifications (4) and (9) respectively to estimate average Willingness To Pay (WTP) for each organization (Table 6) and for each gender matching (Table 7)⁹.

⁹ The WTP is obtained by dividing the corresponding coefficient by the cost coefficient, independently from trip length.

Table 6 shows a clear rejection of hitchhiking, here considered as the baseline. As an example, a respondent is on average willing to pay 3.7 euros to be matched via platform in a real-time carpool rather than hitchhiking, other things being equal. This rejection is even stronger when the individuals are passengers, with a WTP higher than 6 euros to carpool with one of the three other carpooling organization option rather than hitchhiking.

Table 6 : Organization willingness to pay

Mode	Alternative	WTP
Carpool Driver	With a relative/ a colleague	3.3€
	Planned ahead via platform	<i>0.6€</i>
	Real-time via platform	3.7€
	Hitchhiking	Reference
Carpool Passenger	With a relative/ a colleague	6.3€
	Planned ahead via platform	6.2€
	Real-time via platform	6.8€
	Hitchhiking	Reference

Notes: The WTP represents here the price that people would pay to avoid the reference situation i.e. hitchhiking. Values in italic are not significantly different from 0.

Table 7 presents the WTP of respondent for carpooler gender, differentiated according to the distinction between driver and passenger as well as the respondent's gender. The Male/Female WTP shows a gender divergence between the passengers and/or driver modes. The 1.7€ WTP in the driver mode indicates that males seem to prefer this mode compared to females. On the other hand, the -7.6€ WTP in the carpool passenger mode suggests that females are more willing to carpool as passenger than males.

The key result here resides in comparing WTP depending on the carpooler's gender. For females, the comparison is easy as only the Female/Male WTP is enough to observe that females prefer being matched with another female. The -3.6€ WTP found in driver mode implies that females would be willing to pay 3.6 euros on average to avoid being matched with a male passenger. To observe the impact of carpooler's gender on males, the Male/Male WTP should be compared to the Male/Female WTP. In both driver and passenger modes, this difference has been tested and is not significantly different from 0. This result points out that, contrary to females, we do not find that carpooler's gender affects male choices.

Table 7: Matching willingness to pay

Mode	Respondent	Carpooler	WTP
	Driver	Passenger	
Carpool Driver	Male	Male	1.5€
		Female	1.7€
	Female	Male	-3.6€
		Female	Reference
	Passenger	Driver	
Carpool Passenger	Male	Male	-8.4€
		Female	-7.6€
	Female	Male	-3.1€
		Female	Reference

Notes: In this table WTP can be negative. In this case, it represents here the price that people would pay to access to the reference situation which here is Female/Female.

5 Welfare Analysis

5.1 Method

Short-distance (e.g. urban) trips are a perfect example of second-best equilibrium setting due to the existence of under-priced externalities caused by cars' traffic. Since numerical platforms impact individuals' utility and their likelihood to carpool, these may also affect social welfare by altering vehicles' occupancy rates and total flows. In order to put our results in this perspective, we now analyse the collective effects of the introduction of a new carpooling platform. This knowledge may offer relevant policy insights about the potential needs for regulating this market.

In the followings, we take as a starting-point situation 1,000 individuals who have to make a 30-minutes trip by either public transport, solo-driving and hitchhiking (i.e. the reference carpool organization). The idea is to observe the impact of a new real-time platform on modal shares according to a wide range of prices set for using it, either as driver or passenger. Individual choices are based on specification (9) and prices range from 1€ received to 1€ paid per minute of in-vehicle travel. We allow both passengers and drivers to pay or to be paid (or to be subsidized) in order to carpool through the platform. Importantly, carpool waiting times are calculated according to the number of users (the more passengers, the less drivers wait, and *vice versa*) and in-vehicle travel times vary according to the number of cars on the road due to the existence of congestion¹⁰. It is worth noting that modal shares are balanced in cases there

¹⁰ See details in Appendix.

are more carpool drivers than carpool passengers, the latter being the “scarce resource” and the upper bound to the former. New modal shares then modify traffic conditions and travel times which, in turn, lead to new utilities and market shares. This process stops when the loop converges.

As compared to the situation where hitchhiking is the reference carpool organization, we compute the change in social welfare (ΔSW) for 10,201 combinations of prices¹¹ set to use the newly introduced real-time platform:

$$\Delta SW = \Delta Surplus + \Delta Profit + \alpha \Delta Public - \Delta X \quad (4)$$

The change in consumers’ surplus ($\Delta Surplus$) is calculated for each mode by multiplying the monetary equivalent of its utility by the flow of trips made with each mode. For the sake of simplicity, the cost of a driver-passenger pairing for the platform is supposed to be zero. Assuming that the company does not necessarily transfer the entire monetary flow, its profit ($\Delta Profit$) is found by multiplying the total volume of carpool users by the gap between what comes from passengers and what goes to drivers. Moreover, public subsidies may cover loss-making activities so that $\Delta Profit$ is bounded to zero. The public finance balance ($\Delta Public$) contrasts earnings linked to gasoline taxation and costs linked to pavement maintenance, net of potential subsidies and accounting for the marginal opportunity cost of public funds (α , here fixed at 1.2). As compared to previous components of ΔSW which are based on the number of travellers, $\Delta Public$ is based on the number of cars. In the same vein, the variation in external costs (ΔX) caused by cars’ traffic (GHG, local pollutants, noise and accidents) is calculated on a per vehicle basis. Parameters’ values are detailed in Appendix.

5.2 Carpool organization and welfare

Computing equation (4) for all the simulations, we can identify and discuss some illustrative configurations. It is important to notice that numbers in Table 8 correspond to the differences between the reference situation (i.e. where carpool is made by hitchhiking) and those under study. The column “Without monetary exchange” - for which carpool passengers (drivers) do not pay (receive) anything – thus shows there are 101 solo-drivers less than in the hitchhiking baseline case, which increases the cars’ occupancy rate from 1.26 individuals per vehicle to 1.35. This column therefore indicates the “pure” welfare effect of the real-time platform, i.e. a

¹¹ From -1 to 1 € per kilometer (from -30 to +30 € for the 30-km trip tested)

corollary of the WTPs shown in Table 6. Since numerical platforms are likely to decrease the safety risks linked to sharing a vehicle with strangers, this situation results in higher carpooling shares and – with less cars on the road – to a worse situation in terms of public finance balance because gasoline taxation currently exceeds pavement damages. Logically, this situation also implies savings on external costs of cars’ traffic. Adding the gains in consumers’ surpluses, we get a higher social welfare (+9%).

Table 8: Simulation Results

	Hitchhik. (reference)	Real-time platform				
		Without monetary exchange	Profit max	Welfare max	Welfare max bis	Private platform
Price Driver (€/trip)	0	0	21.3€	6.3€	0	-2.1€
Price Pass. (€/trip)	0	0	16.5€	-4.5€	-7.8€	3€
#Dsolo	560	-101	+142	-111	-183	-55
#CpDriv	193	+55	-84	+16	+66	+30
#CpPass	193	+56	-72	+106	+134	+31
#PT	54	-10	+13	-11	-18	-6
Welfare	-28673	+2606	+1162	+3331	+3053	+2362
Platform Profit	0	0	+4321	0	0	+203
Pub. Fin. Balance (in which subv.)	1274	-78	+99	-196	-3260	-43
External costs	1853	-113	+144	-235	-287	-63
Surplus	-28094	+2571	-3115	+3292	+6026	+2139
<i>Solo Drivers</i>	-11592	+2532	-3996	+3121	+4582	+1435
<i>Carp. Drivers</i>	-6219	-507	+590	-237	-115	+508
<i>Carp. Pass.</i>	-7184	-57	+1180	-7474	+467	-140
<i>Pub. Transport</i>	-3099	+602	-889	+699	+1091	+336
WT driver	5m40s	-25s	-20s	-2m30s	-2m10s	-15s
WT passenger	4m15s	-15s	+55s	+55s	+10s	-10s
Travel Time	40.6	-2.3	3.7	-4.4	-5.2	-1.4
#Cars	753	-46	+58	-95	-117	-25
Cars’ occupancy rate	1.26	1.35	1.15	1.45	1.51	1.31

Notes: The Hitchhiking column indicates the welfare components results as the reference situation. Other columns present the differences compared to the reference situation. In these situations, positive (resp. negative) prices indicate how much drivers or passengers pay to (resp. receive from) the platform. There is no direct monetary exchange between drivers and passengers.

Welfare, platform profit, and external costs and surplus values are the total values in euros (€), calculated for the 1,000 individuals in our simulations.

Surplus is calculated for each mode as the sum of the surplus of the mode users. As the individual surplus is negative, an increase in modal share leads to a negative delta for the mode surplus if its utility remains constant.

The platform profit increases when its users pay high prices and receive low earnings. However, excessive prices lead to potentially low carpool modal shares. Table 8 shows that the platform gets maximal profits when passengers pay 16.5€ for their trip. Interestingly, even drivers should pay the platform (21.3€) to host one individual in their vehicles. This counter-intuitive result comes from the fact that individuals prefer driving one car as compared to being driven, reason why the tipping point is associated with higher prices for drivers. Logically, this setting leads

to very lower carpool shares and to a higher number of cars on roads as compared to the reference hitchhiking situation (the vehicles' occupancy rate decreases to 1.15)¹². Despite reduced consumers' surpluses and higher external costs of road traffic, the situation is profitable in terms of social welfare thanks to the increase in the private operator's profit as well as the improvement in the public finance balance (here magnified by the shadow price of public funds). It seems unrealistic, however, that such carpool organization could be accepted by users.

As shown in Table 8, the social welfare is maximized when passengers are encouraged to carpool through subsidies which would amount approximately to 4.5€ per trip. Conversely, drivers should still pay to receive passengers in their cars, around 6.3€ per trip. These findings mirror results found previously (Le Goff et al., 2022) stressing that passengers are – among potential drivers – the scarce resource for daily carpooling. In this setting, we see that modal shares of solo-driving substantially decreases (-20%) and, on the opposite, the vehicles' occupancy rate grows from 1.26 in the benchmark to 1.45, as carpool's market share. Even if the required subsidies are costly for public finance, the drop in external costs (by -13%) and the huge improvements in travellers' surpluses (by +12%) lead to a +11.5% increase in the social welfare.

The “Welfare Max Bis” column has been created to find a more “acceptable” situation for drivers. In fact, it seems very unlikely that people accept to share their car if they must pay for it. Hence, this situation describes the maximal welfare when the carpool drivers do not have to pay. Among the scenarios in Table 8, this situation allows the highest number of carpool passengers (+70%) and consequently the lowest number of cars on roads (-16%), which reduces the corresponding external costs. The social welfare is lower than in previous situation since the subsidy needed to attract as much passengers as possible must be very high (from 4.5 to 7.8 € per trip), which dramatically affects public expenses.

Finally, the “Blablacar” situation was created considering a passenger cost of 3€ per trip, partly reversed to the driver who earns 2.1€, which reflects what the private company could propose for a 30km trip. Therefore, this situation is a compromise between the profit maximization setting and relatively acceptable prices, for both drivers and passengers. As shown in Table 8, the social welfare is slightly lower in that case than in the situation without any monetary

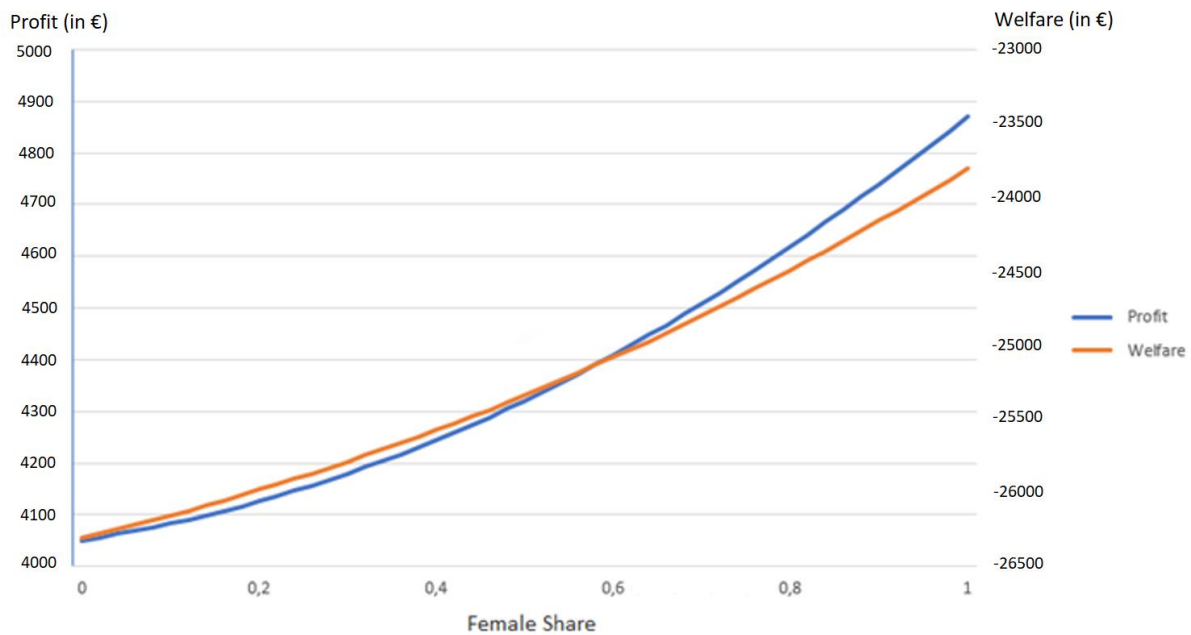
¹² In this scenario, demand is still existing at very high price levels. It may be explained by the use of a logistic function, which can lead to surprising results as it becomes highly inelastic when the alternatives have high differences in utility levels. In this case, carpool modal share may be overestimated.

exchange. It is noticeable, however, that most of the welfare gains arisen from the platform effect are still mainly captured through consumers' surplus and that public subsidies are not required in this setting.

5.3 Gender matching and welfare

Since the utility levels of carpooling differ by both respondents' and carpoolers' genders, we can also analyse what happens when we randomly match individuals and make vary the gender shares within the population. To simulate these matches, we again consider the introduction of a real-time carpool platform and we use utility functions implied by the specification 9 (see more details in the appendices).

Figure 1: Evolution of the maximal profit and social welfare depending on the female's share within the population



We consider a random process in which individuals are matched proportionally to the shares of men and women in the population. Hence, social welfare and modal shares evolve differently according to the proportion of men and women in the population. These results are presented graphically below.

Figure 1 shows that the maximal social welfare reaches higher values when the female share is higher. Two results found in the previous section can explain this phenomenon. First, women prefer to carpool as passengers compared to men. Since the passenger mode is "limiting" because more people want to carpool as drivers, higher carpool modal shares are found when there is a higher proportion of women in the population, *ceteris paribus*. Second, women are

preferred as carpoolers, both as drivers and as passengers. Therefore, carpooling is more often accepted if the probability to carpool with a woman is higher, *ceteris paribus*. For the same reasons, we can also notice that prices displayed in following figures are lower for drivers and higher for passengers when the female share in the population is higher.

Figure 2: Modal shares and prices applied for profit maximized situations depending on female share

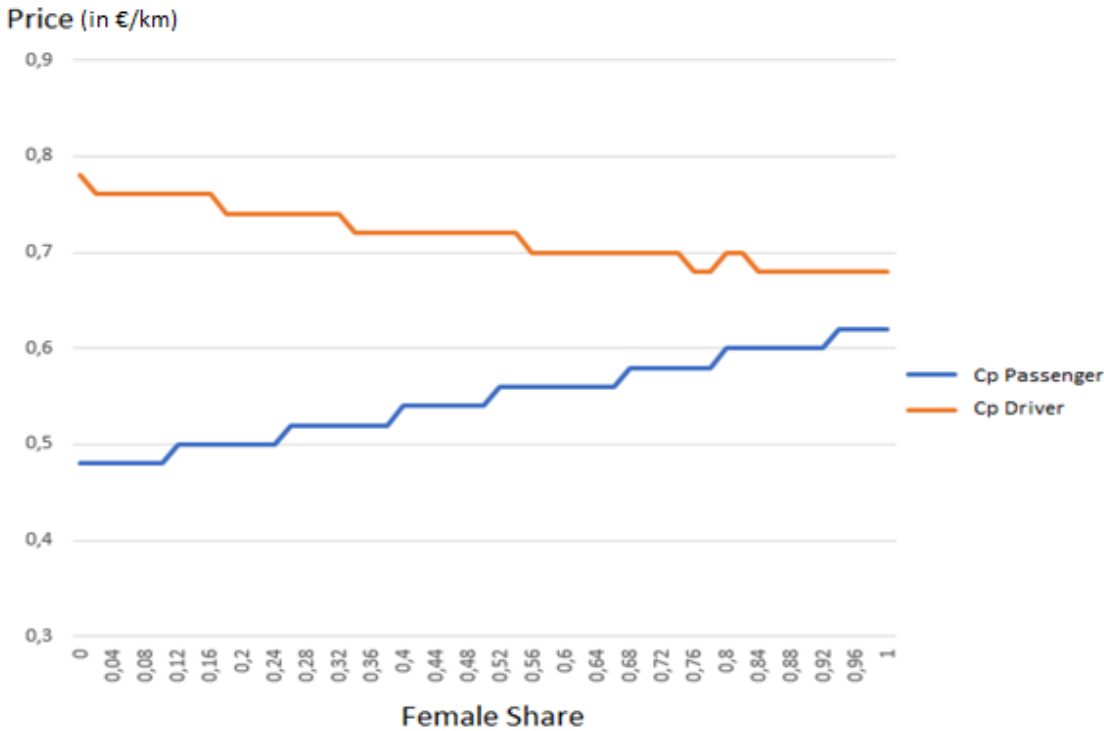
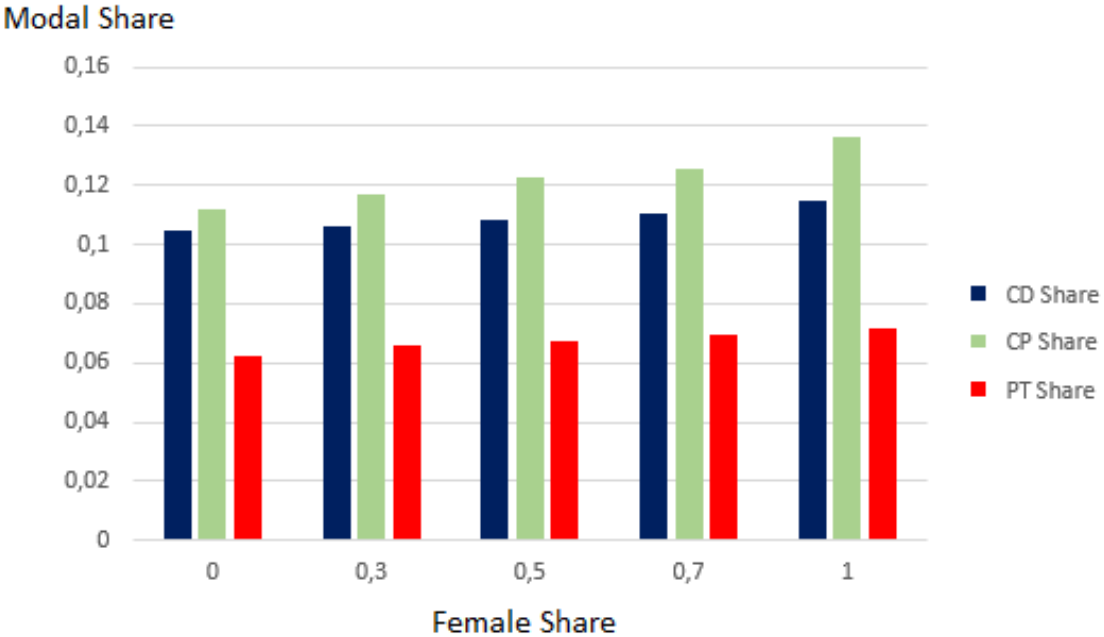
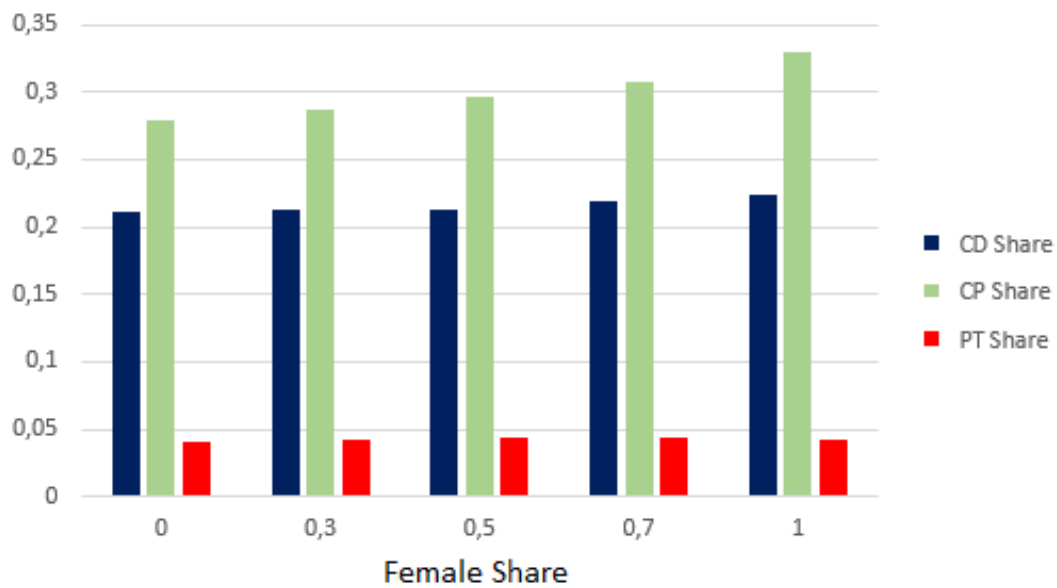
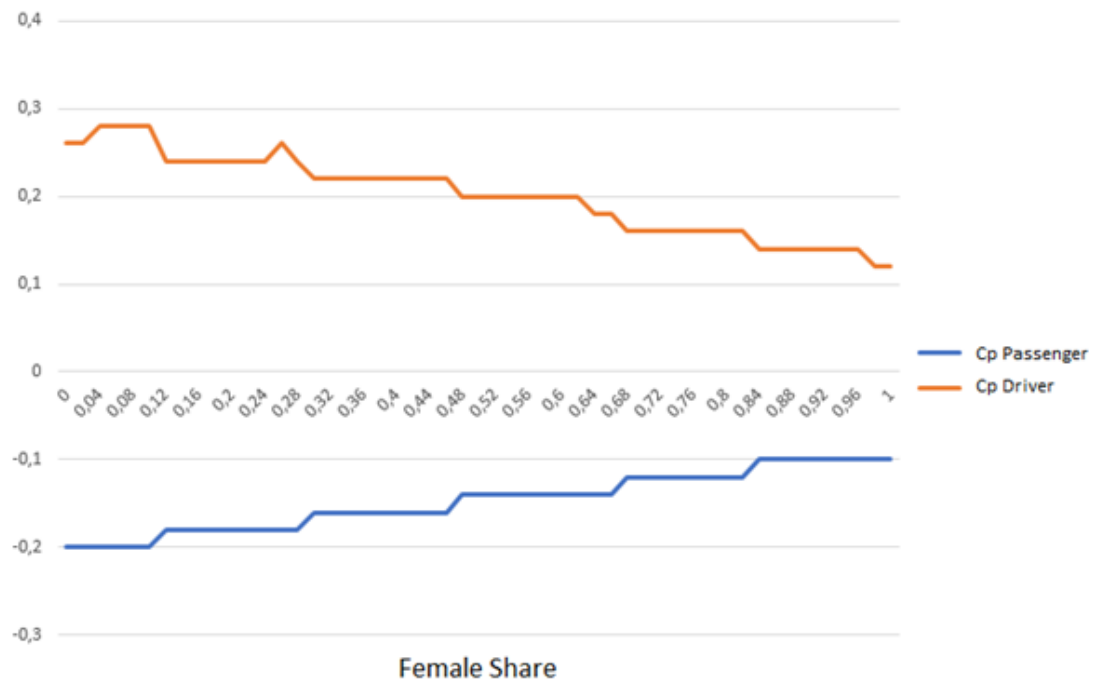


Figure 3: Modal shares and prices applied for welfare maximized situations depending on female share

Modal Share



Price (in €/km)



If we compare profit maximization to welfare maximization situation, we can see higher prices when profit is maximized (Figure 2) than when welfare is maximized (Figure 3). This result is expected as the platform seeks to charge passengers as much as possible without decreasing their modal share too much (since passengers are the carpooling limiting resource). This implies lower carpool modal shares and a driver/passenger ratio close to 1.

In the welfare maximization scenario, we find more passengers in number and proportionally compared to drivers. This result is explained because one passenger more is one car less and therefore externalities less. Hence, the maximum welfare is obtained for situations which tends to increase the modal share of passengers.

6 Conclusion

This paper addresses the issue of individual preferences in the transport modal choice for daily trips, with a specific focus on the effects of carpooling platforms. For this purpose, we conducted a stated choice survey on 3,632 inhabitants of the Lyon's region who responded to 6 choice tasks each for more than 20,000 choices observed. Their preferences are analyzed in terms of carpooling organization variables and socio-demographic differences – or similarities – between the respondent and its potential carpooler.

Our results indicate that carpooling platforms are valuable from the individuals' perspective. They seem efficient to build trust and willingness to carpool, with even stronger effects for passengers.

The analysis of matching effects shows a strong influence of the carpooler's gender, as the willingness to carpool is higher when the carpooler is a woman rather than a man, both as a driver and as a passenger. On the opposite, there is no impact of the carpooler's age on the respondent choices. In addition, the effects of the carpooler's gender are different depending on the respondent's gender. Indeed, this impact is higher for female respondents than for male. This result suggests that carpooling could potentially be easier to implement in areas with a high female presence, such as hospitals in France¹³. This result is also confirmed by our welfare analysis, that indicates higher carpool modal shares and lower prices and retributions to maximize welfare when the female share is higher.

¹³ In 2018 in France, more than 3 out of 4 hospital civil servant are females according to the national institute of statistics : <https://www.insee.fr/fr/statistiques/6528822>

Furthermore, the welfare analysis built thanks to these individual preferences underlines a potential lack of carpool passengers, with an optimal welfare reached in a situation where drivers pay and passengers are paid. This situation is in complete contradiction to what is currently done and seems unacceptable from the drivers' perspective.

Finally, this welfare analysis is incomplete since our estimates are based on a single transport supply situation for all individuals. To better understand the effects of a carpooling pricing policy, such variations need to be applied to concrete data, with transport supplies varying from one individual to another, depending on its departure and arrival locations. These results therefore remain to be optimized for a given case study, which can be applied in further research.

References

- ADEME. 2015. Leviers d'actions pour favoriser le covoiturage de courte distance, évaluation de l'impact sur les polluants atmosphériques et le CO₂ – Leviers d'actions, benchmark et exploitation de l'enquête nationale Transports et déplacements (ENTD) – Etude réalisée par INDIGGO et EnvirOconsult.
- Bachmann, F., Hanimann, A., Artho, J., & Jonas, K. (2018). What drives people to carpool? Explaining carpooling intention from the perspectives of carpooling passengers and drivers. *Transportation research part F: traffic psychology and behaviour*, 59, 260-268.
- Bergerot, A., Comolet, G., Salez, T. (2021). Les usagers de la route paient-ils le juste prix de leurs circulations ?. Direction générale du Trésor. *Lettre Trésor-Éco* 283.
- Björkqvist, K. (2018). Gender differences in aggression. *Current Opinion in Psychology*, 19, 39-42.
- Borghans, L., Heckman, J. J., Golsteyn, B. H., & Meijers, H. (2009). Gender differences in risk aversion and ambiguity aversion. *Journal of the European Economic Association*, 7(2-3), 649-658.
- Bulteau, J., Feuillet, T., Dantan, S., & Abbes, S. (2021). Encouraging carpooling for commuting in the Paris area (France): which incentives and for whom?. *Transportation*, 1-20.
- Buunk, B. P., Dijkstra, P., Fetchenhauer, D., & Kenrick, D. T. (2002). Age and gender differences in mate selection criteria for various involvement levels. *Personal relationships*, 9(3), 271-278.
- Chan, N. D., & Shaheen, S. A. (2012). Ridesharing in North America: Past, present, and future. *Transport reviews*, 32(1), 93-112.
- Chaube, V., Kavanaugh, A. L., & Perez-Quinones, M. A. (2010). Leveraging social networks to embed trust in rideshare programs. In *2010 43rd Hawaii International Conference on System Sciences* (pp. 1-8). IEEE.
- Chaudhuri, A., & Gangadharan, L. (2003). *Sending Money in the Trust Game: Trust or Other-Regarding Preferences*. Working Paper, Department of Economics, University of Auckland, Auckland, New Zealand.
- Cui, S., Li, K., Yang, L., & Wang, J. (2022). Slugging: Casual carpooling for urban transit. *Manufacturing & Service Operations Management*, 24(5), 2516-2534.

- Deakin, E., Frick, K. T., & Shively, K. M. (2010). Markets for dynamic ridesharing? Case of Berkeley, California. *Transportation Research Record*, 2187(1), 131-137.
- Delcampe, D. (2018). Covoiturage courte et moyenne distance. Retour d'expériences, freins et leviers. Rapport d'étude, CEREMA, Lyon.
- Dillen, N., Ilievski, M., Law, E., Nacke, L. E., Czarnecki, K., & Schneider, O. (2020, April). Keep calm and ride along: Passenger comfort and anxiety as physiological responses to autonomous driving styles. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems* (pp. 1-13).
- Farajallah, M., Hammond, R. G., & Pénard, T. (2019). What drives pricing behavior in peer-to-peer markets? Evidence from the carsharing platform BlaBlaCar. *Information Economics and Policy*, 48, 15-31.
- Garcia-López, M. À., Jofre-Monseny, J., Martínez-Mazza, R., & Segú, M. (2020). Do short-term rental platforms affect housing markets? Evidence from Airbnb in Barcelona. *Journal of Urban Economics*, 119, 103278.
- Gheorghiu, A., & Delhomme, P. (2018). For which types of trips do French drivers carpool? Motivations underlying carpooling for different types of trips. *Transportation Research Part A: Policy and Practice*, 113, 460-475.
- Haghani, M., Bliemer, M. C., Rose, J. M., Oppewal, H., & Lancsar, E. (2021). Hypothetical bias in stated choice experiments: Part I. Macro-scale analysis of literature and integrative synthesis of empirical evidence from applied economics, experimental psychology and neuroimaging. *Journal of choice modelling*, 41, 100309.
- Hawlitsek, F., Teubner, T., & Weinhardt, C. (2016). Trust in the sharing economy. *Die Unternehmung*, 70(1), 26-44.
- Hess, S., Rose, J.M. & Polak, J.W. (2010) Non-Trading, lexicographic and inconsistent behaviour in stated choice data. *Transportation research Part D*, 15, 405 – 417.
- Lee, K. H., & Kim, D. (2019). A peer-to-peer (P2P) platform business model: The case of Airbnb. *Service Business*, 13(4), 647-669.
- Le Goff, A., Monchambert, G., & Raux, C. (2022). Are solo driving commuters ready to switch to carpool? Heterogeneity of preferences in Lyon's urban area. *Transport Policy*, 115, 27-39.

- Leurent, F., & Simonet, P. (2001). Fonctions temps-débit sur les autoroutes interurbaines-renovation des relations entre temps de parcours et débit pour la simulation du trafic - Rapport technique.
- Malardé, V., & Pénard, T. (2019). Airbnb, Blablacar, Le Bon Coin... À qui bénéficient les plateformes de consommation collaborative?. *Economie prevision*, (1), 1-28.
- Monchambert, G. (2020). Why do (or don't) people carpool for long distance trips? A discrete choice experiment in France. *Transportation Research Part A: Policy and Practice*, 132, 911-931.
- Monchambert, G. (2023). Pricing of myopic multi-sided platforms: theory and application to carpooling. halshs-03980205.
- Montero, J. J. (2019). Regulating transport platforms: The case of carpooling in Europe. In *The governance of smart transportation systems* (pp. 13-35). Springer, Cham.
- Olsson, L. E., Maier, R., & Friman, M. (2019). Why do they ride with others? Meta-analysis of factors influencing travelers to carpool. *Sustainability*, 11(8), 2414.
- ONISR (2021). Bilan des chiffres définitifs 2020. https://www.onisr.securite-routiere.gouv.fr/sites/default/files/2021-05/20210531_Bilan_D%C3%A9finitif_ONISR_2020%20vMS.pdf Accessed Apr. 2022.
- Sengoelge, M., Laflamme, L., & El-Khatib, Z. (2018). Ecological study of road traffic injuries in the eastern Mediterranean region: country economic level, road user category and gender perspectives. *BMC public health*, 18(1), 1-9.
- Shaheen, S., Stocker, A., & Mundler, M. (2017). Online and app-based carpooling in France: Analyzing users and practices—A study of BlaBlaCar. In *Disrupting mobility* (pp. 181-196). Springer, Cham.
- Shaheen, S., Cohen, A., & Bayen, A. (2018). The benefits of carpooling.
- SYTRAL (2016). Enquête déplacements 2015 de l'aire métropolitaine lyonnaise. https://www.scot-rivesdurhone.com/wp-content/uploads/2016/08/EnqDeplcmt2015_plaq_generale_27062016_120dpi_pourWEB.pdf, Accessed Apr. 2022.

Ter Huurne, M., Ronteltap, A., Corten, R., & Buskens, V. (2017). Antecedents of trust in the sharing economy: A systematic review. *Journal of Consumer Behaviour*, *16*(6), 485-498.

Walker, J., & Ben-Akiva, M. (2002). Generalized random utility model. *Mathematical social sciences*, *43*(3), 303-343.

Yaraghi, N., & Ravi, S. (2017). The current and future state of the sharing economy. *Available at SSRN 3041207*.

Appendices

Appendix A. Planned and Real-time carpooling presentation screens

Planned carpooling presentation screen

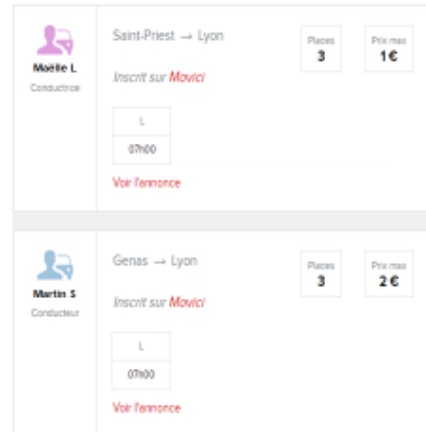
Carpooling is arranged before the trip begins with a set location and time for the passenger to pick up.

This may involve a time to get to the meeting point, a time to wait and a time to get to the final destination.

The trip is organized:

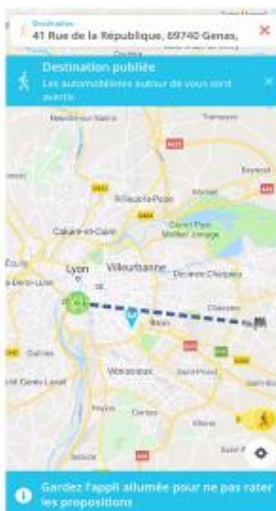
- Either via a platform (like BlaBlaCar) where members are listed
- Or informally with a relative/neighbor/colleague

Your return can be done by carpooling under the same conditions.



Example of a carpooling application

Spontaneous carpooling presentation screen



A real time application

In this survey, carpooling is organized spontaneously during the trip, and carpoolers may meet at a station or at the roadside.

This may involve a time to get to the meeting point, a time to wait and a time to get to the final destination.

The trip is organized:

- Either via a smartphone application in real time that links driver and passenger
- Or with a stranger in hitchhiking

Your return can be done by carpooling under the same conditions.



A carpooling station

Appendix B. Example of choice screen for a respondent with an 8:30 preferred arrival

Mode	Driver Alone	Driver in a Carpool	Passenger in a Carpool	Public Transport
Trip Characteristics	Start : 7:20 Drive Alone: Between 30 and 40 min Arrival: Between 7:50 and 8:00	Start : 7:30 Join the station: no detour Wait: 5 min Carpool : Between 25 and 40 min Join your destination: 5 min walk Arrival : Between 8:15 and 8:30	Start : 7:35 Join the station: 5 min walk Wait: 5 min Carpool : Between 30 and 40 min Join your destination: 5 min walk Arrival : Between 8:20 and 8:30	Start : 7:30 Join the station: 10 min by car Wait: 5 min Public Transport: Between 25 and 40 min Join your destination: 5 min walk Arrival : Between 8:15 and 8:30
Monetary aspects	You pay your usual transportation costs	You pay your usual transportation costs Carpooling makes you earn 1€	You save on your usual transportation costs Carpooling costs you 1€	You save on your usual transportation costs Public Transport costs you 0,80€
Carpooler's profile		Your passenger: 45 years old, Hitchhiker	Your driver: 25 years old, Referenced on the carpool platform	
Which mode do you choose ?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

time

Appendix C. Utility functions details

For the solo driver (ds):

$$V_{Dsolo} = ASC_{ds} + Cost + TT_{ds} + TV_{ds} + SchedEarly + SchedLate + Z_{ds}$$

Where ASC_{ds} is the constant specific to the solo driver mode, $Cost$ is the price, TT , TV are the on-board vehicle and variable time respectively. The subscript ds indicates that the coefficients associated with these variables are estimated specifically for this mode. $SchedEarly$ and $SchedLate$ are the variables indicating early and late scheduling. Finally, Z represents the socio-economic characteristics of the respondent (for the moment only gender has been tested in the models).

For the carpooling driver (dcp):

$$\begin{aligned} V_{Dcarpool} = & ASC_{dcp} + Cost + Gain + TT_{dcp} + TV_{dcp} + DT + WT_{dcp} + Spont_{dcp} \\ & + Platform_{dcp} + Spont_{dcp} * Platform_{dcp} \\ & + NotRelative(MM_{dcp} + MF_{dcp} + FM_{dcp} + FF_{dcp} + AgeMatch_{dcp} \\ & + (Platform_{dcp} * male)) + Z_{dcp} \end{aligned}$$

Where *Gain* measures the difference between the sensitivity to money paid versus money received. *DT* and *WT* measure the sensitivities to detour time and wait time respectively. *Spont_{dcp}* measures the impact of spontaneous (vs. planned) carpooling organization. *Platform_{dcp}* measures the impact of the platform on the propensity to accept carpooling. We also consider the interaction between spontaneous and platform effects via the interaction *Spont_{dcp} * Platform_{dcp}*.

Finally, the influence of matching with the carpooler is treated. Gender interactions are modeled via the coefficients associated with *MM_{dcp}* *MF_{dcp}* *FM_{dcp}* et *FF_{dcp}* where the first letter symbolizes the gender of the respondent (M=Male, F=Female) and the second symbolizes the gender of the proposed carpooler. We also test if the age of the proposed carpooler has an impact via the age difference between this carpooler and the respondent via *AgeMatch*. Finally, we check if the impact of the platforms on the perception of the carpooler changes according to the gender of the respondent by using the interaction measured by *Spont_{dcp} * Platform*.

For these variables concerning the matching with the carpooler, we observe differences between the platform situations vs. the hitchhiking situation, taking care to exclude the situations where one is facing a relative via *NotRelative*.

For carpooling passenger (*pcp*):

$$\begin{aligned}
V_{Pcarpool} = & ASC_{pcp} + Cost + TT_{pcp} + TV_{pcp} + AT_{pcp} + CorrespAcc_{pcp} \\
& + ET + CorrespEgr + WT_{pcp} + Spont_{pcp} + Platform_{pcp} + Spont_{pcp} * Platform_{pcp} \\
& + NotRelative(MM_{pcp} + MF_{pcp} + FM_{dcp} + FF_{pcp} + AgeMatch_{pcp} \\
& + (Platform_{pcp} * male)) + Z_{pcp}
\end{aligned}$$

Where *Corresp* are the variables indicating a change in transportation mode. This can be for access, where the passenger is likely to drive to the carpooling station with their own car, and then exit from the carpooling, where the individual is likely to take public transportation to finish their trip. *AT* and *ET* are the corresponding access and egress times in the modes mentioned above.

For public transports (*pt*):

$$V_{PubTransport} = ASC_{pt} + Cost + TT_{pt} + TV_{pt} + AT_{pt} + CorrespAcc_{pt} + WT_{pcp} + Z_{pt}$$

Where we find only previously used variables. There is no egress time (*ET*) since we assume that the public transports drop off near the individual's final destination and therefore does not imply a change of transport mode.

Appendix D. Econometric Models

Table: Organization Effects		Model 0	Model 1	Model 2	Model 3	Model 4	Model 5
Model name	Times only	Platform Effects	Spontaneous Effects	Spout x Platform interaction	Driver vs Passenger Effects	Gender differentiated effects of platform	
# individuals	3632	3632	3632	3632	3632	3632	3632
# observations	21792	21792	21792	21792	21792	21792	21792
# parameters	29	30	30	32	35	41	41
LL(final)	-26561.8	-26553.5	-26557.9	-26516.2	-26503.8	-26464.3	-26464.3
Adj. Rho-square (0)	0.1198	0.1200	0.1199	0.1212	0.1215	0.1226	0.1226
AIC	53181.5	53166.9	53175.9	53096.3	53077.6	53010.6	53010.6
BIC	53413.2	53406.6	53415.5	53352.0	53357.2	53338.1	53338.1
Estimates							
ASC							
Carpooling Driver	1.589 ***	1.548 ***	1.589 ***	1.664 ***	1.663 ***	1.842 ***	1.842 ***
Carpooling Passenger	1.487 ***	1.419 ***	1.487 ***	1.620 ***	1.583 ***	1.608 ***	1.608 ***
Public Transport	0.746 ***	0.746 ***	0.746 ***	0.759 ***	0.753 ***	0.749 ***	0.749 ***
Organization		0.102 ***				Driver Effects	Driver Effects
Platform						-0.171 ***	-0.271 ***
Spout						-0.208 ***	-0.593 ***
Spout x Pthm						0.406 ***	0.658 ***
Cost	-0.068 ***	-0.070 ***	-0.067 ***	-0.064 ***	-0.063 ***	-0.063 ***	-0.063 ***
Individual Characteristics							
Male							
Carpooling Driver	-0.099 **	-0.099 **	-0.100 **	-0.099 **	-0.099 **	-0.099 **	-0.099 **
Carpooling Passenger	-0.410 ***	-0.411 ***	-0.411 ***	-0.409 ***	-0.413 ***	-0.413 ***	-0.413 ***
Public Transport	-0.195 ***	-0.195 ***	-0.195 ***	-0.195 ***	-0.196 ***	-0.196 ***	-0.196 ***
Age							
Carpooling Driver	-0.031 ***	-0.031 ***	-0.031 ***	-0.031 ***	-0.031 ***	-0.031 ***	-0.031 ***
Carpooling Passenger	-0.040 ***	-0.040 ***	-0.040 ***	-0.040 ***	-0.040 ***	-0.040 ***	-0.040 ***
Public Transport	-0.024 ***	-0.024 ***	-0.024 ***	-0.024 ***	-0.024 ***	-0.024 ***	-0.024 ***
Income							
Carpooling Driver	0.120 ***	0.121 ***	0.121 ***	0.121 ***	0.121 ***	0.121 ***	0.121 ***
Carpooling Passenger	0.138 ***	0.139 ***	0.138 ***	0.139 ***	0.140 ***	0.140 ***	0.140 ***
Public Transport	0.185 ***	0.185 ***	0.185 ***	0.185 ***	0.185 ***	0.185 ***	0.185 ***
Time components differentiated by mode	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time components differentiated by stage of the trip	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Organization x Male						Driver Effects	Passenger Effects
Platform x Male						0.181 *	-0.134 *
Spout x Male						0.677 ***	0.386 **
Spout x Pthm x Male						-0.443 ***	-0.265 *

Notes: *P*-values: 1 () 0.1 (.) 0.05 (*) 0.01 (**) 0.001 (***) 0.

Table: Matching Effects

	Base (Model 4 Table 1)		Model 6 Relative Male		Model 7 Age Match		Model 8 Carpooler Male		Model 9 CplrMale x Rspdt Male	
Model name	Times only		Relative Male		Age Match		Carpooler Male		CplrMale x Rspdt Male	
# individuals	3632		3632		3632		3632		3632	
# observations	21792		21792		21792		21792		21792	
# parameters	35		37		39		41		43	
LL (final)	-26516,2		-26516,2		-26487,0		-26479,7		-26473,8	
Adj. Rho-square (0)	0,1215		0,1220		0,1220		0,1221		0,1223	
AIC	53077,6		53050,2		53051,9		53041,9		53033,7	
BIC	53357,2		53345,8		53363,5		53368,6		53377,2	
Estimates										
ASC										
Carpooling Driver	1,663	***	1,824	***	1,822	***	1,827	***	1,829	***
Carpooling Passenger	1,583	***	1,580	***	1,579	***	1,595	***	1,599	***
Public Transport	0,753	***	0,749	***	0,748	***	0,756	***	0,756	***
Organization	Driver	Passenger	Driver	Passenger	Driver	Passenger	Driver	Passenger	Driver	Passenger
Platform	-0,171	***	-0,005	***	-0,406	***	-0,010	***	-0,300	***
Sport	-0,208	***	-0,397	***	-0,426	***	-0,383	***	-0,340	***
Sport x Pflm	0,406	***	0,442	***	0,641	***	0,427	***	0,534	***
Cost	-0,063	***	-0,064	***	-0,064	***	-0,063	***	-0,063	***
Matching	Driver	Passenger	Driver	Passenger	Driver	Passenger	Driver	Passenger	Driver	Passenger
Respondent Male	-0,099	**	-0,413	***	0,001		-0,407	***	0,104	.
Male x Relative	NA	NA	-0,390	***	0,003		-0,390	***	-0,286	***
Carpooler Male	NA	NA	NA	NA	NA	NA	-0,102	**	-0,226	***
CplrMale x RspdtMale	NA	NA	NA	NA	NA	NA	NA	NA	0,217	**
Age Match	NA	NA	NA	NA	0,045		-0,037		0,044	.
Individual Characteristics										
Male										
Public Transport	-0,196	***	-0,194	***	-0,194	***	-0,194	***	-0,194	***
Age										
Carpooling Driver	-0,031	***	-0,031	***	-0,031	***	-0,031	***	-0,031	***
Carpooling Passenger	-0,040	***	-0,040	***	-0,040	***	-0,039	***	-0,040	***
Public Transport	-0,024	***	-0,024	***	-0,024	***	-0,024	***	-0,024	***
Income										
Carpooling Driver	0,121	***	0,122	***	0,122	***	0,122	***	0,122	***
Carpooling Passenger	0,140	***	0,140	***	0,140	***	0,139	***	0,139	***
Public Transport	0,185	***	0,185	***	0,185	***	0,185	***	0,185	***
Time components										
Time differentiated by mode	Yes		Yes		Yes		Yes		Yes	
Time components differentiated by stage of the trip	Yes		Yes		Yes		Yes		Yes	

Notes: P-values: 1 (.) 0.1 (.) 0.05 (*) 0.01 (**) 0.001 (***) 0.

Appendix E. Simulation details

1) Congestion

In order to model road congestion, we use is the following BPR function:

$$TT = T_0 * \left(1 + \gamma \left(\frac{\#cars}{K}\right)^\alpha\right)$$

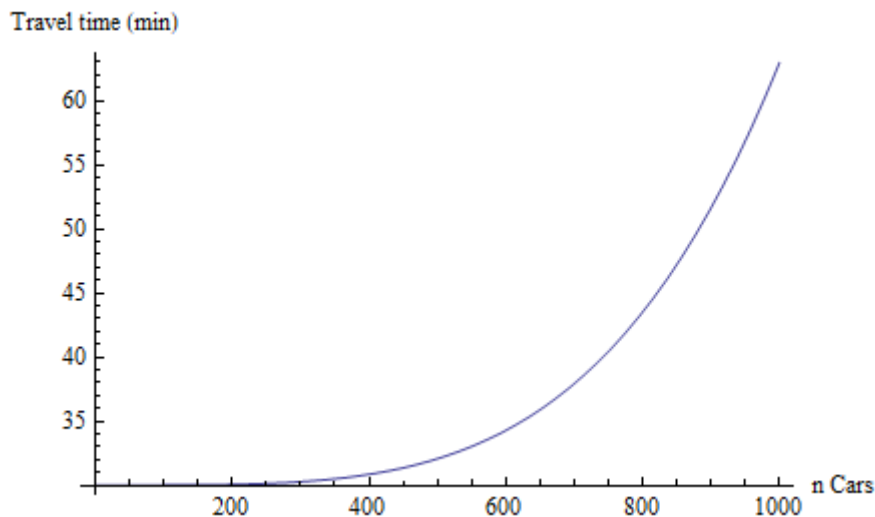
Where TT is the total travel time, T_0 the initial travel time, in our case equal to 30 minutes. Following Leurent & Simonet (2001), the γ parameter is set to 0,45.

In this simulation, we want to test how 1,000 individuals who want to travel would react in a potentially congested situation. We need to fix a capacity parameter K for which the congestion is consistent. In an extreme case, if everyone uses his own car, the result obtained must be such that the travel time increases considerably. Let us consider the situation where these 1,000 people want to use a 2-lane road during a time interval of a quarter of an hour. If we consider that one lane can accommodate 1,600 people per hour, then the capacity of a two-lane road for a quarter hour is 800 people. We then fix K to 800 in this simulation.

The road use is then measured by the total number of cars, which depends on the mode choices individual have made. In this simulation, we consider every driver will take up space on the road and passengers will not. That is why the number of people who chooses public transportation or carpooling as passenger will not affect congestion. We have $\#cars$ equal to the number of people who chooses solo driver plus the number who chooses carpool driver.

Finally, α is set to 4 as recommended by Leurent & Simonet (2001) for a 2-lane axis.

Graphically, we get:



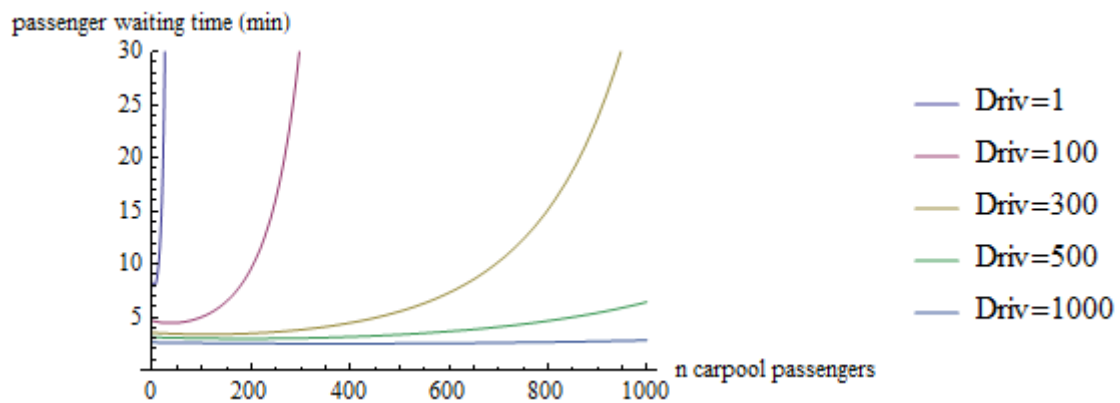
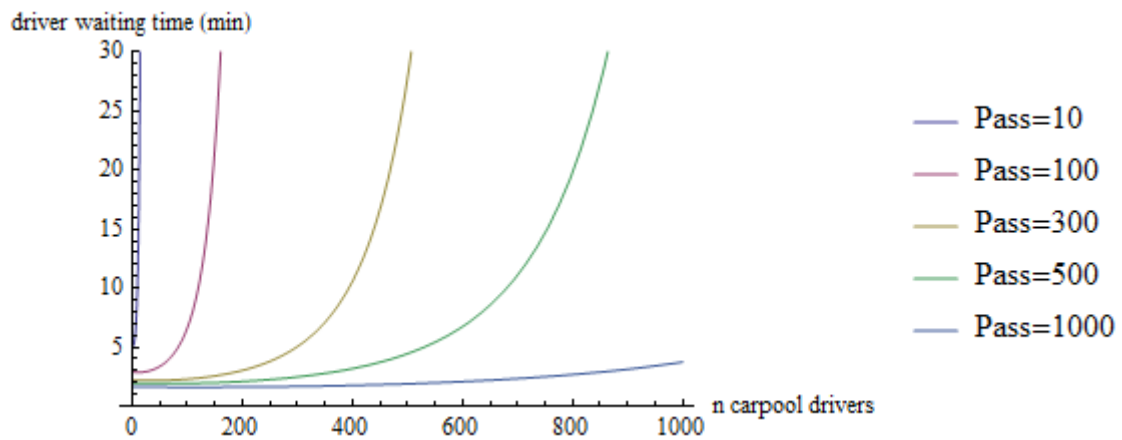
2) Waiting times

We want waiting times to be slightly different for passengers and drivers as a driver can allow several passengers while the reverse situation is impossible. Hence, drivers' waiting time should be such that the lack of passengers (more drivers than passengers) should increase more the waiting time compared to a situation where there are more passengers than drivers. We also want to add a component which takes into account the total number of carpoolers. The more the carpoolers, the fewest the waiting time. We hence model waiting times as:

$$WT_{cd} = \frac{\exp\left(\left(\frac{N_{driv}}{N_{pass}}\right)^2 - 1\right) * 25}{(N_{driv} + N_{pass})^{\frac{1}{4}}}$$

$$WT_{cp} = \frac{\exp\left(\left(\frac{N_{pass}}{2 * N_{driv}}\right)^2 - 1\right) * 40}{(N_{driv} + N_{pass})^{\frac{1}{4}}}$$

Graphically, these waiting time function give:



3) Public finance balance

Three factors here affect public finance. The first one is the money collected by fuel taxation. We consider the average fuel cost is around 0.09€ per vehicle-kilometer (Cordier, 2019). From this fuel cost, around 60% is taken by taxes (Source: Government <https://www.economie.gouv.fr/facileco/prix-lessence> Accessed Nov. 21).

The second one is the cost of road wear maintenance, approximated to 0.008€- per vehicle-kilometer by Bergerot et al. (2021).

Finally, public finance balance also takes into account a possible subsidy to the carpool platform. In this simulation, we consider that if the platform gives more than it receives, it must be subsidized by the amount of the deficit.

Considering a 30 km trip (which is the average trip distance in the Lyon's area, see SYTRAL, 2016) and a shadow cost of public funds (SCPF) of 1.2, as recommended by Quinet (2014), we get:

$$Publifinance = SCPF * (\#Cars * distance * (0.6 * FuelCost - RoadWear) - Subsidy)$$

4) External costs

Finally, the external costs due to car traffic are estimated based on Bergerot et al. (2021), who propose an average cost of 0.082 € per vehicle-kilometer considering noise, air pollution and road insecurity. Hence:

$$Externalities = \#Cars * distance * 0.082$$