Supplementary material

The association between the carbon footprint and the socio-economic characteristics of Belgian households

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1. Tabulations of categorical variables (weighted data)

Table 1. Distribution of households by number of adults

Number of adults in the household	Percentage of households
1	37.0
2	45.3
3	10.3
>=4	7.5
Total	100.0

Source: authors' computations, Belgian Household Budget Survey 2014.
Note: Household members younger (older) than 14 are categorized as children (adults).

Table 2. Distribution of households by number of children

Number of children in the household	Percentage of households
0	75.6
1	12.0
2	9.2
3	2.7
>=4	0.7
Total	100.0

Source: authors' computations, Belgian Household Budget Survey 2014.
Note: Household members younger (older) than 14 are categorized as children (adults).

Table 3. Distribution of households by the professional status of the reference person

Professional status of reference person	Percentage of households
working	60.7
unemployed	6.8
student	0.7
housewife	0.6
incapacitated	5.1
pension	26.2
Total	100.0

Source: authors' computations, Belgian Household Budget Survey 2014.

Table 4. Distribution of households by the highest level of educational attainment in the household (all household members taken together)

Highest educational attainment in the household	Percentage of households
primary	6.5
lower se	10.6
upper se	34.3
tertiary	48.5
Total	100.0

Source: authors' computations, Belgian Household Budget Survey 2014.

Table 5. Regional distribution of households

Region	Percentage of households
Brussels-Capital Region	11.3
Flanders	56.5
Wallonia	32.2
Total	100.0

Source: authors' computations, Belgian Household Budget Survey 2014.

Table 6. Distribution of households by tenure status

Occupancy status	Percentage of households
Owner	70.0
Tenant	30.0
Total	100.0

Source: authors' computations, Belgian Household Budget Survey 2014.

Table 7. Distribution of households by number of rooms in the dwelling

Number of rooms in the dwelling	Percentage of households
1	1.8
2	8.8
3	19.9
4	29.0
5	23.2
>=6	18.0
Total	100.0

Source: authors' computations, Belgian Household Budget Survey 2014.

Table 8. Distribution of households by type of dwelling

Type of dwelling	Percentage of households
Detached	33.2
Semi-detached	39.7
Apartment	26.4
Other	0.7
Total	100.0

Source: authors' computations, Belgian Household Budget Survey 2014.

2. Treatment of non-frequent expenses

Expenditures that do not occur on a regular basis are recorded only for a small fraction of all the households in the data. Such expenditures include, for example, durable goods (e.g. fridge), maintenance services, or holiday expenses. Even though only a small number of households report expenditures on these goods and services, it is most likely that other households also purchase them at times that fall outside the period of observation.

Infrequent expenditures appear in two ways in the dataset: (1) as part of the monthly logbook that households keep, if the expense occurred within the period covered by the logbook; (2) as part of the personal questionnaire, which covers infrequent purchases that occurred in the four months preceding the interview. We treat all COICOP categories with expenses recorded in the personal questionnaire as 'infrequent'. As regards the purchases recorded in the logbook, we only consider COICOP categories infrequent, if they fall within the COICOP definition of 'durables'.

To smooth non-frequent expenditures among households, we used a slightly modified version of the mean-imputation method proposed by Beznoska and Ochmann (2013). We created 14 household clusters based on net monthly household income quartiles and a categorical household size variable (1,2,3, or higher)[1]. Then, for each non-frequently purchased product and each cluster, we calculated total expenditures and allocated a proportional fraction of total expenditures to every household, as is explained in more detail below. This way, a small amount of durable expenditures is allocated to each household, instead of observing a small number of households consuming large amounts and the majority of the households consuming zero. We used survey weights throughout the analysis[2].

The smoothing was done differently for two types of consumption categories. The first type consists of 12 durable goods about which ownership information was collected during the survey. During the personal interview, the interviewer asked how many of each of the following 12 goods the household possesses: cell phone, landline phone, motor, scooter, desktop, laptop, tablet, television, washing machine, dishwasher, fridge and cars. The second category consists of 141 products and services about which we do not have ownership information. For example: furniture, household appliances and tools, smaller electronic products, some maintenance and repair services, holiday expenses.

In case of the first group (i.e. where we have ownership information about the number of possessed items for each household), we smoothed durable expenditures by carrying out the following steps.

[1] The initial number of clusters was 16 (4 income groups times 4 household size groups). However, due to their small sample size, the third and fourth household size groups within the first income quarter, and the first and second household size groups in the fourth income quarter were concatenated.
[2] To facilitate readability, weights are not shown in the equations that follow.

In the first step, we calculated a cluster-specific expenditure-possession ratio (EPR) by dividing total expenditures by the total number of items possessed within each cluster:

$$EPR_{kc} = \sum_{i=1}^{n_c} p_{ik} \Big/ \sum_{i=1}^{n_c} q_{ik}$$

EPR_{kc} stands for the expenditure-possession ratio of durable good *k* in cluster *c*, p_{ik} stands for expenditures of household *i* on durable good *k*, q_{ik} stands for number of *k* possessed by household *i*, and n_c is the number of households in cluster *c* where household *i* belongs to[3].

In the second step, we allocated a smoothed expenditure amount to each household by multiplying the cluster-specific expenditure-possession ratio with the number of items possessed by the household:

$$p_{ikSM} = EPR_{kc} * q_{ik}$$

p_{ikSM} stands for smoothed expenditures of household *i* on durable good *k*, UP_{kc} was calculated in the first step and stands for the unit price of good *k* in cluster *c*, where household *i* belongs to, and q_{ik} stands for the number of *k* possessed by household *i*. Note that if a household does not possess durable good *k*, zero smoothed expenditures on *k* are allocated to that household. If a household possesses two *k*s, the allocated smoothed expenditures on *k* are two times as large as in case of a household that possesses only one *k*. This method implicitly assumes that newly purchased durable goods replace existing durable goods. However, there are very few households (maximum 8, in case of the 'motor and scooter' category) that purchase any of these goods and do not already own one. Thus, we do not redistribute from owning households to non-owning households.

In case of the second category of non-frequently purchased goods and services (i.e. where we do not have ownership information), we allocated total cluster-level expenditures equally to the households in the cluster:

$$p_{ikSM} = \sum_{i=1}^{n_c} p_{ik} \Big/ n_c$$

Again, p_{ikSM} stands for smoothed expenditures of household *i* on good *k*, p_{ik} stands for expenditures of household *i* on durable good *k*, and n_c is the number of households in cluster *c* where household *i* belongs to. Note, that p_{ikSM} is the same for each household within a cluster but varies between different clusters.

3. Correcting underreported fuel expenses of households with a company car

3.1. Introduction

In Belgium, part of the fuel expenses (for driving a motorised vehicle) of households with a company car are paid by the employer and do not appear among the expenditures of the households in the HBS. A Wald test showed that the mean monthly fuel expenses of households with company car (M = 78.31, se = 5.67) is significantly lower than that of households without a company car (M = 104.98 , se = 1.64), F(1,337) = 19.10, p = 0.000. Moreover, the proportion of households that report zero expenditures on fuel is higher for households that use a company car (Table 9). Due to the fact that we calculate household emissions based

[3] We used survey weights throughout the calculations.

on reported expenditures in the HBS, our estimation about the emissions of these households is biased downwards. Therefore, we impute fuel expenses for households that use a company car.

Table 9. Households reporting zero expenditures on fuel broken down by car ownership

Cars in household	Weighted number of households	Percentage of households reporting zero fuel expenditures
No car	799,450	90.3
Only private car	3,390,620	12.8
Only company car	187,383	64.8
Private and company car	266,798	22.5
Total number of households	**4,644,251**	

Note: Households that own a scooter or motor are excluded
Source: authors' computations, Belgian Household Budget Survey 2014.

When imputing fuel expenses for households with a company car, four issues needed to be resolved. Firstly, we found that the proportion of company cars is slightly underestimated in the HBS when compared to official statistics. Thus, we corrected the data and identified some company cars that were previously labeled as private cars. Secondly, when households own both cars and motorcycles, it is not possible to identify the share of fuel bought for the car. Thirdly, we observe that fuel expenditures do not grow linearly with the number of cars in the household, thus we had to account for the number of vehicles during the imputation. Lastly, we needed to make assumptions about the imputed fuel mix.

3.2. Number of company cars in Belgium and in the HBS

The exact number of company cars in Belgium is not known. Depending on the source and the method used, in 2015 there were between 550,000 and 670,000 company cars in Belgium (Denys, Beckx, & Vanhulsel, 2017; May, 2017). In the HBS, we identified 455,598 company cars. However, we noted that there are 121 households who indicate to make freely use of a car provided by the employer, even though they do not report using a company car (i.e. relevant information stored in two separate variables do not correspond with each other). If we assume that each of these households has access to one (rather than zero) company car, the total number of reported company cars in the dataset reaches 579,825, which is more in line with macro estimates of the number of company cars in Belgium.

3.3. Motorcycle ownership

The HBS contains information about both car and motorcycle ownership. There are 544 households that have both car(s) and motorcycle(s), representing 7.7 percent of all the households (Table *10*). In case of these households, it is not clear if fuel was bought for the car, for the motorcycle, or for both. In order not to blur the picture of fuel purchases, it is reasonable to exclude these households from the estimation of average expenditures on fuel. However, they represent 10.3 percent of car-using households. Given that this is a high share, we reduce the number of excluded households based on the observation that motorcycle engines run on gasoline and not on diesel. Thus, we can always be sure that diesel was purchased for cars and not for motorcycles. If a household owns car(s) and motorcycle(s), there are three possible fuel expenditure cases:

1. The household buys gasoline and does not buy diesel. In this case, we cannot know how much gasoline was used for the motorcycle. These households (147 in total) were excluded from the estimation of average expenditures on fuel.

2. The household buys diesel and does not buy gasoline. We can safely assume that the diesel was purchased for the car and not for the motorcycle. These households (183 in total) were included for the estimation of average expenditures on fuel.
3. The household buys both gasoline and diesel. In this case, if the household has one car, we can assume that the diesel was bought for the car, and the gasoline was purchased for the motorcycle. If there are more cars, we cannot know the share of gasoline purchased for the car and for the motorcycle. Thus, we excluded these households (92 in total) from the estimation.

Table 10. Percentage of households broken down by car and motorcycle ownership

Car	Motorcycle		
	No	Yes	**Total**
No	16.1	0.9	**17.0**
Yes	75.3	7.7	**83.0**
Total	**91.4**	**8.6**	**100.0**

Source: authors' computations, Belgian Household Budget Survey 2014. Survey weights were used for the computation.

3.4. Fuel expenditures and number of vehicles in the households

Table *11* and Table *12* show mean monthly fuel expenditures of households broken down by the number of company and private cars possessed by the household. Columns 'a' and 'b' in Table *11* represent means estimated with and without zero expenditures, respectively. We highlight two observations based on these tables.

Our first observation is that for the same number of cars, the mean monthly fuel expenses is always lower when at least one of the cars is a company car. In case of households with one car, the mean monthly fuel expenditures are 88 euros when the car is private and 47 euros when the car is provided by the company. In case of households with two cars, the mean monthly fuel expenses of households that own two private cars is 151 euros, while that of households that own one private and one company car is 93 euros. Households with two company cars spend 68 euros on fuel on average.

Our second observation is that monthly fuel expenditures do not grow proportionally with the number of cars used by the household, i.e. fuel expenditures do not double when the number of cars double. Households that own two, three and four private cars, spend 72, 116, and 149 percent more than households that own only one private car (and do not own company cars). Thus, it would be incorrect to impute twice the amount of the fuel expenditures of a one-car household for a two-car household. Based on this observation, we took into account the number of cars in the household and followed the above-mentioned percentages during the imputation.

There are 849 households in the survey that do not have a car. Out of these, 108 report expenditures on fuels. There can be several reasons why households without car ownership spend on fuel: motorcycle ownership (24 out of the 108 own motorcycle), participating in a car sharing program, or renting a car.

Table 11. Mean monthly fuel expenses (euro) broken down by number of private and company cars used by the household.

Nr. of private cars	Number of company cars							
	zero		one		two		three	
	a	b	a	b	a	b	a	b
0	9	73	44	178	67	121	100	166
1	88	103	92	118	38	108	0	0
2	151	163	105	129	33	33	n.a.	n.a.
3	188	205	174	174	0	0	n.a.	n.a.
4	213	219	146	146	139	139	n.a.	n.a.
5	140	140	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Note: a: zero expenditures calculated in mean. b: zero expenditures excluded from calculation of mean. Households that own any motorcycle and buy gasoline are excluded.

Table 12. More information about the distribution of fuel expenses (euro) in the most populated cells

	Mean	Linearized std. err.	95% Conf. Interval		Min	Max	Median
no cars	8.7	1.0	6.5	10.4	0	419.8	0
1 private, 0 company	87.7	1.6	84.5	90.8	0	729.9	80
0 private, 1 company	44.04	14.8	14.4	73.7	0	693.9	0
2 private, 0 company	150.6	3.1	144.5	156.7	0	592.0	145.8
1 private, 1 company	91.9	6.4	79.3	104.5	0	664.7	74.6
0 private, 2 company	66.7	8.1	50.4	83.0	0	343.6	40

Note: households that own any motorcycle and buy gasoline are excluded.

3.5. Fuel mix

Table *13* presents how the fuel mix changes with the number and type (private/company) cars the household uses. The table shows the mean share of household expenditures in all fuel expenses. We can see that the mean share of diesel expenditures in total fuel expenses is higher for households that use one company car (0.66) than for households that own a private car (0.51). The difference in the fuel mix of company vs. private car using households can be explained by the fact that the percentage of diesel cars in the Belgian company car fleet is higher, than in the private car fleet. According to Denys et al. (2017), 86 percent of company cars ran on diesel in 2014. The share of diesel cars was much lower in the private fleet; only 57 percent of private cars ran on diesel. Based on these numbers, we suspect that underreporting of fuel expenditures by households that use a company car mainly affects diesel and the mean share of diesel expenditures in these households is higher than 66 percent. Thus, we only impute diesel, except for households that only use a company car and report gasoline expenses.

Table 13. Mean share of different fuels in household total expenditures on fuels (gasoline, diesel, other).

Number and type of cars in households	% of house holds	Gasoline			Diesel			Other		
		Mean share	95% LCL	95% UCL	Mean share	95% LCL	95% UCL	Mean share	95% LCL	95% UCL
No car	16.98	0.59	0.48	0.7	0.36	0.26	0.46	0.05	0.01	0.08
1 priv	54.18	0.48	0.45	0.5	0.51	0.48	0.53	0.01	0.01	0.02
2 priv	17.05	0.36	0.33	0.39	0.63	0.6	0.66	0.01	0.01	0.02
3 priv	1.57	0.34	0.27	0.41	0.63	0.56	0.71	0.02	0	0.05
1 comp	2.53	0.34	0.16	0.51	0.66	0.49	0.84	0		
2 comp	1.53	0.46	0.31	0.61	0.51	0.36	0.66	0.03	-0.01	0.06
1 priv, 1 comp	4.7	0.38	0.32	0.44	0.61	0.55	0.67	0.01	0	0.03
Other	1.47	0.45	0.35	0.54	0.55	0.46	0.64	0.01	0	0.01
Total	**100**	**0.45**	**0.43**	**0.46**	**0.54**	**0.52**	**0.56**	**0.01**	**0.01**	**0.02**

Note: LCL = lower confidence limit UCL = upper confidence limit

3.6. Imputation

We carried out mean imputation according to the following procedure. If the fuel expenses of a household with company car(s) were smaller than the threshold presented in Table *14*, we imputed additional fuel expenses so that the total fuel expenses reach the threshold. The thresholds are based on the mean fuel expenditures of households that own only the equivalent number of private cars (see the first column of Table *11*). For example, if a household with one company car and one private car spends 100 euros on fuels in a month, we added 51 euros to its fuel expenditures to reach the threshold of 151 euros.

Regarding the imputed fuels, we only imputed diesel expenses[4], because we expect that company cars are diesel vehicles as explained in the previous section. We disregarded expenditures on other fuels, because they represent only a small percentage of total fuel expenditures (Table *13*). Total fuel expenses in the sample grew by 6.7 percent after the imputation.

Table 14. Thresholds for mean imputation of fuel expenses

Cars in household		Threshold (euros)
Nr of company cars	Nr of private cars	
1	0	88
2	0	151
3	0	188
1	1	151
2	1	188
3	1	213
1	2	188
1	3	213

There are two implicit assumptions in our imputation method. Firstly, the threshold for imputation is based on total fuel expenses of households, which includes diesel, gasoline and other fuel expenses. The share of

[4] Except the case when a household use one company car and reported gasoline expenses. In this case we can be sure that the household has a company car that runs on gasoline.

the latter is so little, that we disregarded it. We only impute diesel, because 86 percent of company cars were diesel in 2014 according to Denys et al. (2017), implying that underreporting of fuel expenses is likely to be related to diesel. However, there is a small percentage of company cars that run on gasoline. If gasoline is more expensive than diesel, we implicitly assume that these households consume more fuel. Secondly, the thresholds for the imputation is based on private-car using households. Thus, we implicitly assume that the private car fleet has similar characteristics to the company car fleet, both in terms of fuel efficiency and in terms of use (distance driven). However, company cars are bigger and newer than private cars. Bigger cars tend to consume more, newer cars tend to be more fuel efficient, thus consuming less. The total effect of the two factors are not known to us, because we do not have information on average fuel consumption of company cars and private cars. Furthermore, it can be expected that people with a company car drive more kilometres, given that the cost of car driving is so low. Therefore, overall, we probably underestimate the greenhouse gas emissions of households that use a company car.

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