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Sustainable Commuting: Results from a Social Approach and International Evidence on Carpooling

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Abstract: Sustainable commuting (SC) usually refers to environmentally friendly travel modes, such as public transport (bus, tram, subway, light rail), walking, cycling, and carpooling. The double aim of the paper is to summarize relevant prior results in commuting from a social approach, and to provide new, international empirical evidence on carpooling as a specific mode of sustainable commuting. The literature shows that certain socio-demographic characteristics clearly affect the use of non-motorized alternatives, and compared to driving, well-being is greater for those using active travel or public transport. Additionally, this paper analyzes the behavior of carpooling for commuting, using ordinary least squares (OLS) models, which have been estimated from the Multinational Time Use Study (MTUS) for the following countries: Bulgaria, Canada, Spain, Finland, France, Hungary, Italy, South Korea, the United Kingdom, and the United States. Results indicate that carpooling for commuting is not habitual for workers, as less than 25% of the total time from/to work by car is done with others on board. With respect to the role of the socio-demographic characteristics of individuals, our evidence indicates that age, gender, education, being native, and household composition may have a cross-country, consistent relationship with carpooling participation. Given that socializing is the main reason for carpooling, in the current COVID-19 pandemic, carpooling may be decreasing and, consequently, initiatives have been launched to show that carpooling is a necessary way to avoid crowded modes of transport. Thus, the development of high-occupancy-vehicle (HOV) lanes by local authorities can increase carpooling, and draw attention to the economic and environmental benefits of carpooling for potential users.

Keywords: sustainable commuting; human approach; carpooling

1. Introduction

Commuting is, obviously, a transportation issue, with multiple implications for the daily life of individuals and families, in terms of household responsibilities [1], employment [2–4], and well-being [5,6]. Additionally, commuting generates a high level of CO_2 emissions globally, with this increasingly being a result of environmentally unfriendly transport behaviors. In this context, it is necessary for policy-makers to design and implement efficient strategies [7–9], primarily taking into account the public opinion of users [10], aimed at decreasing these emissions and promoting better management of the environment.

Sustainable commuting (SC) usually refers to environmentally friendly travel modes, such as public transport (bus, tram, subway, light rail), walking, cycling, and carpooling. The literature has shown that the use of public transport may be beneficial for the environment, as it helps to reduce

greenhouse gas emissions. The use of physical modes of transport contributes more to the reduction of CO_2 emissions, since such modes are, ultimately, 'zero carbon' and an environmentally friendly solution for personal transport [11–14].

The double aim of this paper is to summarize important prior results in commuting studies from a social approach, and to provide new international, empirical evidence on carpooling as a specific mode of sustainable commuting. SC has a number of important relationships with disciplines other than transportation, largely related to population issues, from the perspective of social behaviors. This paper first reviews the most important results derived from the relationship between SC and these social disciplines, beginning with an analysis of the objective and subjective determinants of commuting, which requires the use of economic/econometric methods in the context of psychological theories. Second, SC has obvious implications for the physical and mental health of individuals. School/university SC also has important links to education, along with significant associations with labor demand, given the important role of employers in the commuting modes of their employees.

Additionally, this paper provides empirical evidence of transport behavior around the world regarding carpooling, understood as the sharing of the same car by two or more individuals at the same time. To that end, we use information obtained from time use surveys to analyze the behavior of workers in several countries, with a focus on the patterns of carpooling during commuting (as both drivers and passengers). We document that carpooling for commuting is a practice that, up to now, is not habitual for workers.

2. Literature Review

2.1. Subjective and Objective Determinants

The transport literature has routinely employed the theory of planned behavior [15,16], one of the most influential theories of behavioral decisions. Specifically, this theory has been used to examine choices of travel mode. With respect to the subjective determinants, the literature has demonstrated that SC, in the context of the theory of planned behavior, is mainly influenced by intentions, which, in turn, are predicted by three social-cognitive factors: attitudes, subjective norms, and perceived behavior controls. Beyond these factors, we must also account for the presence of restrictions, such as limited skills, life-chances, and external conditions, that also influence SC [17–19].

The psychological factors of SC have been modeled using the theory of planned behavior [20]. Results indicate that both the intention and the perceived behavioral controls have a direct impact on SC. In the same line, it is possible to incorporate environmental concerns in the theory of planned behavior, to explore the effect of subjective factors on SC [21]. Using a random sample of 1355 commuters in Beijing and Shanghai, results show the direct effect of intentions on SC. Consequently, the increasing development of transport infrastructure and the provision of external conditions can help to reduce the limitations consumers encounter in adopting SC. Another important result using the theory of planned behavior shows that residents in areas of high population density are more likely to adopt SC [22].

Regarding other determinants, the relationship between an individual's income and SC is central, although the evidence is less than conclusive. The bulk of the literature shows that lower-income regions have a greater prevalence of SC (walking, cycling, and public transportation) compared with areas of higher income. Other objective determinants are related to the physical environment, with the literature showing that such factors are more important for the prevalence of public transportation than for that of walking or cycling to work. The relationship between these two objective determinants shows that physical environmental factors are more important for SC participation in higher-income neighborhoods than in lower-income areas.

Non-motorized commuting in the US, including cycling and walking to work, is examined using the 2001 American Housing Survey [23]. Employing detailed commuting information for about 60,000 individuals, the survey shows that higher income and more expensive housing are associated with a lower propensity to walk or cycle, and college education is usually associated with a greater

propensity to use non-motorized modes within a metropolitan area. Additionally, car ownership, race, gender, and other neighborhood features also affect the use of non-motorized alternatives. Lower-income tracts have a greater prevalence of active commuting compared to higher-income tracts in the US [24]. However, these results are not general. In a different line, data from the New Zealand Household Travel Survey shows, for the case of Wellington (New Zealand), that the probability of walking and cycling increases with income [25]. These authors also show that physical environmental factors (e.g., favorable climate) are more important for active commuting participation in higher-income neighborhoods.

2.2. Health and Well-Being

A subgroup of SC modes, including walking and cycling to work, is known as active commuting (AC). There are, at least, five reasons for attempting to stem and reverse shifts away from AC, that is to say, health, public finance, climate change, social connectedness, and labor productivity. Physical inactivity is currently a major international public health issue (leading to obesity and cardiovascular issues) and more efforts are needed to promote physical activity, not only in the leisure sphere, but also within the commuting element of the work experience.

The literature shows that greater AC is associated with higher levels of physical well-being. However, studies examining the impact on well-being of travel for recreational purposes are much more common than those that examine routine commuting. There is no definitive association between AC and mental well-being, although most of the evidence shows that, compared to driving, well-being is greater for those using active travel or public transport, with this positive effect being considered in cost-benefit assessments of public interventions seeking to promote AC. In this context, the promotion of AC should include urban planning, workplace programs and policies, and installing bicycle lanes, among others.

With respect to health, it is useful to examine, specifically, whether active commuting is an effective method of controlling obesity and, consequently, of enhancing the cardiovascular health of the population [26]. This review provides mixed results, with the author concluding that more information and analysis is needed concerning the impact of active commuting on overall attitudes to physical activity. Additionally, using an online survey conducted in Manhattan, Kansas, in 2008, the study examines a range of significant influences, from individual to environmental features, on active commuting, with the results having important implications for public health researchers and practitioners [27].

Greater active commuting is associated with well-being in a study employing cross-sectional data from Cambridge, UK, and its surrounding area, in 2009; higher levels of physical well-being are found, with the strongest association being linked to at least 45 min of active commuting per day [28]. However, the authors find no significant association between active commuting and mental well-being. In the same line, data on 17,985 adult commuters in eighteen waves of the British Household Panel Survey (1991/2-2008/9) were applied to fixed-effects models in the UK, with the main objective being to analyze the impact of commuting behavior on psychological well-being. Results indicate that well-being is greater when using active travel or public transport, compared to driving [29].

2.3. Commuting to School

Despite the high policy interest of school/university SC, there is only limited academic research examining this kind of commuting among students (elementary/high school/university). Some evidence shows that between 40% and 50% of high-school students report using AC to get to and from school. Students are less likely to actively commute to school if they are girls, daily smokers, or attending a rural school. Curiously, weather conditions (temperature, precipitation) do not appear to predict active commuting to school. Negative correlates include parental perception of other children in the neighborhood, a lack of traffic lights or crossings, and a busy road barrier en route to school.

The literature shows that reducing barriers to using active modes, such as reducing actual and perceived travel time by bus and bicycle, would have the greatest impact on commuting patterns.

Employing a sample of 235 children aged 5 to 6 years and 577 children aged 10 to 12 years, from 134 elementary schools in Melbourne, Australia, one study finds that the negative correlates of active commuting to school include parental perceptions of few other children in the neighborhood, no lights or crossings for their child to use, and an objectively assessed busy road barrier en route to school [30]. Additionally, children are more likely to actively commute to school if their journey is less than 800 m. There is limited research examining active commuting among high-school students, with this being a clear topic of interest for future research [31]. Employing a sample of 21,345 students from 76 Ontario high schools (grades 9–12) between 2005 and 2006, the authors show that only 42.5% of these students reported actively commuting to school. Students were less likely to actively commute to school if they were girls, were in grade 12, smoked daily, were low-to-moderate in physical activity, or attended a rural school.

With respect to university students, a study employing a sample of 2567 members of staff and 12,974 students at the University of Western Australia examines the commuting patterns [32]. Results show that reducing actual and perceived travel time by bus and bicycle would have the greatest impact on commuting patterns, with this result suggesting that the implementation of a subsidized public transport pass would have a significant effect.

2.4. Labor Demand/Employees

Regarding labor demand, one potential solution in the literature for alleviating CO_2 emissions has been to identify the role of the employer in sustainable commuter programs. An increasing body of evidence analyzes the attitudes and policies of employers towards employee travel and sustainable commuter plans. Although larger firms should develop SC plans in the short term, both small and large businesses appear to be committed to a high level of staff parking provisions. Employers are aware of the transport problems their workers face and cite the need for central government legislation and tax incentives before themselves taking action to implement sustainable commuter plans.

The attitudes and policies of the small employer (under 100 employees) towards staff travel and green commuter plans are examined using data from 352 Oxfordshire small-firm employees [33]. Results indicate that, even though there should be a role for the small employer in developing green commuter plans, in the short term, it is the large firms that are more likely to implement such plans.

Using a sample of 8331 respondents from the Washington and Baltimore Regional Household Travel Survey, during 2007–2008, a study of the role of employers in green commuter programs are examined [34]. Specifically, data from Washington-Baltimore is used to assess the effects of employer attitudes towards green commuting plans on choices of commuter mode. Results confirm the intermediary nature of car ownership in the choice process, with the findings providing helpful information for transportation and planning policy-makers in encouraging green commuting that reduces transportation emissions.

3. Carpooling: International Evidence

Carpooling (also known as ridesharing) dates back to at least the 1940s in the United States [35] and is a scheme in which individuals share a vehicle in order to reach common or proximate destinations [36,37]. In particular, carpooling is an agreement to share the use of a private car by several individuals (frequently commuting), for the same journey, at a mutually compatible time. Although it can refer to several forms of sharing a ride [38–41], three general forms of carpooling can be defined: private, corporate, and urban carpooling. Carpooling provides numerous societal benefits, such as reductions in energy consumption and emissions, and congestion mitigation [42]. Individually, carpool users can benefit from shared travel costs, travel-time savings from driving in (HOV) lanes, reduced commuter stress, and, often, preferential parking and other incentives, in addition to environmental benefits [43–47]. The analysis of carpooling has been developed worldwide, as in

China [48], France [49–51], the United States [52–56], Europe [57], the Netherlands [58,59], Greece [60], India [61], and Canada [62], among others.

To analyze the behavior of carpooling during commuting trips, we use the Multinational Time Use Study (MTUS), an ex-post harmonized cross-time, cross-national, comparative time use database, coordinated by the Centre for Time Use Research at the University of Oxford. The study is constructed from national randomly-sampled time-diary studies, with a common series of background variables, and total time spent in 69 activities [63]. The MTUS contains representative samples of households, and information on daily activities, gathered by means of the completion of personal diaries and household and individual questionnaires. The samples are evenly distributed over the year and the week, in many countries, in order to accurately represent time-use patterns for all days of the year. The survey includes activity diaries that respondents complete on a selected day.

The diary time frame is twenty-four consecutive hours, and respondents record for each episode a main activity (e.g., travel to/from work) together with additional information, such as the mode of transport and who else is present during the episode. From the data, we select countries that use similar surveys, including the same information. In particular, we select the following countries and years: Bulgaria (2001–2002), Canada (2005–2010–2015), Spain (2002–2003–2009–2010), Finland (2009–2010), France (2010), Hungary (2000–2009–2010), Italy (2002–2003–2009–2010), South Korea (2004–2009), the United Kingdom (2000–2001–2005–2014–2015), and the United States (2000, 2003 to 2018).

We select the commuting episodes of individuals, and analyze the duration of those episodes, together with the use of cars and carpooling. In doing so, we select those episodes coded as travelling to/from work, and sum at the individual level the time (minutes per day) devoted to this activity, representing the variable Commuting. We then compute the average duration (minutes per day) of commuting done by car (code "1" defined as "travel by car" in the variable mtrav of the MTUS). Comparing the average duration of these variables, we compute the percentage of commuting time that is done by car, giving us the variable percentage of total commuting. We then compute the average duration (minutes per day) of commuting by car with someone else (e.g., children, spouse, or other adults), which gives us the variable Carpooling. We then compare these two variables.

Table 1 shows the average values of the variables of interest. To compute the average, we use the survey weights included in the MTUS. We observe that the longest durations of commuting are found in South Korea (31.98 min per day) and France (29.98 min per day), while the shortest are found in Italy (19.46 min per day) and Hungary (20.44 min per day). For these episodes, the lowest percentages of time driving are found in Bulgaria (12.07 percent of the time) and Hungary (29.56 percent of the time), while the highest percentages are found in Canada (78.57 percent of the time) and the United States (87.54 percent of the time). The percentage of time carpooling is low in most cases, with the most being found in Bulgaria (36%). In terms of carpooling, South Korea and the United States show percentages below 10% of total commuting. Thus, in general, carpooling for commuting is a practice that is not common for workers, as less than 25% of the total time from/to work by car is done in the presence of others.

We next explore the role that individual socio-demographic characteristics have on the carpooling behavior of commuters. To that end, we use ordinary least squares (OLS) models to examine the proportion of carpooling done by individuals, on a set of socio-demographic characteristics. In particular, we estimate the following equation, by country:

$$PCarPooling_{gik} = \beta_{0k} + \beta_{1k}S_{ik} + \beta_{2k}F_{ik} + \beta_{3k}L_{ik} + \alpha + \varepsilon_{ik}, \quad (1)$$

where, for each individual "i" and omitting the sub-index "k" that identifies countries, $PCarPooling_i$ represents the proportion of carpooling done by the individual, S_i represents the sociodemographic attributes of "i" (gender, age, education, citizenship), F_i represents household variables (household size, urban status, marital status, single parent, dwelling ownership), L_i represents the labor attributes of "i" (full-time status), and ε_i represents unmeasured factors. Estimates include demographic weights from the survey, and standard errors are robust.

Table 1. Commuting, commuting by car, and carpooling, 2000–2018.

	Commuting	Commuting by Car		Carpooling	
	Average Duration	**Average Duration**	**% of Total Commuting**	**Average Duration**	**% of Commuting by Car**
Bulgaria	29.47	3.56	12.07%	1.30	36.49%
Canada	25.10	19.72	78.57%	3.73	18.91%
Spain	21.96	8.83	40.22%	1.96	22.15%
Finland	24.58	15.07	61.31%	2.44	16.21%
France	29.98	20.83	69.48%	2.75	13.21%
Hungary	20.44	6.04	29.56%	1.83	30.27%
Italy	19.46	14.21	73.01%	2.29	16.15%
South Korea	31.98	15.02	46.96%	1.28	8.53%
The United Kingdom	24.16	15.49	64.11%	3.11	20.09%
The United States	21.97	19.23	87.54%	1.15	5.98%

Note: Sample obtained from the Multinational Time Use Study, including commuting episodes, from Bulgaria (2001–2002), Canada (2005–2010–2015), Spain (2002–2003–2009–2010), Finland (2009–2010), France (2010), Hungary (2000–2009–2010), Italy (2002–2003–2009–2010), South Korea (2004–2009), the United Kingdom (2000–2001–2005–2014–2015), and the United States (2000, 2003 to 2018).

Education is measured in three levels: primary, secondary, and university education. The variable measuring gender is defined as a dummy variable (1 = Male, 0 = Female), as are the citizenship status (1 = citizen; 0 = non-citizen), urban status (1 = urban status, 0 = rural status), marital status (1 = in couple, 0 = not in couple), single parent status (1 = Yes, 0 = No), dwelling ownership (1 = Owned, 0 = Not owned), and full-time work status (1 = full-time; 0 = part-time).

Table 2 shows the results of estimating Equation (1) for the full set of countries. We observe that age is negatively related to carpooling participation in Bulgaria, Canada, Spain, France, and Italy, while being male is negatively related to participation in carpooling in all countries, with the exceptions of Bulgaria (positively related) and Hungary (no relationship). Regarding education, in comparison with workers with low education, higher levels of education are negatively related to participation in carpooling, since the dummies for secondary and/or university education are negative and statistically significant in Canada, Spain, Finland, France, Italy, South Korea, the UK, and the US. Being native born (i.e., citizen) is negatively related to carpooling participation in Canada and the US, but positively related in Spain, Hungary, Italy, South Korea, and the UK. Living in larger households is positively related to carpooling participation in 7 out of 10 countries, and being married is positively related in 8 out of 10 countries. This may indicate the positive effect of carpooling, if the car can be pooled with the spouse/partner. Living in urban areas, in comparison to rural areas, is negatively related to participation in carpooling in Canada, Spain, Finland, and the United States, but positively related in the United Kingdom. Finally, home ownership is negatively related to carpooling participation in Canada, Spain, Hungary, the UK, and the US, and working full-time (vs. part-time) is negatively related to participation in carpooling in Canada, Hungary, Italy, the UK, and the US and positively related in Spain, Finland, and South Korea. Thus, we can conclude that factors such as age, gender, education, being native, and household composition have a limited cross-country and consistent relationship with carpooling participation.

Table 2. Socio-demographic determinants of carpooling.

	Bulgaria	Canada	Spain	Finland	France	Hungary	Italy	South Korea	The United Kingdom	The United States
Age	−0.12 ***	−0.16 ***	−0.07 ***	−0.03	−0.09 ***	0.07	−0.09 ***	0.00	−0.02	−0.01
	(0.05)	(0.02)	(0.01)	(0.06)	(0.03)	(0.05)	(0.02)	(0.01)	(0.02)	(0.01)
Male	3.44 ***	−3.31 ***	−0.69 **	−4.15 ***	−2.77 ***	1.21	−1.38 ***	−1.14 ***	−1.71 ***	−3.43 ***
	(1.08)	(0.50)	(0.30)	(1.22)	(0.49)	(0.93)	(0.35)	(0.19)	(0.54)	(0.15)
Secondary educ.	2.09	−4.78 ***	−1.45 ***	−2.72	−2.31 ***	−1.46	−2.64 ***	−1.04 ***	−1.78 **	0.15
	(1.43)	(1.06)	(0.42)	(2.27)	(0.74)	(1.07)	(0.47)	(0.26)	(0.84)	(0.35)
University educ.	1.60	−4.17 ***	−0.37	−5.51 **	−1.58 *	0.32	−4.32 ***	−1.54 ***	−4.96 ***	−0.52
	(1.51)	(0.93)	(0.44)	(2.29)	(0.81)	(1.25)	(0.57)	(0.29)	(0.82)	(0.33)
Citizen	-	−2.62 *	1.89 ***	-	−1.07	10.18 ***	7.58 ***	9.74 ***	2.49 **	−1.99 ***
	-	(1.48)	(0.69)	-	(1.46)	(1.20)	(0.37)	(0.19)	(0.98)	(0.32)
Household size	0.11	0.86 ***	0.39 ***	0.02	1.55 ***	1.26 **	1.29 ***	0.09	0.44 **	0.81 ***
	(0.33)	(0.24)	(0.11)	(0.48)	(0.26)	(0.50)	(0.15)	(0.08)	(0.20)	(0.07)
Urban status	-	−1.90 ***	−2.25 ***	−4.23 **	-	0.01	0.50	−0.21	5.09 ***	−0.97 ***
	-	(0.59)	(0.31)	(1.89)	-	(1.03)	(0.33)	(0.31)	(0.53)	(0.21)
Marital Status	−1.03	5.33 ***	2.02 ***	4.95 ***	2.57 ***	-	3.84 ***	1.23 ***	5.34 ***	4.03 ***
	(1.23)	(0.67)	(0.33)	(1.67)	(0.74)	-	(0.39)	(0.22)	(0.61)	(0.20)
Single Parent	2.28	1.87 *	−0.52	−3.34	5.75 ***	-	−0.36	−0.48	−0.78	1.31 ***
	(3.15)	(1.02)	(0.75)	(2.54)	(1.67)	-	(1.24)	(0.86)	(1.24)	(0.28)
Home ownership	−1.78	−1.69 ***	−3.98 ***	-	−0.18	−4.20 **	0.31	0.30*	−1.68 ***	−0.70 ***
	(2.48)	(0.63)	(0.31)	-	(0.56)	(1.69)	(0.37)	(0.18)	(0.64)	(0.18)
Full-time worker	−8.34	−2.55 ***	0.95 **	4.00 ***	−0.68	−3.88 ***	−1.61 ***	1.04 ***	−1.32**	−1.78 ***
	(5.27)	(0.98)	(0.47)	(1.48)	(0.57)	(1.37)	(0.38)	(0.33)	(0.67)	(0.26)
Constant	14.88 **	27.24 ***	11.32 ***	12.52 ***	11.37 ***	−3.09	10.34 ***	−0.63	10.18 ***	7.03 ***
	(6.11)	(2.31)	(1.11)	(4.41)	(2.01)	(3.71)	(1.09)	(0.68)	(1.77)	(0.58)
Observations	1,535	21,106	46,284	2,782	14,652	3,659	55,127	70,878	19,844	102,848
R-squared	0.026	0.015	0.008	0.017	0.015	0.01	0.021	0.057	0.019	0.023

Notes: Robust standard errors in parentheses. Sample obtained from the Multinational Time Use Study, including commuting episodes, from Bulgaria (2001–2002), Canada (2005–2010–2015), Spain (2002–2003–2009–2010), Finland (2009–2010), France (2010), Hungary (2000–2009–2010), Italy (2002–2003–2009–2010), South Korea (2004–2009), the United Kingdom (2000–2001–2005–2014–2015), and the United States (2000, 2003 to 2018). * Significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level.

4. Conclusions and Future Lines of Research

This paper first surveys recent results derived from the relationship between sustainable commuting and certain social disciplines. The analysis of subjective determinants uses the theory of planned behavior to conclude that individual intentions have a direct impact on SC, and that residents who live in areas of high population density are more likely to adopt SC. College education is usually associated with a greater propensity to use non-motorized modes within the metropolitan area. Additionally, car ownership, race, gender, and neighborhood features also affect the use of non-motorized alternatives. Studies reveal that physical environmental factors (e.g., favorable climate) are more important for active commuting participation in higher-income neighborhoods. With respect to implications for the mental health of individuals, the preponderance of evidence shows that, compared to driving, well-being is greater for those using active travel or public transport, with this positive effect being considered in cost-benefit assessments of public interventions seeking to promote SC.

Associations with education level of school/university SC show negative correlates of active commuting, including parental perceptions of few other children in the neighborhood, no lights or crossings for their child to use, and an objectively assessed busy road barrier en route to school. Additionally, students are less likely to actively commute to school if they are girls, are in grade 12, smoke daily, are low-to-moderate in physical activity, or attend a rural school. With respect to university students, evidence indicates that reducing actual and perceived travel time by bus and bicycle would have the greatest impact on commuting patterns.

Studies show that the role of employers, in terms of the commuting modes of their employees, is that large firms are more likely to implement green commuter plans in the short term, with these results providing helpful information for transportation and planning policy-makers to encourage green commuting and reduce transportation emissions.

This paper provides empirical evidence of carpooling for commuting in several countries, documenting that it is not a common practice for workers. Among the reasons for this low participation in carpooling, it has been shown that demographic characteristics are limited in explaining carpooling behavior, in part because individuals have diffused and non-predictable travel patterns [63,64]. Other factors, such as comfort, safety, socializing, and external third-party interventions are more important in this context. Regarding these factors, socializing is the primary reason for carpooling, and in the current context of the COVID-19 pandemic and the need to social distance and wear a mask, carpooling may be at risk of decreasing in importance [65,66]. Many initiatives have been launched concerning how to carpool safely during the pandemic, with a focus on carpooling as a way to avoid crowded modes of transport as it is a lower-density commuting mode compared to public transit. For municipal authorities, the development of high-occupancy-vehicle (HOV) lanes can facilitate and increase carpooling, as well as highlighting the economic and environmental benefits to potential users, along with the creation of closed carpooling platforms. Other interventions in the context of sustainable transport, not related to carpooling, include the creation of flexible transport services offering dedicated solutions for special groups, in parallel with the conventional public transport network, in which mass coverage and the ability to function as a full transport mode play a crucial role.

Additionally, the paper explores the role of the socio-demographic characteristics of individuals in carpooling behavior, using ordinary least squares (OLS) models. Results indicate that age, gender, education, being native, and household composition may have cross-country consistent relationships with carpooling participation.

In the future, the research should first address the limitations of the existing literature with respect to data and models. The bulk of the work has used, as the best option, only cross-sectional data, with some papers employing a very small number of observations (fewer than 100). In these circumstances, the lack of both longitudinal and register data makes it difficult to derive causal effects, with only correlations being possible. This is a disadvantage of the recent literature, and future work should attempt to overcome this important limitation. Following this argument, the availability of more attractive data would allow the use of more sophisticated econometric models, which, in turn, would provide evidence more akin to actual situations. In sum, the use of richer data and more rigorous quantitative methods should be encouraged in the effort to determine relevant conclusions.

Another future avenue for work in the field of SC is the production of cross-cultural papers. The great majority of recent papers only relate to a single country, or region within a country, and cross-country analysis could provide very rich, comparative evidence in terms of policy implications. It is already clear that social norms have a very significant impact on individual behaviors.

A recent line of research has focused on the sharing economy, which allows travelers to request a private driver and vehicle, access a car, bicycle, or scooter for a short trip, ride a private shuttle on a crowd-sourced route, or on-demand, and have groceries or take-out food delivered in someone's personal vehicle. The particular cases of shared mobility—car-sharing, scooter-sharing, and bike-sharing—have positive impacts with respect to cost savings and convenience, reduced personal vehicle ownership, and vehicle miles traveled (VMT)/vehicle kilometers traveled (VKT), which can translate to greenhouse gas (GHG) emission reductions. Thus, car-sharing may represent a sustainable strategy for the development of urban areas and represents a promising line for future research [67].

Finally, the future sustainable society, and, specifically, green transport, needs to be built on the basis of industrial ecology, with the success of environmental policy being founded on cooperation between public and private actors. In this way, the recent literature has developed an innovative tool, the Industrial Environmental Sustainability Index, which verifies the efficiency of industrial sustainability policy in every region and country [68].

A range of attractive avenues of research are open for development by social scientists. The use of richer data and superior econometric methods are crucial strategies in order to approach a future that will need to provide valid recommendations to policy-makers when deciding policies that have direct implications for sustainable mobility.

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