Modelling car-related socio-economic stress among French households : choice of indicators, contribution of energy costs, and impact of public transportation alternatives

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INTRODUCTIVE SECTION

Transport-related social issues and energy costs

- Transport disadvantage and car dependence :

  - ✓ Transport-related social concerns were originally focused on travel deprivation and the resulting social disadvantage, given the contribution of motility to access employment, consumption and social interactions (e.g., Lucas, 2012). This gave birth to the concept of transport poverty (e.g., Lucas et al., 2016 ; Mattioli et al., 2017), inspired from Sen's definition of poverty (1992), designing household's inability to satisfy their essential transport needs at reasonable cost with respect to their resources. With this definition, poverty is a (lack of) potential, implying that it can manifest under the complementary forms of financial stress and deprivation, depending on trade-offs made by households.

  - ✓ In particular, with the car becoming necessary to achieve most of daily travel needs (Lucas, 2010 ; Sovacool et al., 2012), car deprivation became a cause for transport disadvantage (e.g., Church et al., 2000 ; Dodson et al., 2006 ; Ahern et al., 2016 ; Hine et Mitchell, 2017 Xiao et al., 2018) and social exclusion (e.g., Cervero, 2002 ; Pucher et Renne, 2003 ; Orfeuil, 2004 ; Cornut and Madre, 2017). This risk is particularly strong among car-less households (e.g., Cornut and Madre, 2017 ; Zhao and Bai, 2019), especially if located in car-dependent areas.

  - ✓ With rising energy prices, energy-related social issues have also been a growing concern, either in the housing or transport sector, giving birth to the notions of fuel poverty (Boardman, 1991 ; Hills, 2012), that was originally developed in the housing field, and oil vulnerability (Dodson et Sipe, 2007; Nicolas et al., 2012), which emerged in the transport sector.

Transport-related social issues and energy costs

- Fuel poverty:
  - ✓ Various indicators were built to characterize energy poverty (Moore, 2012 ; Verry et al., 2017), leading to contrasting results (Lovelace et Philips, 2014 ; Ricci et Legendre, 2015 ; Berry, 2019) : the ratio indicator, corresponding to the energy budget share (e.g., Bennet et al., 2002 ; ONPE, 2015) ; the available income, after deduction of real (or necessary) housing- and/or transport-related energy expenditures (or costs) (e.g., DWP, 2010) ; the LIHC indicator (Hills, 2012 ; Mayer et al., 2014).
- Fuel vulnerability:
  - ✓ The notion of fuel vulnerability refers to socio-economic risks resulting from financial stress caused by disproportionate energy costs (Coulombel and Leurent, 2013 ; Demoli, 2015; Curl et al., 2018), depending on economic scenarios and household adaptive capacities, notably through the existence of efficient transport alternatives (Mattioli et al., 2019).
  - ✓ This risk is strong among low-income households living and/or working in low-density areas (Pochet and Nicolas, 2007 ; Dodson and Sipe, 2007; Belton-Chevallier et al., 2018). It is aggravated by the regressivity of motoring costs (Poterba, 2017 ; Chatterton et al., 2018), resulting from the eviction of low-income households from inner suburbs caused by tensions on housing markets (Wetzstein, 2017 ; Cao et Hickman, 2018), that was likely encouraged by prudential measures (Coulombel, 2018), not accounting for the dependence of transport costs on location effects (Viddyatama et al., 2013; CEREMA, 2016).
  - ✓ The emergence of this concept occurred in a context of fuel shortages (Leung et al., 2017, Leung et al., 2018 a,b) and rising fuel prices (Hivert et Madre, 2012). Besides, new taxation measures such as the carbon tax increase the regressivity of car travel costs, raising equity concerns (Mathur et Morris, 2014 ; Berry, 2019) and arousing popular protests (e.g., Leung et al., 2017).

An integrated approach to car-related socio-economic stress

- Complementary forms of car-related socio-economic stress:
  - ✓ Financial stress and car travel restrictions can be considered as complementary forms of car-related socio-economic stress, depending on trade-offs between controlling transport budgets and satisfying travel needs. This concept allows unifying different notions from the social literature on transport through a common framework : considering only indicators or budgetary stress ignores households out of budgetary stress but undergoing travel restrictions (Nicolas et al., 2012), such as for those remaining car-less ; considering only those submitted to travel restrictions ignores some of those made economically vulnerable by excessive transport costs. This situation concerns a fraction of the middle class, but also the « working poor » located in low-density areas, which might be « forced » to own cars, despite low income (Mattioli and Colleoni, 2016 ; Curl et al., 2018 ; Walks, 2018).
- Degrees of car-related socio-economic stress :
  - ✓ Degrees of restrictions : no restrictions, moderate restrictions, deprivation (or social vulnerability).
  - ✓ Degrees of budgetary stress : budgetary constraint, (economic) vulnerability, precarity/poverty.
- A model of car travel needs :
  - ✓ Car travel restrictions are only meaningful in relation to car travel needs, that are difficult to model at the household level because of many unobserved factors influencing them and the lack of appropriate data, notably allowing to disentangle essential from non-essential needs (Berry et al., 2016). As a result, most studies focus on budgetary indicators, that are easier to calculate. Budgetary stress is unobserved either, but can be revealed through the frequency of car travel restrictions. This first requires the estimation of car travel needs, which therefore appear as the cornerstone in the assessment of car-related socio-economic stress. In order to estimate the frequency and severeness of car travel restrictions, one does not need to get a perfect knowledge of household needs but only to simulate their distribution.

How to account for energy costs ?

- Poverty and vulnerability can be defined as different degrees of socio-economic stress : vulnerable households can be defined as those at greater risk of falling into poverty under deteriorated economic conditions and/or higher costs (Mayer et al., 2014). As a result, they tend to concern different social groups: fuel poverty is largely redundant with monetary poverty (Palmer et al., 2008 ; Lucas, 2012), while fuel vulnerability is rather found among the lower middle class. However, both can be integrated in the « low-income » category, corresponding to the lower half of the income distribution (Hills, 2012).
- In order to measure budgetary stress, the remaining income is a better indicator than fuel budget shares, which can be interpreted differently according to income groups. Among high-income groups, high fuel budget shares might reflect unbalanced budgets without strong budgetary pressure.
- Deducing required rather than real energy expenditures is a more adequate measure of budgetary stress preceding car travel restrictions (e.g., Healy et Clinch, 2002 ; Hills, 2012). It can be calculated once car travel needs have been estimated. From there, the contribution of energy costs to financial stress can be assessed, by comparing financial stress before and after the deduction of energy costs. By accounting for travel behavior adjustment to fuel prices, the model will also allow estimating their impact on car travel restrictions, by comparing simulated car travel to estimated car travel needs, before and after travel behavior adjustment to energy costs.

Detailed methodology

Datasets

- The French Car Fleet Surveys :
  - ✓ A panel survey on the French vehicle fleet, conducted over a sample of 10 000 households, representative of the French population, resulting in roughly 6 - 7 000 volunteer respondents. Households are described according to their structure (household type, number of adults and children…), socio-economic characteristics (income, age and sex of the household head and partner, working status of adults, etc.) and residential location (by municipality of residence).
  - ✓ This database also provides information on car ownership, annual car mileage and vehicle fuel consumptions per mile, allowing to calculate fuel expenditures associated with car travel needs, by combining these data with annual fuel prices. Main fuel types are diesel, petrol, LPG, electric and hybrid engine types.
  - ✓ Only the waves 1994-2017 will be used in this study, corresponding to our period of data availability.
- The French Base of CEREMA-Certified Household Travel Surveys (BU EMC2) :
  - ✓ More than 200 local household travel surveys, including different survey types : Household Travel Surveys (HTS) for large cities, Travel Surveys for Average Cities (TSAC), and Travel Surveys for Large Territories (TSLT). All rely on a standardized methodology, focusing on travel habits of a typical weekday, including all transportation modes and trip motives. From 2009, all new surveys were aggregated into a single database, the BU EMC2, which is completed every year, resulting in a new “vintage”.
  - ✓ All household members aged more than six are questioned about their daily trips realized the day before the survey. The dataset includes household-level (family composition, residential location, occupational status, number of vehicles) and individual-level information : socio-demographic attributes, motility, and travel habits (trip frequencies and travel distances by mode).

The model of car travel (needs)

➢ <u>The modelling work relies on the following principles :</u>

- The BU EMC2 can be used to calibrate a model of car travel (needs) for essential motives, by making the distinction between essential - commuting, shopping, or visits to family and friends - and « non-essential » motives (holiday, leisure), by reference to Sen's definition of poverty.

- In order to address the large number of zeros, one resorts to a sequential approach, by jointly modelling the probability of using the car during a given day, and the expected car mileage, if any.

- A distinction is made between variables shaping car travel needs (family composition, residential location, working status…), and those hindering their satisfaction (driving license restrictions, parking difficulties at workplace, fuel prices…). Car travel needs are defined as the theroretical car mileage in the absence of these limitations. Two kinds of essential motives are separated : commuting (for work/studies), and other essential trips.

- The model is estimated through maximum likelihood for a given weekday, before extrapolating the results to the whole year through a Monte-Carlo simulation, relying on French Car Fleet Surveys.

The model of car travel (needs)

➢ Model specification :

✓ **A Tobit or sample selection model** including two levels, for the probability of using the car during (level I), and the expected car mileage (level II) :

$$h_i^* = X_{1i}\beta_1 + \epsilon_{1i}, \epsilon_{1i} \sim N(0,1)$$

$$Log\ (y_i^*) = X_{2i}\beta_2 + \epsilon_{2i}, \epsilon_{2i} \sim N(0, \sigma_2^2)$$

✓ **From utilities to events** :

$$h_i^* \leq 0 \rightarrow h_i = 0, y_i = 0$$

$$h_i^* > 0 \rightarrow h_i = 1, y_i = y_i^*$$

✓ **Extrapolation through Monte-Carlo simulation (K repeated draws):**

$$P(h_{ik} = 1) = \phi(X_{1ik}\beta_1)$$

$$E(logy_{ik}|h_{ik} = 1) = X_{2ik}\beta_2 + \sigma_{12}\,\lambda_i(X_{1ik}\beta_1), \text{ with } \lambda_i(X_{1ik}\beta_1) = {\varphi(X_{1i}k\beta_1)}\Big/{\phi(X_{1ik}\beta_1)}$$

$$\hat{Y}_i = \sum_1^K \hat{y}_{ik}$$

✓ K depends on essential motives : 220 draws (44 weeks) for commuting trips, 240 draws (48 weeks) for other essential trips * 1.2 (1 travelling day per week-end).

The model of car travel (needs)

- As the BU EMC2 includes household characteristics for all members aged more than six, more variables can be included, by accounting for the characteristics of the partner :
  - ✓ Family composition : existence of a partner, number of children < 6 years, number of other working adults (> 15 years).
  - ✓ Socio-demographic attributes of the household head and the partner : generation, sex, working status, level of qualification, socio-professional group.
  - ✓ Built environnement attributes : residential zoning type, density of population, commuting distance.
  - ✓ Motility : transit cards, driving license holding, parking availability at workplace.
  - ✓ Economic variables : fuel prices.
  - ✓ Instruments in the level I model (probability of using the car) : generation effects and intra-week variability.

Indicators of car-related socio-economic stress

1 Car travel restriction thresholds :

- ✓ Based on ratio 1 between total car travel and car travel needs for essential motives, defined as the satisfaction rate of car travel needs :
  - Lack of restrictions: if total car travel is higher than car travel needs for essential motives.
  - Moderate restrictions : if total car travel is lower than car travel needs for essential motives.
  - Deprivation : if total car travel is lower than half the median of the distribution of ratio 1.
- ✓ Based on ratio 2 between simulated car travel for essential motives and car travel needs for essential motives, defined as the satisfaction rate of essential car travel needs. Restriction thresholds are then defined by using the same quantiles of the distribution than for ratio 1.

2 Degrees of budgetary stress, based on restriction frequencies by income group:

- *Budget precarity*: Income lower than the relative poverty threshold, defined as half the median of the income distribution in 2006.
- *Budget vulnerability*: Available income below which the deprivation frequency exceeds the average.
- *Budgetary constraint*: Available income below which the restriction frequency starts increasing in relation to income.
- *Lack of budgetary constraint*: Available income higher than the threshold of budgetary constraint.

3 Categories of car-related socio-economic stress :

- Situations of pure budgetary stress (poverty or financial vulnerability), with no car travel deprivation.
- Situations of budgetary stress completed by car travel deprivation.
- Car travel deprivation in the absence of budgetary stress. Deprivation may then be caused by non-monetary drivers.

Indicators of car-related socio-economic stress

4 Degrees of public transportation adequacy :

- *Good adequacy*: public transportation is considered well-suited to travel needs, if all adults regularly use it (at least once a week).
- *Partial adequacy*: public transportation is considered partially appropriate, if at least one adult regularly uses it, or if no adult resorts to it, but service exists less than five minutes by walk, and serving the reference person's workplace, if working.
- *Weak or uncertain adequacy*: public transportation is considered inappropriate, or of uncertain adequacy, if no adult member regularly uses it, and there is no service close to home by walk, or it does not serve the reference person's workplace, if working.

5 Travel restrictions :

✓ Restrictions are diminished by one degree in presence of adequate PT (e.g. Moderate car travel restrictions * Adequate PT = Lack of travel restrictions).

6 Categories of travel-related socio-economic stress :

✓ Situations of pure budgetary stress, with no travel restrictions.

✓ Situations of budgetary stress completed by travel restrictions.

✓ Travel restrictions in the absence of budgetary stress.

Results

Model estimation results

Exogenous variables	Modalities	Commuting trips		Other necessary trips	
		Level I	Level II	Level I	Level II
Intercept		-	+ 3,761	-	+ 3,481
Generation (birthdate)	1920-30	+ 0,204	-	- 0,048	-
	1930-40	+ 0,155	-	+ 0,212	-
	1940-50	+ 0,371	-	+ 0,441	-
	1950-60	+ 0,527	-	+ 0,467	-
	1960-70	+ 0,603	-	+ 0,5	-
	1970-80	+ 0,624	-	+ 0,518	-
	1980-90	+ 0,598	-	+ 0,503	-
	1990-2000	+ 0,307	-	+ 0,429	-
Type of residential area	ISUA200+	+ 0,061	+ 0,102	+ 0,128	+ 0,076
	OSAU200+	+ 0,099	+ 0,221	+ 0,144	+ 0,123
	CCUA200-	- 0,101	- 0,124	- 0,013	- 0,183
	ISUA200-	- 0,069	+ 0,033	+ 0,106	- 0,112
	OSUA200-	- 0,061	- 0,037	- 0,015	- 0,065
	Rural space	- 0,199	+ 0,182	- 0,128	+ 0,145
Density	Density/1000	- 0,056	-	- 0,054	-
	Log-density	-	- 0,075	-	- 0,07
Sex of RP	Woman	+ 0,032	- 0,148	+ 0,068	- 0,049
Occupation status of RP	Diverse non-working	- 0,982	- 0,317	+ 0,089	+ 0,095
	Retired	- 1,186	- 0,321	+ 0,28	+ 0,012
	Student	- 0,439	- 0,534	- 0,686	- 0,029
Level of qualification of RP	Lower than baccalaureate	- 0,066	- 0,005	+ 0,054	- 0,045
	Undergraduate	+ 0,13	+ 0,095	+ 0,089	+ 0,028
RP's socio-professional group	Farmer	+ 0,409	+ 0,117	+ 0,099	+ 0,033
	Workmen, service staff	+ 0,34	- 0,04	- 0,085	+ 0,008
	Employees	+ 0,24	- 0,101	- 0,074	+ 0,023
	Craftsmen, shopkeepers	+ 0,478	+ 0,077	+ 0,126	+ 0,055
	Intermediate professions	+ 0,34	+ 0,04	+ 0,006	+ 0,041
	Executives	+ 0,377	- 0,008	+ 0,03	+ 0,03
RP unlicensed		- 0,725	- 0,191	- 0,779	+ 0,051
Parking difficulties at RP's workplace		- 0,208	- 0,062	-	-

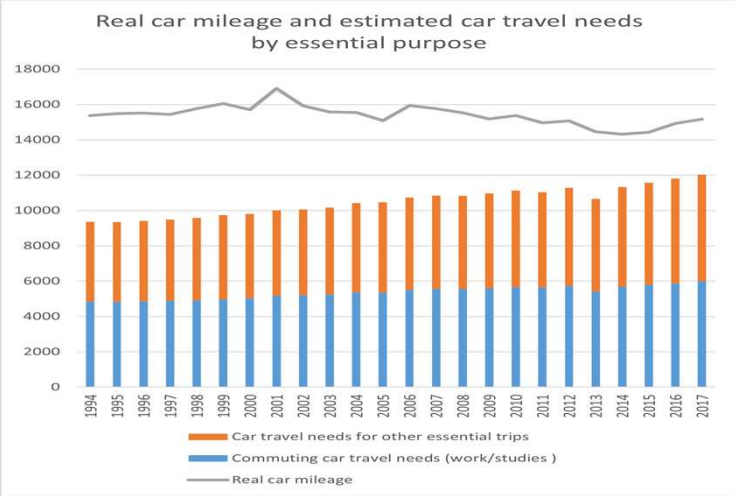
- **Level I (probability of using the car)** :
  - ✓ The probability of using the car increases across cohorts until those born in the 1970's, and falls down among those born during the 1990's.
  - ✓ It generally increases with distance to city centre, and decreases with density. It rises with the size of cities, possibly in relation to the geographical extension of living areas.
  - ✓ It increases with the number of children and other working adults.
  - ✓ The existence of a partner positively affects the probability of using the car for working trips, but has a negative effect for other essential trips.
  - ✓ Inactivity causes a strong reduction in car commuting, partially offset by an increase in car use for other essential trips.
  - ✓ The level of qualification has little influence, apart for the ungraduated, who display a slightly lower probability of using the car.
  - ✓ Belonging to an upper socio-professional group is associated with higher car commuting. Being a freelance worker has opposite influence between the reference person and its partner.
  - ✓ Car use is less likely on Monday and Wednesday for commuting, and more likely on Wednesday and Friday for other essential trips.
  - ✓ Driving license restrictions, parking difficulties at workplace, higher fuel prices, reduce the probability of using the car.

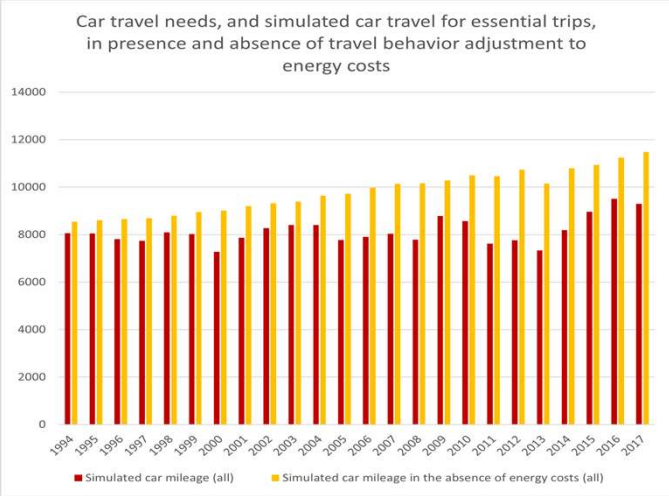
Model estimation results

Exogenous variables	Modalities	Commuting trips		Other necessary trips	
		Level I	Level II	Level I	Level II
Existence of a partner		+ 0,334	+ 0,08	- 0,249	- 0,082
Occupation status of partner	Diverse non-working	- 0,593	- 0,121	+ 0,092	+ 0,125
	Retired	- 0,846	- 0,104	+ 0,087	+ 0,045
	Student	- 0,51	- 0,168	- 0,136	+ 0,017
Level of qualification of partner	Lower than baccalaureate	- 0,032	- 0,089	- 0,124	-
	Undergraduate	+ 0,032	- 0,005	- 0,026	+ 0,004
Partner's socio-professional group	Farmer	- 0,296	- 0,422	+ 0,031	+ 0,051
	Workmen, service staff	+ 0,078	- 0,028	+ 0,152	+ 0,09
	Employees	+ 0,017	- 0,11	+ 0,131	+ 0,054
	Craftsmen, shopkeepers	- 0,111	- 0,118	+ 0,087	+ 0,045
	Intermediate professions	+ 0,127	+ 0,014	+ 0,211	+ 0,119
	Executives	+ 0,149	+ 0,032	+ 0,122	+ 0,108
Partner unlicensed		- 0,241	- 0,157	- 0,339	- 0,031
Parking difficulties at partner's workplace		- 0,002	- 0,062	-	-
Number of children less than 15	Number of children	+ 0,099	-	+ 0,195	-
	Log (Number of children)	-	- 0,094	-	- 0,038
Number of other working adults (NOWA)	NOWA	+ 0,445	-	+ 0,209	-
	Log (NOWA)	-	+ 0,232	-	+ 0,205
Fuel price	Fuel price	- 0,541	-	- 0,291	-
	Log (Fuel price)	-	- 0,525	-	- 0,354
Weekday	Monday	- 0,092	-	- 0,059	-
	Wednesday	- 0,127	-	+ 0,049	-
	Thursday	- 0,031	-	+ 0,007	-
	Friday	- 0,025	-	+ 0,111	-
Correlation coefficient between levels I and II		- 0,055		- 0,395	

- **<u>Level II (Car mileage among households using the car) :</u>**
  - ✓ Daily car mileage increases from core cities to outer suburbs, with city size, and decreases with density.
  - ✓ More frequent but shorter trips if the reference person is a woman, and with the number of children.
  - ✓ The existence of a partner and other working adults raise both commuting trip frequencies and travelled distances, while negatively affecting the same indicators for other essential motives.
  - ✓ Inactivity results in lowering commuting trip frequencies and travelled distances, while having the opposite effects on other essential trips.
  - ✓ The level of qualification has limited influence, apart for the ungraduated, who travel a slightly lower distance on average.
  - ✓ The partner belonging to an upper socio-professional group is associated with a higher car mileage for non-commuting essential trips.
  - ✓ Self-employment has opposite effects for the reference person and the partner.
  - ✓ Both trip frequencies and travelled distances are negatively affected by limitations to car use.
  - ✓ Car use frequencies and travelled distances are negatively correlated, revealing variable thresholds of car use, depending on travel preferences.

Rising travel needs and adjustment to energy costs





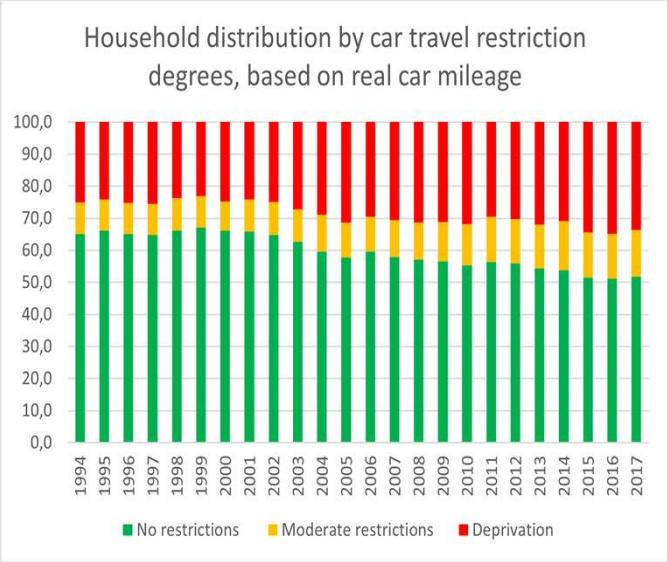
- ✓ The average car mileage per household can be estimated at 16 000 km, and the required car mileage for essential motives above 10 000 km, distributed by half between commuting and other essential motives, resulting in the average satisfaction rate of car travel needs of 156 %.
- ✓ Car travel needs have increased over time, from 9 350 km in 1994 to 12 000 km in 2017, i.e., + 28,6 %, while the average car mileage per household tends to remain stationary. As a result, car use gradually restrains to the satisfaction of essential needs, with the average satisfaction rate - average satisfaction rate of essential car travel needs - households satisfy three quarters of their essential car travel needs on average.

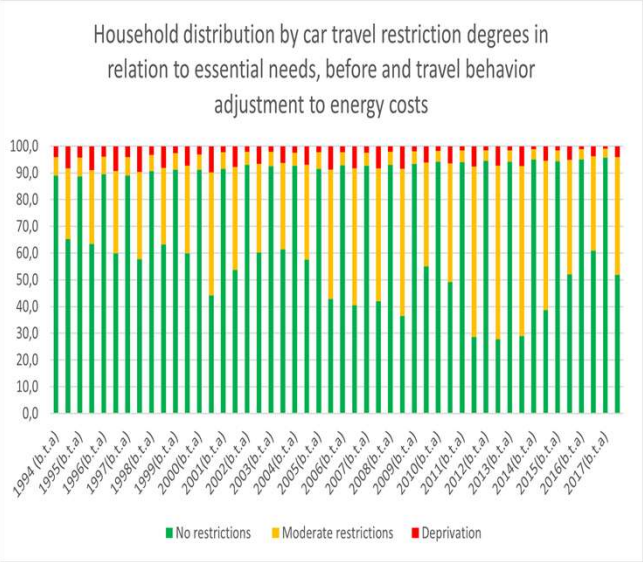
- ✓ In the absence of behavior adjustment to energy costs, satisfaction rates would reach 88,7 and 99,2 %, respectively for commuting and other essential needs. Car travel would follow the evolution of car travel needs.
- ✓ However, when accounting for travel behavior adjustment, simulated car travel is stationary. Adjustment to energy costs can therefore explain the stabilization of car travel, despite growing car travel needs, resulting in a growing gap between simulated car travel for essential motives and essential car travel needs.

Car travel restriction thresholds

- ✓ With a median satisfaction rate of car travel needs estimated at 120 %, one can set the car travel deprivation threshold at 60 %, using ratio 1, leading to set two car travel restriction degrees :
    - *Moderate restriction*, if total car travel stands between 60 and 100 % of car travel needs for essential motives.
    - *Deprivation*, if it is lower than 60 % of car travel needs for essential motives.
- ✓ Using the 2nd ratio, the deprivation threshold can be estimated at 38 %, and the moderate restriction threshold at 71,4 %, using the 40th quantile of the distribution of ratio 2, leading to the corresponding restriction degrees:
    - *Moderate restriction,* if simulated car travel for essential motives stands between 38 and 71,4 % of car travel needs for essential motives.
    - *Deprivation,* if it is lower than 38 % of car travel needs for essential motives.

Car travel restrictions

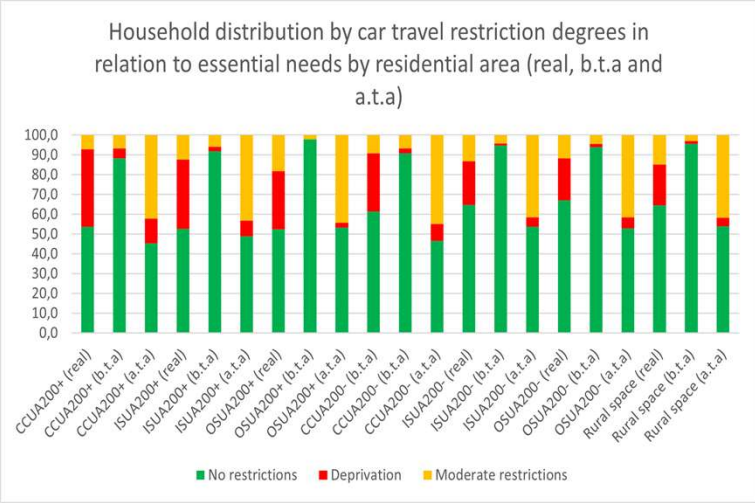


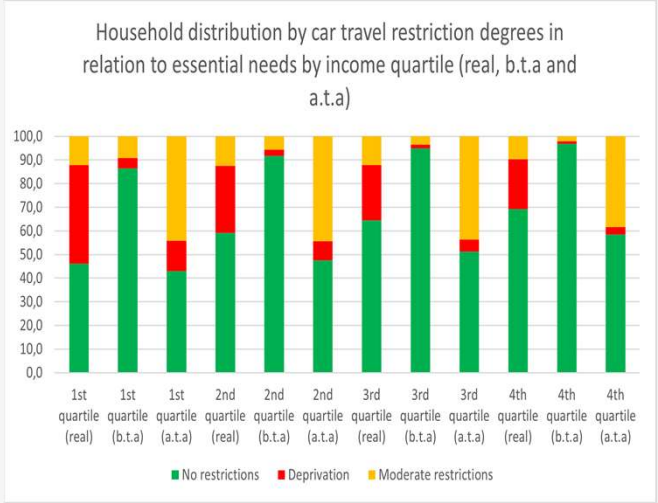


- ✓ With these thresholds, 40,3 % households undergo car travel restrictions, among which 28,7 % experience deprivation, and 11,6 % moderate restrictions.
- ✓ Restriction rates have increased over time, from 34,9 to 48,2 % between 1994 and 2017, and deprivation from 9,7 to 14,5 %.
- ✓ It can be explained by divergent trajectories between real car travel and car travel needs, as travel behavior adjustment to rising fuel prices and to the slowdown in income growth led to the stabilization of car travel, despite rising car travel needs.

- ✓ Car travel restrictions would concern less than 10 % households in the absence of energy costs, and would be diminishing over time.
- ✓ Because of behavior adjustment, this proportion is much stronger, and is increasing over time: car travel restrictions increase from 30 % to 50 % between 1994 and 2017; as a result, the contribution of energy costs to car travel restrictions is rising.
- ✓ Most households only experience moderate restrictions, driven by the goal of stabilizing energy budget shares, rather than by budgetary stress. Deprivation is limited to a smaller fraction of households, reaching less than 10 %, which tends to decrease over time, thanks to a rising income.

Car travel restrictions

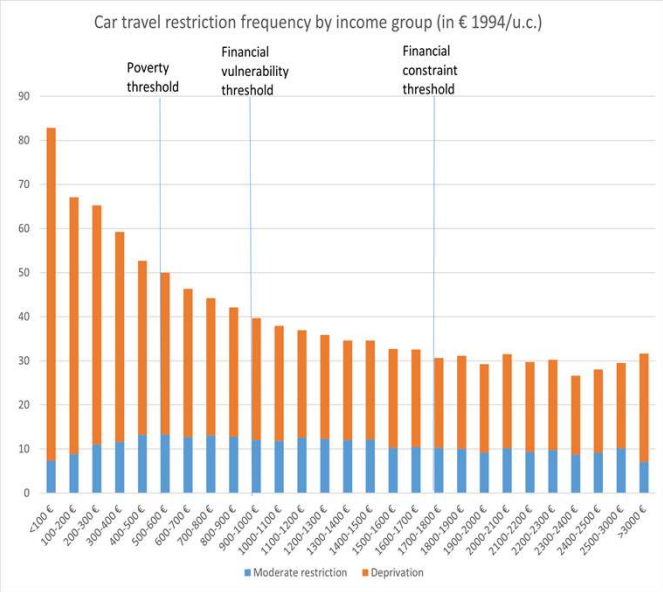


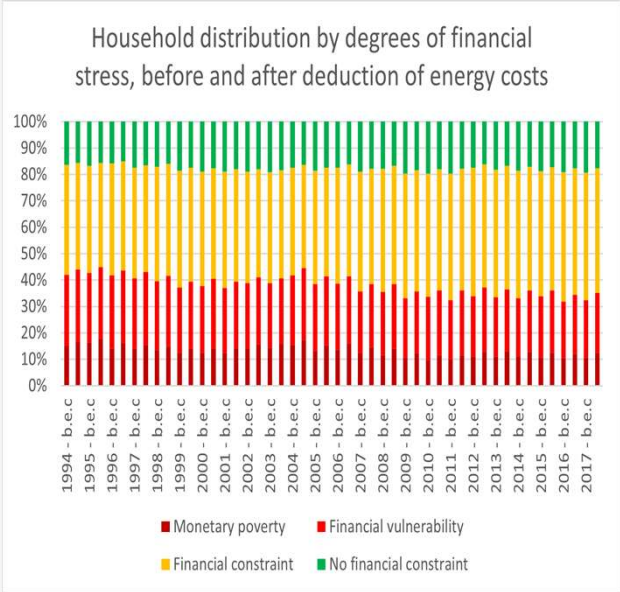


- The frequency of car travel restrictions does not strongly depend on distance to city centre in large urban areas, but depends on it in small urban areas. It might be explained by the PT heterogeneity, allowing residents of large cities to consent to car travel restrictions, while this capability is restricted to central locations in smaller urban areas.
- Car travel deprivation reaches 40 % households in the 1st income quartile, and 30 % in the 2nd quartile; 20 % are concerned in the upper half of the distribution. By contrast, moderate restriction is independent from income, concerning a little more than 10 % households.

- Adjustment to energy costs strongly raises the frequency of moderate car travel restrictions in all areas (+ 40 points). Deprivation becomes more frequent, with the larger impact in central cities of large urban areas (+ 7 points). In absolute terms, the reduction in car mileage is higher in low-density areas : - 2 800 km in outer suburbs of large cities, vs. - 1200 km in central cities of large urban areas.
- The contribution of energy costs to moderate restrictions is independent from income (+ 35 to + 40 points). The impact on deprivation is more income-specific, from + 9 to + 2.5 points between the lowest and the highest income quartiles.

Financial stress by degrees

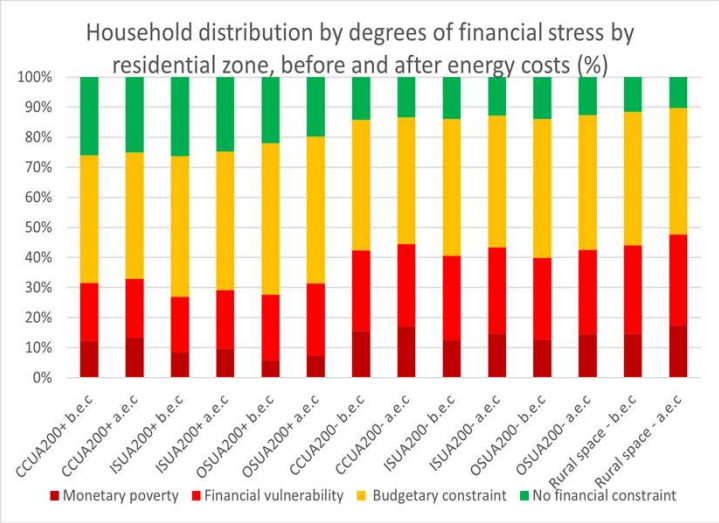


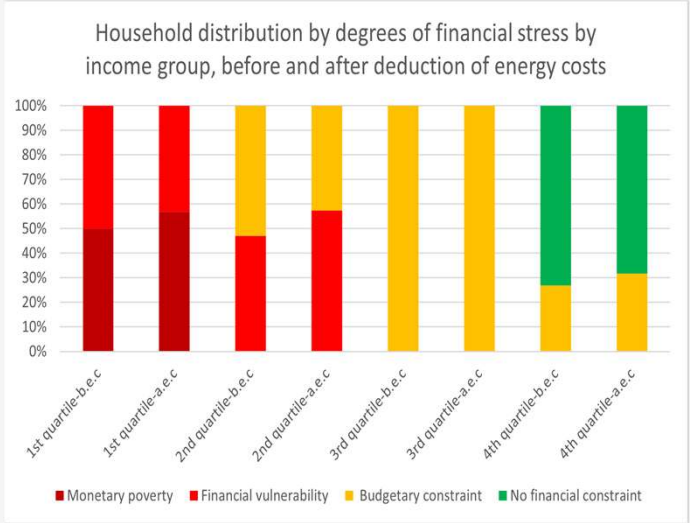


- Degrees of financial stress are revealed through the frequency of car travel restrictions depending on income, which falls down from 83 % under 1000 € 1994/month*c.u., to 30 % above 1700 €. An irreducible proportion of households is undergoing car travel restrictions, caused by non-monetary constraints. This variability is caused by deprivation, which is more income-specific, while moderate restriction is almost independent from income.

- Degrees of financial stress can be defined by visual observation or by using quantitative criteria :
  - Financial precarity : < 525 €
  - Budget vulnerability : 525-900 €
  - Budget constraint : 900-1700 €
  - No budget constraint : > 1700 €
- The proportion of households under financial stress has decreased, while more households undergo light budgetary constraints, without being vulnerable.
- The impact of energy costs is moderate on average. The most significant effect is on poverty (+ 1,5 to +2,5 points), vs. + 0,5 to +2 points for financial vulnerability. However, it is increasing over time, because of rising car travel needs. The main outcome of energy costs is to spread and intensify budgetary stress among budget-constrained households.

Financial stress by degrees

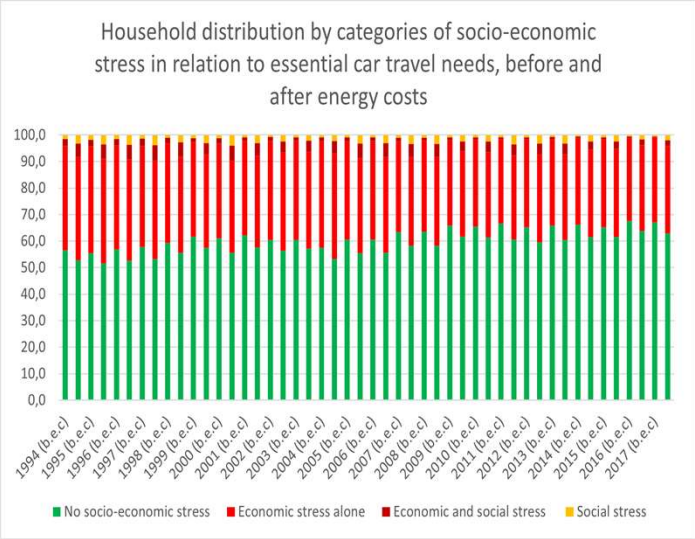


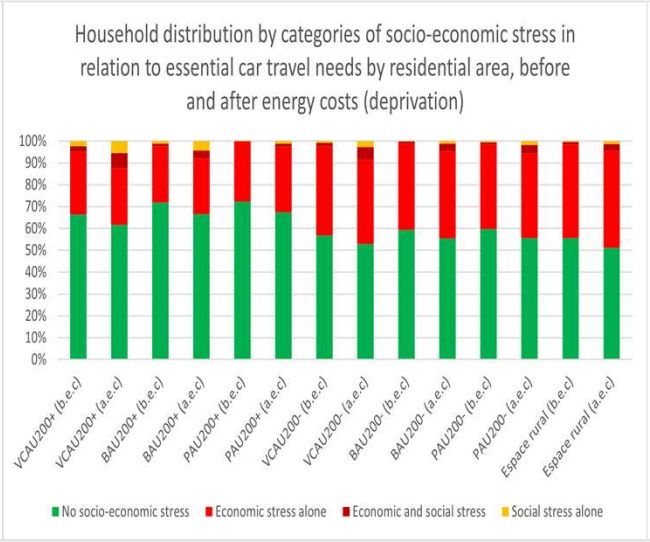


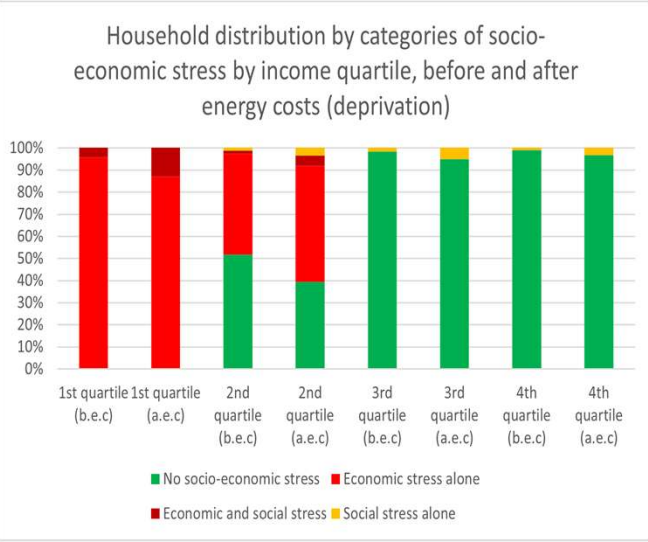
- The proportion of budgetary unconstrained households reaches 30 % in large urban areas, vs. 10-15 % in smaller urban areas and the rural space. Households under budgetary stress are more frequent in low-density areas : 30 % in large urban areas, vs. 40 % in small to medium urban areas, and 50 % in the rural space.
- Before energy costs, households from the 1st quartile are already all under budgetary stress, distributed by half between precarity and vulnerability ; the 2nd quartile is either financially vulnerable or under budgetary constraint ; households from the 3rd quartile are all budgetary constrained without vulnerability ; and 75 % from the upper quartile, are free from budgetary constraints.

- Energy costs raise the proportion of financially-stressed households in all areas. This impact is more substantial in smaller urban areas and the rural space (resp. + 3 and + 4 points), increasing gaps between residents of large conurbations and other areas. The degree of financial stress increases in all zones : from vulnerability to precarity in smaller urban areas and the rural space, from budget constraint to vulnerability in large urban areas.
- The impact of energy costs is more significant among low-income groups : + 7 points in the poverty rate in the 1st income quartile, and + 6,3 points in financial vulnerability in the 2nd quartile.

Categories of socio-economic stress

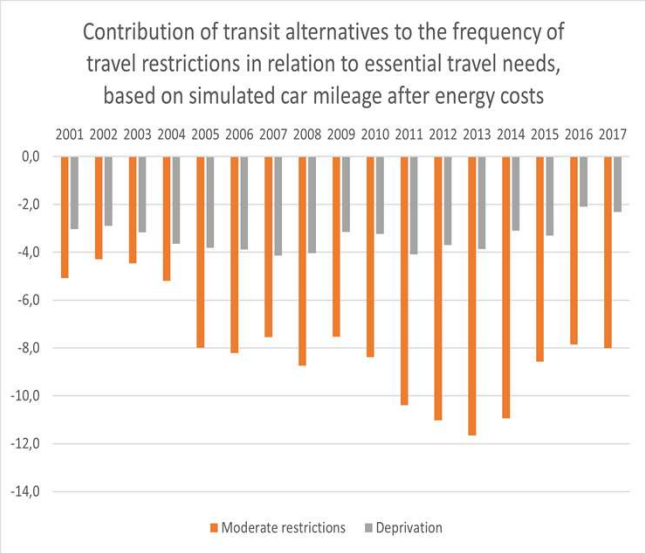


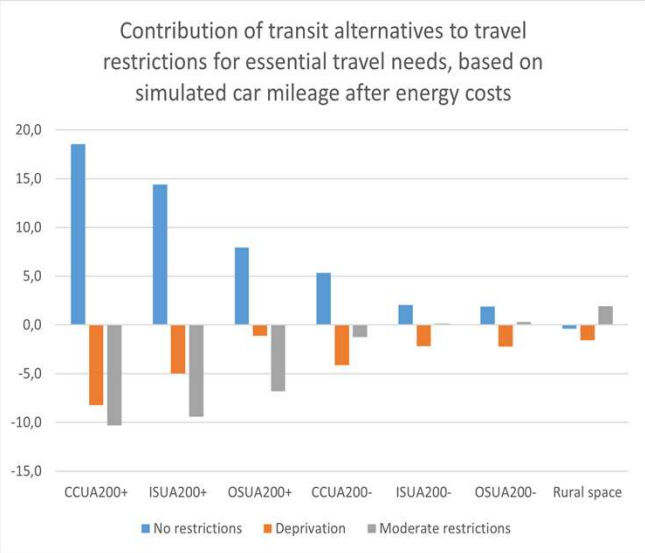




- Initially, the majority of car-related socio-economic stress consists in budgetary stress. Very few of these situations are accompanied with car travel restrictions. Its frequency has decreased, mostly through the reduction of economic stress; it is higher in smaller urban areas and the rural space (40-50 % households, vs. 30 % in large urban areas). It is limited to the lower half of the income distribution, mostly consisting in budgetary stress : all households from the 1st income quartile, and nearly half of those from the 2nd quartile.
- Energy costs raise the frequency of car-related socio-economic stress from + 4-5 points in all areas, transferring households from economic stress alone to joint economic and social stress or social stress alone. Most significant impacts are noticed in central cities (+ 4 points in joint economic and social stress) and in the 2nd quartile (from 48 to 60 %), then in the 1st quartile (+ 8 points). Impacts on the upper half of the income distribution remain limited. The main outcome of energy costs is therefore the intensification of car-related socio-economic stress among the poor, and its greater diffusion in the lower middle class.

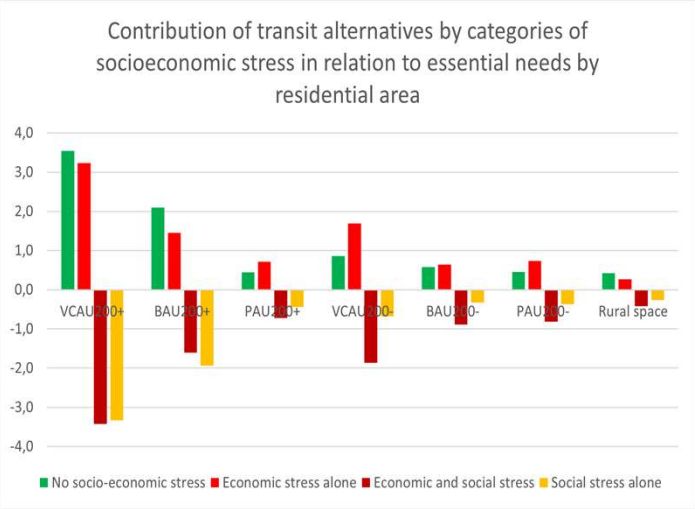
Benefits of public transportation alternatives





- PT alternatives significantly reduce the frequency of travel restrictions, in particular for moderate restrictions. This benefit is greater in large conurbations, causing – 18 points in the frequency of travel restrictions in their central cities, and – 14 points in their inner suburbs. It is still substantial in outer suburbs of large cities and core cities of smaller urban areas, and negligible in suburbs of smaller urban areas and the rural space. Contrasting benefits can be explained through the degree of PT adequacy, with 55 % households benefitting from good PT adequacy in metropolitan areas, vs. 7,3 % in the rural space. This benefit is increasing with income, thanks to the greater ability of high-income groups to reduce car travel needs ahead by locating in well-desserved areas, allowing them to decorrelate motility from the car. If limiting to deprivation, the most important benefit is among low-income households. In the lower half of the income distribution, PT alternatives are used to reduce the acuteness of travel restrictions, while among higher-income households, they respond to the goal of stabilizing transport budget coefficients.

Benefits of public transportation alternatives



- PT alternatives reduce the frequency of joint economic and social stress, and of social stress alone. More households become free from car-related socio-economic stress as a result, and the frequency of economic stress alone also increases. Most significant benefits are for large conurbations, especially in their core cities (- 7 points in car-related socio-economic stress), then in their inner suburbs (- 3,5 points) and in core cities of smaller urban areas (- 2,5 points). They are much more limited in outer suburbs of large cities, suburbs of smaller cities and the rural space. This benefit is also strongly related to income, by allowing a 4 points transfer from joint economic and social stress to economic stress alone in the 1st quartile. It plays a similar role in the second quartile, although to a lesser extent (-1,5 points). In the upper half of the income distribution, it only causes a transfer from social stress alone to the absence of car-related socio-economic stress.

Conclusive section

Conclusion

1. An **integrated approach to car-related social concerns** implies accounting for budgetary stress and car travel restrictions at the same time : this can be done through the concept of car-related socio-economic stress.
2. Car-related socio-economic stress can be hierarchized by degrees. In particular, poverty and vulnerability can be viewed as **degrees of financial stress, in relation to income and energy costs**. One can also make a distinction between moderate restrictions and deprivation.
3. The cornerstone to the assessment of car-related socio-economic stress is the estimation of car travel needs, which is generally understated.
4. This can be fixed through the design of a car mileage model, which can be used to estimate the distribution of car travel needs for essential motives and the corresponding restriction frequencies, along with the contribution of energy costs to car-related socio-economic stress, and the benefit of PT alternatives.
5. Rising fuel prices contribute to explain the stabilization of car travel, despite rising car travel needs. As a result, car travel growingly restrains to the satisfaction of essential needs, although most restriction behaviours are only moderate.
6. Car-related socio-economic stress is more frequent in small to medium urban areas and the rural space, and is mostly found in the lower half of the income distribution, corresponding to the poor and the lower middle class.
7. Energy costs raise the frequency of car-related socio-economic stress among low-income households, with the intensification of car-related socio-economic stress among the poor, and its greater diffusion in the lower middle class.
8. PT mitigates the severeness of car-related socio-economic stress in large conurbations and core cities of smaller urban areas. It strengthens the advantage of high-income groups, by allowing them to decorrelate motility from the car, but also benefits to the poor and the lower middle class, as more of them turn towards public transportation because of budgetary pressure.

Discussion

- The benefits from this approach :
  - Its ability to give account of contemporary social issues, by linking the vision of energy poverty with energy vulnerability among the lower middle class, which may feel fragilized through the combination of rising energy prices with the deterioration of their economic perspectives. It confirms higher economic vulnerability among residents of smaller cities and the rural space.
  - It highlights the contribution of evolving needs, in relation to changing consumption patterns, to the evolution of car-related socio-economic stress among low-income households, despite income growth and energy efficiency benefits.
- Limitations :
  - Crossing travel surveys with fiscal data would allow overcoming the limitation which is a missing income in Household Travel Surveys. The characterization of PT supply could be completed by external data on public transportation networks.
  - A complementary model could be designed to estimate car travel needs for non-essential motives, such as leisure and holiday trips.
- Policy implications :
  - Our results confirm the significance of controlling energy costs, notably in small cities and the rural space, and for the lower half of the income distribution, where situations of car-related socio-economic stress are found more sensitive to energy costs. A plausible option would consist in modulating the trajectory of fuel taxation, depending on changes in the way of life, fuel prices, income growth, and progress in fuel efficiency.
  - Our results demonstrate the relevance of location effects, either in terms of PT adequacy, which allows to reduce the severeness of car-related socio-economic stress in large cities, or because of the inappropriate spatial distribution of social groups with respect to transport costs. Another policy orientation can consist in reducing car dependence through the provision of new public transportation supply in small to medium cities, while reducing the spatial mismatch of social groups by implementing affordable housing programs for the lower middle class in central locations, especially in large cities.

Thank you for your attention…