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The Differential impact of Covid-19 on Household Carbon Footprint: A Gender Perspective

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This study investigates the impact of Covid-19 containment measures on household carbon footprints, with a focus on gender dynamics and redistributive effects. Using data from the Belgian Household Budget Survey for 2018 and 2020, we find that households with male breadwinners experienced a more substantial decrease in carbon footprints. This reduction is primarily due to a significant decline in the consumption of carbon-intensive goods and services, such as transportation and dining out, which these households utilize more extensively. Our findings emphasize the importance of incorporating gender considerations in the assessment of carbon reduction policies. By understanding the link between gender and consumption behaviors, policymakers can design more equitable and effective interventions to mitigate household carbon emissions. Understanding this link also presents opportunities for targeted policies and incentives, particularly in transportation, ensuring that decarbonization efforts address the distributive nature of carbon footprints.

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1. Introduction and Context

Motivation. Since the International Panel on Climate Change's first report in 1990, the urgent need to curb human-driven global warming has been universally acknowledged (Masson-Delmotte et al., 2022). To meet the Paris Agreement's objective of capping the temperature increase to 2°C above pre-industrial levels, substantial reductions in emissions from both the supply side (how production is organized) and the demand side (consumer purchasing and usage behaviors) are imperative. The latter, influenced by consumer behavior, accounts for between 40 to 70% of potential sector-wide reductions in greenhouse gas emissions (Schmidt, 2022). Designing policies to nudge demand-side emissions downard requires a precise knowledge of individuals' consumption patterns and heterogeneity in carbon footprints across individuals, both to maximize their efficiency and to identify their potential distributional unintended consequences. This paper provides insights into demand-side decarbonization strategies for Belgium, by investigating the differentiated effects of the Covid-19 pandemic on household emissions across gender and spending patterns. Prior research indicates that men typically consume more carbon-intensive goods than women, highlighting the importance of considering gender in analyzing household emissions. Our study further explores which expenditure categories have seen the most significant impact on emission reductions, taking into account gender dynamics.

Context. The outbreak of Covid-19 in March 2020 marked the beginning of an unparalleled transformation in societal behaviors. Governments across the globe enforced strict movement restrictions and social distancing measures that led to changes in individual behaviors, impacting emissions. While existing studies have investigated the impact of the pandemic on greenhouse gas emissions (Abu-Rayash and Dincer, 2020; Fatmi, 2020; Malik et al., 2020), the literature has failed to use the exogenous brutal changes in lifestyles to identify heterogeneity in households consumption decisons and induced emissions. Covid-19 related measures such as lockdowns and closing of non essential shops have constrained individuals to reshape consumption patterns: using transportation only for essential trips, not purchasing unessential goods or purchasing them online, eating home-cooked food more or ordering-in, and adapting energy consumption because of stay-home requirements. Agents' changes in emissions with the pandemic thus depend crucially on their pre-pandemic carbon footprints and behavior changes with the restrictions. We use the Covid-19 shock to identify efficient levers to reduce households' greenhouse gas emissions, and their differentiated impact across genders.

Methodology. Household carbon footprints and spending patterns are computed using the Belgian Household Budget Survey from 2018 and 2020 and Exiobase, respectively a household survey recensing purchasing habits of a representative sample of the belgian population, and emissions factors providing the emissions intensity of 1 euro spent on each good. In analyzing the impact of Covid-19 on household carbon footprints, we conduct a cross-sectional analysis that interprets the pandemic as an exogenous shock to household dynamics, employing the stringency of Covid-19 measures as a separate, independent variable influencing lifestyles. Our methodology differentiates between households based on the gender of the primary income earner, referred to as the household's 'breadwinner'.[1] By looking at the gender of the breadwinner, we make the implicit assumption that the individual with the largest income has the largest decision-making power on consumption decisions in the household. Although we are aware of the complexity of intra-household dynamics and the multiplicity of factors impacting bargaining within households, it is out of the scope of this paper to precisely estimate intra-household barganing. We do however control for income, age, household compsition and other relevant factors for bargaining in the analysis. This strategy allows us to precisely estimate the differentiated effect of Covid-19 on household emissions across gender and spending patterns.

Results. Results of the study unveil a notable gender-based disparity in how household carbon footprints were influenced by the Covid-19 pandemic. Specifically, households with male breadwinners saw a larger decrease in their overall carbon footprint compared to those with female breadwinners, primarily due to reduced consumption of carbon-intensive goods and services in male-led households, particularly in terms of fuel, restaurant dining, and energy use. Households with male breadwinners did observe a minor increase in their emissions from in-home food consumption with respect to female-led households, however low enough not to counteract the drop in emissions related to other consumption groups. Our research also shows that during the pandemic's heightened mobility restrictions, such as travel bans and stay-home orders, households with a male breadwinner experienced a more pronounced reduction in their mobility-related carbon footprint than those led by females, largely due to differences in car usage patterns between these household types. These findings underscore the significance of the breadwinner's gender in shaping household consumption and environmental impact during the pandemic.

Policy recommendations. Results of our study enable policymakers to craft strategies for reducing carbon footprints by understanding temporary but revealing adjustments in household habits. This approach underscores the potential for policies that foster

[1] We use 'breadwinner' and 'household head' interchangeably in the paper.

sustainable changes, informed by pandemic-era adaptations. Previous studies have established that goods with high carbon intensity exhibit greater income elasticity, leading to larger energy footprints among individuals with higher incomes (Oswald et al., 2020). Building upon these findings, our study unveils a significant gender disparity in carbon emissions, underscoring the necessity for interventions that are sensitive to gender differences. It advocates for the implementation of gender-informed demand-side strategies, emphasizing the promotion of sustainable consumption practices that are specifically designed to align with the distinct behaviors of households led by men and women. Policy options might include targeted subsidies for sustainable transport options appealing to the specific needs and habits of these households, or educational campaigns addressing gender-specific preferences and barriers to sustainable consumption. Exploiting gender differences in consumption patterns during the Covid-19 pandemic offers insights into household behavior under constraints.

The structure of the paper is as follows: we present the literature review and place the contribution of the paper in section 2. Section 3 presents the quantitative foundations of the analysis, where the data used are presented, a descriptive statistical analysis is conducted, and the chosen econometric approach is described. Moving on to section 4, the results obtained from the main analysis are depicted. To ensure the robustness of the findings, section 5 delves into various sensitivity tests and validation exercises. Section 6 concludes.

2. Literature review and contribution

Examining the gendered changes in household emissions during the Covid-19 pandemic positions this paper's contributions across various dimensions.

Socioeconomic factors and carbon footprints over time. This study contributes to the existing literature on the impact of socioeconomic factors, such as income, household size, education, and social status, on carbon footprints, with a novel emphasis on temporal variations (Salo et al., 2021; Christis et al., 2019; Gill and Moeller, 2018; Sekhokoane et al., 2017; Bjelle et al., 2018; Druckman and Jackson, 2016). While cross-sectional research traditionally underscores income as the principal determinant of household carbon footprints (Oswald et al., 2020), our findings during the Covid-19 pandemic reveal that this may not hold true when examining changes over time. Contrary to the static view presented by Minx et al. (2013) that other factors could be equally influential, our research uncovers that the gender of the breadwinner plays a more significant role than income in driving the dynamics of household carbon footprints between 2018 and 2020. This observation challenges the conventional wisdom and suggests that gender-related factors may emerge as predominant influencers of carbon footprint variations during significant global events, such as the Covid-19 pandemic. Our study also aligns with the broader discourse on household composition and consumption patterns (Nelson, 1988; Deaton and Paxson, 1998; Vernon, 2005), and supports the concept of household economies of scale in emissions, as corroborated by recent findings from Guo et al. (2022).

Covid-19 and carbon footprints. Secondly, this paper contributes to the body of research on Covid-19's impact on emissions. Various studies have documented the pandemic's effect on global and regional CO_2 emissions. For instance, Le Quéré et al. (2020) observed a 17% reduction of global emissions during the first wave of Covid-19 early 2020, while Pomponi et al. (2020) reported a more modest annual decrease of 1 to 3%. In Europe, Andreoni (2021) noted a 12.1% drop in the first half of 2020, with mobility emissions significantly declining as per Schulte-Fischedick et al. (2021). More localized studies, such as those by Marinello et al. (2020) in Italy and Turner et al. (2020) in San Francisco, also report substantial reductions. Our research adds to these findings by examining Belgian household emissions, which decreased slightly from 2018 to 2020, echoing findings of Long et al. (2021) in Japan. Similar to Long et al. (2021), We also observe category-specific trade-offs in carbon footprint, similar to patterns reported in other regions. We further dissect these trends by considering the gender of the breadwinner.

Gender differences and carbon footprints. Thirdly, our research provides new insights to the literature on gender differences in pro-environmental behaviors. Consistent with findings that women often exhibit more eco-friendly behaviors than men (Briscoe et al., 2019; Dzialo, 2017; Kennedy and Dzialo, 2015), we further explore this divergence, particularly in the context of Europe where men are generally found to have slightly higher carbon footprints (Hjorth et al., 2020; Treu et al., 2017; Mertens et al., 2021). Key factors contributing to this discrepancy include dietary choices and transportation habits, with men typically favouring carbon-intensive options (Hamilton and Jenkins, 2000; Johnsson-Latham, 2007; Moser and Kleinhückelkotten, 2018). Our study extends this understanding by empirically demonstrating that households with male breadwinners have higher carbon footprints than those with female breadwinners, even after controlling for other observable factors. Methodologically, this paper diverges from the typical stated preferences approach often used in gender-related environmental behavior research. Instead, we adopt a revealed preferences methodology, providing a more objective assessment of actual consumption patterns and their environmental impact.

3. Quantitative framework

3.1. Data and variables

The paper relies on two main databases: The Belgian Household Budget Survey (Statbel, 2021) for information on households characteristics and expenditures, and Exiobase (Exiobase, 2019) for information about environmental impacts of consumption. Both are for 2018 and 2020 and are described in the subsections below.

3.1.1. The Belgian Household Budget Survey

The Belgian Household Budget Survey (BHBS), conducted biennially by Statbel, the National Institute of Statistics in Belgium, collects comprehensive data on household income, expenditures, and consumption patterns.[2] The survey, encompassing 6,136 and 6,105 households for 2018 and 2020 respectively, is built to be representative of the Belgian population, covering various household sizes, income levels, and demographics in both urban and rural areas. Data are weighted to reflect national averages, accounting for household income, size, gender, age, and unemployment rate.

Each participating household in the BHBS is given a logbook to record all expenditures over a two-week period, either in a paper or online format.[3] Households document details of their expenditures, including type, price, and quantity. Expenditures in the BHBS are organized using the Classification of Individual Consumption by Purpose (COICOP) (UN, 2018), an international standard developed by the United Nations. COICOP divides household expenditures into twelve primary groups, further detailed into four subgroups, with Belgium adopting an additional fifth level for a total of 1,154 categories. For this study, these categories are condensed into 67 groups based on emission factors from Exiobase's Multi-Regional-Input-Output data, detailed in Appendix A. For food-related expenses (COICOP codes 1 and 2), additional weighting is used to adjust for potential absences of households during the data collection period, ensuring a more accurate representation of typical consumption behavior.

After this period, a trained interviewer visits the household to complete a questionnaire. This questionnaire gathers comprehensive data on household composition and socioeconomic characteristics, such as labour income, age, region, education, as well as information on the household's dwelling, periodic expenses, and ownership of major appliances such as cars. It also includes queries about the purchase of durable goods in the

[2] A notable limitation of the BHBS is the reliance on self-reported expenditure diaries, which may lead to underreporting and potential underestimation of household carbon footprints.

[3] The diary is filled out from the 1st to the 15th or from the 16th to the end of the month, with adjustments made by Statbel's methodologists for months of varying lengths.

prior four months. Socioeconomic variables enable the differentiation of households and the inclusion of socioeconomic factors as covariates in the analysis. In this study, the 'breadwinner' of a household is identified as the primary income earner, determined by the highest income among all household members.

During the Covid-19 period, face-to-face interviews persisted (except from March until June 2020), and a subsequent supplementary study did not identify a significant impact of Covid-19 on data collection when comparing differences in responses between the period when the Covid-19 prevented visits and the period when it did not (Statbel, 2020).

Households' carbon footprints are calculated based on their expenditures. The next subsection 3.1.2 provides more information on the emission factors used, and subsection 3.1.3 details how we matched expenditure data to the emission factors.

3.1.2. Exiobase

Exiobase 3.7 is a comprehensive global Environmentally-extended Multi-Regional Input-Output (EMRIO) database widely used for analyzing economic and environmental interactions globally. It details production, consumption, and trade activities across various sectors and countries, with an environmental extension that offers data on resource use, emissions, and other environmental indicators. This feature is instrumental in assessing the environmental impacts of different economic sectors and regions, aiding in sustainability and environmental policy analysis.

Conceptually, the database is based on input-output tables derived from supply-use tables, which represent the entire economy of a country. These tables categorize production into multiple economic sectors and consumption into various product and service groups, quantifying in monetary value how much each sector produces. This model demonstrates the interdependencies within an economy, showing how outputs from one sector serve as inputs for others, thereby illustrating the economy's interconnectedness.

In the inter-industry matrix of the EMRIO framework, Column entries represent inputs to an industrial sector, and row entries denote outputs from that sector. This model integrates emissions and primary resource use associated with trade, creating environmentally extended Input-Output (IO) tables for major global economies. These tables detail the trade flows between specific sectors across different countries.

The MRIO framework links environmental pressure data, such as direct emissions of greenhouse gases, to financial transactions between economic sectors (intermediate demand). This approach allows for attributing these environmental pressures to the consumption of various product groups (final demand). Consequently, it enables the calculation of the carbon footprint or other environmental impacts of consumption expenditures.

In practice, the emission factors used to compute the carbon footprints are inclusive of emissions from various gases, employing the Global Warming Potential (GWP) values from the AR5 report by the IPCC (2014) to convert into CO2 equivalent.[4] The conversion factors are designed to represent the CO2 equivalent emissions associated with one euro of household spending across different types of goods, based on their respective environmental impact. Appendix B provides detailed explanations about the EMRIO framework and the calculation of emission factors.

3.1.3. Matching Exiobase and BHBS

Concordance between household data and emission factors. In order to find emissions related to household consumption per consumption category, we need to multiply expenditures data from the BHBS with emission factors calculated by the EMRIO analysis. The integration of Exiobase emission factors with BHBS expenditure data is accomplished using concordance tables developed by Ivanova and Wood (2020), which facilitate the merging of the two datasets, primarily due to the compatibility of the expenditure data classification according to the COICOP framework used in both. These concordance tables play a crucial role in aligning BHBS expenditure categories with corresponding Exiobase conversion factors, especially for categories not directly listed in Exiobase. They establish a link between each expenditure and its associated emission factor, allowing for the calculation of carbon footprints by multiplying these two elements. For a more detailed description of this harmonization process, refer to Appendix C.

Approaches. Emissions from the BHBS expenditures are calculated using a hybrid approach that combines both bottom-up and top-down methodologies. The bottom-up method, detailed and specific, analyzes individual consumption patterns from the BHBS, focusing on household-level data to capture the intricacies of personal expenditures. To translate these expenditures into carbon footprints, emission factors from Exiobase are employed. These factors represent a top-down approach, applying broader, aggregated data on sectoral or national emissions to the detailed consumption data from the survey. This integration of methodologies provides a comprehensive framework: the bottom-up perspective ensures precise capture of household behaviors, while the top-down element allows for a wider estimation of emissions, balancing detailed accuracy with broader context.

Subsection 3.1.4 presents descriptive statistics related to household demographics and carbon footprint.

[4]The gases included in the AR5 GWP100 metric include carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), chlorofluorocarbons (CFCs), hydrofluorocarbons (HFCs), hydrochlorofluorocarbons (HCFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF6).

3.1.4. Descriptive Statistics

In calculating descriptive statistics for the Belgian population, weights from Statbel are applied to the BHBS data to ensure representativeness. These weights, which account for the varying probabilities of household selection, help generate accurate estimates of household expenditures at a population level. They correct for any sampling bias by reflecting the number of households in the general population that each surveyed household represents.

Socioeconomic characteristics. The precise delineation of the breadwinner of the household, operationalized through the identification of the primary income earner, holds pivotal significance for the accurate interpretation of the research outcomes. Table 1 elucidates the demographic characteristics of four distinct subsets in 2018 and 2020: households led by single male adults, households led by single female adults, households with multiple adults where the breadwinner is a man, and households with multiple adults where the breadwinner is a woman.[5]

Notably, there exists a predominant prevalence of households with multiple adults wherein the breadwinner is a man (Column (3)), followed by households led by a sole woman adult (Column (2)). Men are thus generally more likely to be the primary earners in multi-adult households. Female-led households typically have more children, a pattern attributed to differences in parental roles post-separation, with women more likely to take on primary residential care and economic support (Maccoby et al., 1993; Holden and Smock, 1991; McLanahan and Booth, 1989). Additionally, male breadwinners tend to have higher individual and overall household earnings, consistent with the observed gender pay gap in Belgium (Statbel, 2023).

The analysis shows that households with male breadwinners generally have fewer children, higher incomes for the primary earner, and greater total household income. Notably, female primary earners in multi-adult households are, on average, younger. These demographic differences, including variations in income, number of children, and age of the breadwinner, are critical factors influencing household carbon footprints and are controlled for in the subsequent analysis.

Carbon footprints over time. To analyze gender-specific differences in emissions before the pandemic in 2018, Table 2 presents a gender-disaggregated comparison of average carbon footprints across various consumption categories. This snapshot indicates that,

[5] An adult is considered to be 'single' if no other adult shares the same household. The empirical analysis was run for different groups with different demographics. Again, no significant difference emerged. Table 1 was also calculated for 2018 and 2020 separately, but no significant difference emerged except for income and carbon footprints. Results for years separated are available in Appendix D.

Table 1: Mean and standard deviation of variables used in the analysis based on different head of households for 2018 and 2020

	Single adult		Not single adult	
	Male Head	Female Head	Male Head	Female Head
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Household size	1.06	1.19	2.87	2.84
	(0.31)	(0.58)	(1.11)	(1.02)
Number of working individuals	0.46	0.43	1.14	1.19
	(0.50)	(0.49)	(0.95)	(0.77)
Number of retired	0.36	0.40	0.64	0.19
	(0.48)	(0.49)	(0.86)	(0.50)
Number of unemployed	0.15	0.15	0.25	0.31
	(0.36)	(0.36)	(0.52)	(0.57)
Number of students	0.01	0.01	0.24	0.39
	(0.08)	(0.11)	(0.60)	(0.69)
Number of children	0.06	0.19	0.53	0.69
	(0.31)	(0.58)	(0.91)	(0.94)
Income of hh head (€/month)	1956.46	1819.24	2356.74	2091.73
	(972.88)	(1044.33)	(1289.74)	(1008.82)
Household income (€/month)	1966.50	1837.57	4063.05	3442.22
	(969.34)	(1060.88)	(2346.40)	(1786.54)
Age hh head	55.85	56.35	55.03	46.42
	(16.48)	(16.41)	(15.36)	(13.02)
Household carbon footprint (kgCO2e)	9042.72	9429.28	15815.79	13656.60
	(4910.50)	(4607.60)	(7543.94)	(6360.74)
Individual carbon footprint (kgCO2e)	8766.40	8617.36	6020.53	5167.13
	(4883.78)	(4559.64)	(3267.85)	(2576.23)
Private car	0.79	0.72	1.29	1.09
	(0.85)	(0.52)	(0.71)	(0.69)
Company car	0.01	0.00	0.18	0.11
	(0.09)	(0.04)	(0.48)	(0.38)
Observations	1668	2465	6325	2160

Column 1 and 2 consider household in which there is one single adult, and column 3 and 4 consider household in which there is more than one single adult. Column 1 and 3 consider households in which the primary income earner is a male, and column 2 and 4 considers household in which the primary income earner is a female. Income of the household head represents the monthly income of the primary income earner in €/month, and household income represents the aggregated monthly income of the household in €/month.

generally, households with male breadwinners had higher carbon footprints across the considered expenditure categories.

There is a significant disparity in carbon-intensive activities between male and female breadwinner households. Before the pandemic, males led households exhibited higher carbon footprints in areas like food consumption (both at home and in restaurants), fuel usage, vehicle purchase, energy consumption, and water and waste with differences of

Table 2: Carbon footprint differences across genders before Covid-19 in 2018

Variable	(1) Female	(2) Male	(3) Difference	(3) % diff
Food at home	2,537.678	3,322.638	341.252***	+13%
	(1,609.545)	(1,956.990)	(40.740)	
Restaurant	233.332	365.462	84.603***	+36%
	(348.830)	(463.285)	(10.543)	
Tobacco	57.619	57.653	4.476	
	(177.048)	(177.343)	(4.609)	
Fuel carbon footprint	883.996	1,369.838	319.072***	+36%
	(1,178.741)	(1,576.995)	(35.926)	
Vehicle purchase and maintenance	408.588	884.024	378.109***	+92%
	(2,087.375)	(4,153.542)	(90.392)	
Air travel	146.548	230.971	12.037	
	(828.920)	(1,233.806)	(27.887)	
Public transport	72.751	56.920	-23.686***	-31%
	(341.282)	(291.991)	(8.101)	
Energy	2,109.976	2,400.432	143.409***	+6%
	(999.322)	(1,181.492)	(27.734)	
Telecommunication and tech	337.369	381.239	12.448*	+3%
device	(249.236)	(322.057)	(7.499)	
Furnitures and hh appliances	512.066	722.444	73.509	
	(1,391.602)	(2,113.757)	(47.746)	
Medical and health services	608.185	686.141	0.553	
	(918.248)	(1,058.322)	(25.823)	
Recreational goods and services	480.303	599.626	8.209	
	(753.119)	(964.224)	(22.189)	
Personal belongings	691.468	715.107	-111.019***	-16%
	(940.526)	(1,006.491)	(24.269)	
Water and waste	561.743	564.470	-29.744*	+5%
	(637.157)	(636.119)	(16.534)	
Total hh carbon footprint	10,993.404	14,013.553	1,326.066***	+12%
(kgCO2e)	(5,648.186)	(7,890.823)	(159.843)	
Individual carbon footprint	6,752.734	6,552.090	338.140***	+5%
(kgCO2e)	(3,617.147)	(3,880.412)	(86.348)	
Observations	2,312	4,256	6,568	

Carbon footprint are given in terms of $kgC0_{2e}$. Standard errors in parenthesis. Household weights are used when calculating descriptives. Half-month fixed effects, size of the household and income of the household are controlled for. Significance: *(p < 0.10), **(p < 0.05), ***(p < 0.01).

13%, 36%, 36%, 92%, 6% and 5% respectively.[6] The trend extends to telecommunications and tech devices. However, in public transportation and personal belongings, female breadwinner households have a higher carbon footprint, with male-led households showing 31% and 16% lower footprints in these categories. This pattern suggests that with

[6]These percentages are calculated for categories with statistically significant differences between male and female-breadwinner households.

Covid-19's restrictions of high-carbon activities, male-dominated households might have experienced a more pronounced reduction in carbon emissions due to their pre-pandemic consumption habits, assuming the pandemic significantly altered typical consumption behaviors, especially in high-carbon categories.

Table 3: Carbon footprint differences across categories for man head of household

Variable	(1) Pre-COVID-19	(2) During-COVID-19	(3) Difference
Food at home	3,322.638	3,662.702	446.127***
	(1,956.990)	(1,967.566)	(41.936)
Restaurant	365.462	231.398	-126.690***
	(463.285)	(396.273)	(9.743)
Tobacco	57.653	56.048	-5.054
	(177.343)	(195.032)	(4.365)
Fuel carbon footprint	1,369.838	867.037	-505.226***
	(1,576.995)	(1,183.913)	(32.490)
Vehicle purchase and maintenance	884.024	886.934	47.543
	(4,153.542)	(4,084.334)	(96.710)
Air travel	230.971	73.785	-121.009***
	(1,233.806)	(515.099)	(22.401)
Public transport	56.920	26.121	-27.077***
	(291.991)	(178.478)	(5.776)
Energy	2,399.718	2,213.327	-168.938***
	(1,180.823)	(1,136.444)	(26.696)
Telecommunication and tech device	381.239	406.567	36.989***
	(322.057)	(327.830)	(7.537)
Furnitures and hh appliances	722.444	748.184	65.242
	(2,113.757)	(1,867.737)	(46.462)
Recreational goods and services	599.626	527.578	-57.056***
	(964.224)	(828.943)	(20.524)
Personal belongings	715.107	515.984	-160.602***
	(1,006.491)	(807.534)	(20.791)
Water and waste	564.342	517.103	-41.223***
	(636.160)	(568.917)	(14.236)
Household carbon footprint (kgCO2e)	14,010.649	13,027.334	-599.835***
	(7,890.728)	(7,088.840)	(161.293)
Individual carbon footprint (kgCO2e)	6,552.090	6,168.847	-501.884***
	(3,880.412)	(3,628.929)	(87.822)
Observations	4,256	3,667	7,923

Carbon footprint are given in terms of $kgC0_{2e}$. Standard errors in parenthesis. Household weights are used when calculating descriptives. Household income and the period at which data were collected are controlled for. Significance: *(p < 0.10), **(p < 0.05), ***(p < 0.01).

Carbon footprints over time and by gender. Next, we examine the variation in household carbon footprints over time, particularly focusing on differences attributed to the gender of the breadwinner. This involves analyzing changes in consumption habits between 2018 and 2020 for households with male and female breadwinners. Tables 3 and 4 illustrate the evolution of household carbon footprints across various emission categories for male and female breadwinner households, respectively.

Table 4: Carbon footprint differences across categories for woman head of household

Variable	(1) Pre-COVID-19	(2) During-COVID-19	(3) Difference
Food at home	2,537.678	2,727.478	262.234***
	(1,609.545)	(1,644.021)	(46.107)
Restaurant	233.332	145.625	-81.692***
	(348.830)	(276.508)	(9.360)
Tobacco	57.619	59.822	3.884
	(177.048)	(189.446)	(5.852)
Fuel carbon footprint	883.996	593.553	-315.911***
	(1,178.741)	(927.612)	(32.911)
Vehicle purchase and maintenance	408.588	399.715	35.056
	(2,087.375)	(2,263.249)	(69.103)
Air travel	146.548	63.090	-87.577***
	(828.920)	(445.616)	(21.517)
Public transport	72.751	44.998	-36.213***
	(341.282)	(404.303)	(11.837)
Energy	2,109.976	2,027.543	-52.282
	(999.322)	(1,072.654)	(32.318)
Telecommunication and tech	337.294	352.432	20.518**
device	(249.254)	(271.748)	(8.111)
Furnitures and hh appliances	512.066	611.405	135.574***
	(1,391.602)	(1,714.064)	(49.099)
Recreational goods and services	480.297	424.320	-75.543***
	(753.123)	(682.855)	(22.444)
Personal belongings	691.468	479.463	-176.566***
	(940.526)	(755.886)	(26.240)
Water and waste	561.743	553.315	-12.802
	(637.157)	(608.032)	(19.970)
Household carbon footprint	10,991.215	10,394.889	-393.434**
(kgCO2e)	(5,648.405)	(5,478.237)	(154.786)
Individual carbon footprint	6,752.734	6,596.404	-190.191
(kgCO2e)	(3,617.147)	(3,882.679)	(118.435)
Observations	2,312	2,006	4,318

Carbon footprint are given in terms of $kgC0_{2e}$. Standard errors in parenthesis. Household weights are used when calculating descriptives. Household income and the period at which data were collected are controlled for. Significance: *(p $<$ 0.10), **(p $<$ 0.05), ***(p $<$ 0.01).

From a descriptive perspective, there is a decrease in the overall carbon footprint of both male and female breadwinner households between the pre-Covid-19 and Covid-19 periods. A deeper analysis into specific carbon footprint categories reveals that male-breadwinner households saw substantial reductions in emissions from restaurants, fuel, air travel, energy, and personal belongings during the pandemic.

For female-breadwinner households, energy-related emissions did not decrease significantly. Additionally, both male and female-led households experienced an increase in emissions from food consumption at home and telecommunications and tech devices, with female-led households also showing increased emissions from furniture and household appliances.

The next goal of this paper is to examine the divergent trajectories in carbon footprints between household types, focusing on the gender-differentiated impact of Covid-19 and accounting for other influential household characteristics. The subsequent subsection 3.2 details the quantitative methodology employed in this analysis.

3.2. Econometric Approach

Covid-19 as a shock. The study investigates gender differences in carbon footprints and spending patterns, using Covid-19 to identify gender specific behavior shifts under constraints. We use a cross-sectional analysis to examine the influence of Covid-19's stringency measures on household carbon footprints. The pivotal event is the onset of the Covid-19 pandemic, as confirmed by the WHO on January 13, 2020 (World Health Organisation, 2020), and its subsequent spread to Belgium by early February 2020 (Federal Public Service Health, 2020b). Belgium's response, characterized by varying levels of restrictions in time, starting March 2020 (Federal Public Service Health, 2020a), is quantified using the Oxford Coronavirus Government Response Tracker (OxCGRT) project's Covid-19 stringency index (Hale et al., 2021). This index, a composite of nine response indicators, is averaged over two-week periods to align with the periods when households reported their expenses.[7]

The analysis employs two-week period averages of the stringency index to evaluate its relationship with changes in household carbon footprints, accounting for the gender of the breadwinner, aiming to uncover gender-differentiated impacts. The associated Figure in Appendix E visually represents the variation in the stringency index over 2020, illustrating the temporal dynamics of the pandemic's impact on Belgian households.

Study design. In the spirit of an event study analysis, designed to assess the impacts of specific events, we contrast pre-event and post-event periods to elucidate causal effects. This approach is apt for evaluating the differential impact of Covid-19 stringency on household carbon footprints before and after February 2020. By focusing on households with male or female breadwinners, we aim to isolate the pandemic's specific effect

[7] The Covid-19 stringency index in Belgium in 2020 is a composite measure based on nine response indicators: School closures, workplace closures, cancellation of public events and restrictions on public gatherings, closures of public transport, stay-at-home requirements, public information campaigns, restrictions on internal movements, and international travel controls.

from other confounding factors. Such methodology is particularly effective in examining singular events' influence on distinct groups or entities. We rely on ordinary least square estimates of Equation (1)[8]:

$$CF_h = \beta_0 + \beta_1 Gender_h + \beta_2 Covid_{t(h)} + \beta_3 (Gender_h * Covid_{t(h)}) + Z'_h + \Theta_{t(h)} + \epsilon_h \quad (1)$$

CF_h is a continuous variable measuring the carbon footprint of household h. Its distribution is available in Appendix F. $Gender_h$ is a dichotomous variable equal to 1 if the breadwinner of the household is a man, 0 otherwise, and $Covid_{t(h)}$ is the continuous treatment measured by the Covid-19 stringency index ranging from 0 to 100 at point t in time throughout 2018 and 2020.[9] $t(h)$ is the two-week period during which household h is interviewed. β_3 is the coefficient of interest representing the average effect of being part of a household h in which the breadwinner is a man with an additional unit of Covid-19 stringency on the carbon footprint of his household h compared to when the breadwinner is a woman. β_1 measures the average effect on the household carbon footprint of being part of a household in which the breadwinner is a man compared to a household in which it is a woman when no Covid-19 measure is being implemented. β_2 represents the average effect of an additional unit of Covid-19 stringency compared to when it is null (before the start of the pandemic) on the carbon footprint of female-led households.

The inclusion of relevant covariates in the analysis helps control for potential confounding factors that might interact with the gender composition of households. Z_h is a vector of household covariates (size and overall income of the household, age and professional status of the breadwinner). $\Theta_{t(h)}$ controls for the two-week period fixed effects during which households were asked to fill-in their expenses diary.

Identification assumptions. Given the proximity of our empirical strategy with event studies, we discuss identification assumptions for our results. These assumptions are further detailed and checked for in section 5.

First, the event study analysis assumes that the Covid-19 pandemic, occurring in the year 2020, serves as the exogenous and distinct event of interest that affects household carbon footprints. The temporal alignment of this event allows for the comparison of carbon footprints before and during the pandemic.

[8] Appendix G provides estimation results using quantile regressions instead of OLS, to account for the slight skewness to the right of households carbon footprints in our sample. Results using quantile regressions are in line with those presented in the main text.

[9] An analysis with a dichotomous vairable equal to equal to 0 before and 1 after the start of the pandemic was undertaken. Results remain similar.

Second, the assumption of parallel trends posits that, in the absence of the Covid-19 pandemic, the trajectories of household carbon footprints would have followed similar patterns between households led by male and female primary income earners. This assumption helps in attributing differences in carbon footprints to the pandemic's impact rather than pre-existing divergent trends.

Third, the identification relies on the assumption that there are no other significant shocks or events during the study period that differentially affect households with male and female primary income earners, apart from the Covid-19 pandemic.

Fourth, the identification strategy assumes that any unobserved factor influencing both the event (Covid-19) and household carbon footprints is adequately captured by the observed covariates included in the model and that there is no other unobserved household characteristics that may affect the household carbon footprint. This assumption helps controlling for potential confounding variables that could otherwise bias the estimated effects.

Fifth, the underlying assumption that there is no endogeneity suggests that the gender composition of the household (whether the breadwinner is male or female) is determined exogenously and is not influenced by other variables that might affect the household's carbon footprint. One potential confounding factor is household income, which could influence both the gender composition of the household's breadwinner and the overall carbon footprint.

Last, the identification strategy assumes that the effect of the Covid-19 pandemic on household carbon footprints is homogenous across all households. This threat is disregarded since the Covid-19 pandemic represented a global and widespread shock that affected households irrespective of their gender composition. The pandemic's impact, such as changes in consumption patterns, restrictions on mobility, and economic disruptions, was not inherently dependent on whether the breadwinner was a man or a woman.

The next section presents the main results, and the potential threats of the identification assumptions are discussed in section 5.

4. Results

4.1. Main results

The results of the main specification as presented in equation (1) are available in Table 5. To comprehensively assess the impact of Covid-19 on household carbon footprints with respect to the head of household's gender, we examine different model specifications in distinct columns. Column (1) outlines the specification without covariates or two-week period fixed effects. Column (2) adds two-week period fixed effects, excluding other covariates. Column (3) includes household covariates, omitting covariates specific to the breadwinner. The most comprehensive model in Column (4) incorporates all covariates. Notably, the inclusion of various covariates, whether individually or collectively, does not significantly alter the sign, magnitude, or significance of the coefficient of interest, $\hat{\beta}_3$. The fully specified model in Column (4) thus serves as the primary basis for examining the relationship between the gender of the breadwinner and household carbon footprints amidst the Covid-19 pandemic.

Table 5: Effect of gender of the breadwinner of the household on household carbon footprint during COVID-19

	Household carbon footprint			
	(1)	(2)	(3)	(4)
Male	2,743.889***	2,670.609***	1,021.282***	941.592***
	(157.082)	(157.567)	(144.581)	(146.667)
Covid-19 stringency	-15.183***	-16.317***	-11.637***	-12.174***
	(3.121)	(3.207)	(2.879)	(2.881)
Male × Covid-19 stringency	-6.842*	-7.361*	-7.498**	-7.597**
	(3.871)	(3.864)	(3.467)	(3.465)
Wallonia		97.139	116.750	184.637*
		(123.377)	(111.200)	(111.547)
Brussels		-1,120.258***	-77.125	77.641
		(189.310)	(174.149)	(176.030)
Household size			1,014.261***	1,078.512***
			(50.053)	(52.755)
Household income (€/month)			0.620***	0.583***
			(0.029)	(0.030)
Private car			1,611.348***	1,555.309***
			(78.649)	(79.000)
Company car			524.952***	496.961***
			(146.359)	(147.299)
Age hh head				4.945
				(5.526)
Half-month FE	No	Yes	Yes	Yes
Prof. Status	No	No	No	Yes
Observations	12,241	12,241	12,241	12,208
R^2	0.045	0.051	0.237	0.241

Dependent variable in the four columns is the total household carbon footprint. Carbon footprint are given in terms of kg CO2e. Column 4 also controls for different categories of professional status of the primary income earner (Has a job; Has found a job but has not yet started; Student/in training; Homemaker/caring for household; Incapacity to work; Unemployed; On leave prior to retirement or on pre-retirement; Is retired or on early retirement; Other unemployed situation). Household income represents the aggregated monthly income of the household in €/month. Standard errors in parenthesis. Significance: * ($p < 0.10$), ** ($p < 0.05$), *** ($p < 0.01$).

Gender effect. The analysis reveals gender-based disparities in household carbon footprints before the Covid-19 pandemic. Notably, households with male primary earners, indicated by a positive coefficient for male breadwinners ($\hat{\beta}_1 = 942$), exhibit significantly higher carbon footprints compared to those led by females.

Covid-19 effect. The Covid-19 pandemic had an average negative effect on household carbon footprints, represented by $\hat{\beta}_2$ + $\hat{\beta}_3\times$ *Share male-led households* for an additional unit of Covid-19 stringency. This implies that stricter pandemic-related restrictions, such as lockdowns and movement limitations, are correlated with reduced household carbon emissions. Specifically, an increase in the stringency index from 20 (beginning of March 2020) to 82 (mid-March 2020) correlates with an average decrease in household carbon footprint of approximately 1017 $kgC0_{2e}$ when considering a share of male-led households equal to 63% in 2020. This finding aligns with the hypothesis that increased restrictions lead to lower carbon emissions due to altered mobility patterns, consumption habits, and reduced overall economic activity.

Covid-19 and gender effect. Our results shed light on the differential effect of the pandemic on household carbon footprints for male and female-led households. For female-led households, an additional unit of Covid-19 stringency leads to an average carbon footprint reduction of 12 $kgC0_{2e}$. For male-led households, it is equal to 20 $kgC0_{2e}$. This suggests that the reduction in carbon footprint was more marked in households with male breadwinners as the pandemic measures intensified. Specifically, an increase in the stringency index from 20 (beginning of March 2020) to 82 (mid-March 2020) correlates with an average decrease in the carbon footprint of approximately 744 $kgC0_{2e}$ for female-led households and 1240 $kgC0_{2e}$ for male-led households.[10] It confirms the intuition formulated at the time of data description, namely that there is a gender effect of the pandemic on household emissions. We discuss it further in the next susbection, to shed light on the source of the identified gendered disparities in carbon footprint reductions.

Socioeconomic effects. The analysis of covariates reveals regional differences in household carbon footprints, aligning with Géal and Michel (2023). Looking at Column (4), households in Wallonia exhibit higher carbon emissions compared to Flanders, with no significant disparity between Flanders and Brussels. Household size and income are positively correlated with emissions: an additional household member increases the carbon footprint by over 1000 $kgC0_{2e}$, while each additional euro of income contributes 0.583 $kgC0_{2e}$ to the footprint. An average additional income of 2500 euros (the average Belgian

[10] To put these figures in perspective, it represents a decrease in the average 2018 household carbon footprint of 6% for female-led households and 9% for male-led households. Percentages are calculated using average carbon footprints in Table 2.

wage in 2020 was 2471 euros (Statista, 2023)) would result in an increase of approximately 1457 $kgC0_{2e}$ in household emissions. In addition, ownership of a private car significantly influences household carbon footprints, primarily due to fuel combustion-related emissions. Similarly, possessing a company car also impacts the carbon footprint, albeit to a lesser extent. This reduced impact is attributed to the fact that company cars often include fuel provision, which is not accounted for in household carbon emissions calculations.

In summary, these findings underscore the gender dynamics influencing household carbon emissions during the pandemic. Male-led households not only have higher baseline emissions but also experience a more pronounced reduction in response to Covid-19 measures. The subsequent analysis further explores the mechanisms behind these effects, particularly focusing on the influence of the breadwinner's gender on the reduction of different categories of household carbon emissions during the pandemic.

4.2. Channels

Descriptive analyses of Tables 3 and 4 show larger carbon footprints for male than female breadwinner households, across most categories. These differences are largely due to higher consumption of carbon-intensive goods and services such as fuel and restaurant dining. In addition, Table 5 reveals significant differences in the effect of Covid-19 related restrictions on household carbon footprint across genders of the breadwinner. The gender difference in footprint reductions can be driven by two phenomena: either female breadwinner households decrease their carbon footprint less because they initially had a lower carbon footprint overall, or they observe a lower decrease because of expenditure specific differences across genders. We explore here the mechanisms driving this gender difference.

We analyze the gender effect of Covid-19 on specific carbon footprint categories as a mean to explain the overall gender differential effect of the pandemic on aggregate household emissions.[11] Results are presented in Table 6. In all columns, the most complete specification as given in Column (4) of Table 5 is considered, controlling for all covariates mentioned in the empirical specification. We identify six categories of household carbon footprints that demonstrate a gender differentiated impact of Covid-19 on household emissions. Results for other categories are detailed in Appendix H.

[11] Additionally, we explored other potential explanatory factors, such as the education level of family members and the occupation of the household head, but found these factors to be insignificant. We also examined different samples, including single parents and single individuals, and observed that the differential gender impact of the pandemic on household carbon footprints remains similar across these groups.

Table 6: Effect of gender of the head of the household on household carbon footprint for food at home, restaurant, furniture, energy, air transport and fuel during COVID-19

	Household carbon footprint categories					
	Food at home	Restaurant	Furniture	Energy	Flight	Fuel
Male	266.4757***	89.2816***	124.7752**	29.4190	11.4956	245.1359***
	(41.7872)	(9.9338)	(52.6853)	(26.9614)	(23.0014)	(31.2724)
Covid-19 stringency	2.9717***	-1.9445***	1.6252	-2.2209***	-1.4859***	-5.8527***
	(0.8207)	(0.1950)	(1.0348)	(0.5295)	(0.4518)	(0.6142)
Male × Covid-19 stringency	2.0845**	-1.0913***	-2.0976*	-1.2311*	-0.6409	-3.7770***
	(0.9874)	(0.2346)	(1.2449)	(0.6371)	(0.5435)	(0.7389)
Wallonia	131.9669***	-63.6070***	-177.8785***	128.2297***	-53.9917***	230.2142***
	(31.7812)	(7.5563)	(40.0698)	(20.5055)	(17.4937)	(23.7842)
Brussels	202.0786***	-9.0540	-111.2553*	-269.0977***	220.6392***	-254.4529***
	(50.1531)	(11.9161)	(63.2330)	(32.3592)	(27.6064)	(37.5332)
Household size	576.7743***	-11.2041***	-12.3531	203.2248***	-34.4985***	81.3304***
	(15.0305)	(3.5724)	(18.9504)	(9.6978)	(8.2734)	(11.2484)
Household income (€/month)	0.1674***	0.0363***	0.1147***	0.0295***	0.0488***	0.0344***
	(0.0086)	(0.0020)	(0.0108)	(0.0055)	(0.0047)	(0.0064)
Private car	191.6476***	26.6165***	116.8724***	131.8676***	2.3386	509.4668***
	(22.5082)	(5.3504)	(28.3783)	(14.5224)	(12.3894)	(16.8445)
Company car	153.3293***	75.2972***	191.3468***	129.3177***	98.4218***	-139.1042***
	(41.9673)	(9.9951)	(52.9123)	(27.0776)	(23.1005)	(31.4071)
Age hh head	20.8509***	-0.7761**	-7.5527***	10.9534***	-0.9308	-5.3023***
	(1.5744)	(0.3742)	(1.9850)	(1.0158)	(0.8666)	(1.1782)
Half-month FE	Yes	Yes	Yes	Yes	Yes	Yes
Prof. Status	Yes	Yes	Yes	Yes	Yes	Yes
Observations	12,208	12,177	12,208	12,208	12,208	12,208
R^2	0.308	0.150	0.033	0.126	0.034	0.213

Dependent variables in the columns are the household carbon footprint of different consumption goods and services in terms of kg CO2e (Food at home, restaurant, furniture and household appliances, energy, air transport and fuel). All columns control for different categories of professional status of the primary income earner (Has a job; Has found a job but has not yet started; Student/in training; Homemaker/caring for household; Incapacity to work; Unemployed; On leave prior to retirement or on pre-retirement; Is retired or on early retirement; Other unemployed situation). Household income represents the aggregated monthly income of the household in €/month. Standard errors in parenthesis. Significance: * ($p < 0.10$), ** ($p < 0.05$), *** ($p < 0.01$).

Food. For food consumed at home in Column (1) of Table 6, the interaction between male breadwinner gender and Covid-19 stringency suggests an increase in emissions for male-breadwinner households compared to female-breadwinner households. This could be attributed to a shift from outside dining to home cooking. Conversely, the out of home food category in Column (2) of Table 6 shows a decrease in emissions for male-led households during the pandemic compared to their female counterparts, likely due to mandatory closures and restrictions on dining out.[12] This reduction is offset by the increase in home food consumption emissions, underscoring a shift in consumption patterns rather than an outright reduction.

Household appliance. In the furniture and household appliances in Column (3) of Table 6, a higher decrease in emissions for male-breadwinner households is observed compared to female-breadwinner households. It is consistent with the descriptive statistics illustrating that households in which the breadwinner is female increased their carbon footprint related to this category, while it did not change significantly for their male counterparts during Covid-19. When looking at our data, a deeper analysis into expenditure reveals that female-led households notably increased spending on items enhancing home comfort, such as furniture and decorations, during Covid-19. This trend suggests an emphasis on creating a cozy living environment amidst the pandemic, contributing to a slight increase in their carbon footprint in this category.

Energy. In Column (4) of Table 6, the significant negative coefficient for energy consumption in male-led households during the Covid-19 pandemic implies a larger decrease in energy-related emissions compared to female-led households. This difference stems from a higher baseline energy consumption in male-led households, possibly due to factors like larger dwellings. The pandemic likely presented these households with more opportunities to reduce consumption, such as decreasing non-essential electricity and heating usage, resulting in a notable decline in energy emissions. The significant negative coefficient for energy consumption in male-led households during the Covid-19 pandemic suggests a nuanced change in household energy dynamics, primarily driven by a higher baseline energy consumption in male-led households and by variations in gas consumption. While initial assessments indicated a broad reduction in energy-related emissions, a closer examination of our data reveals that the decrease in energy consumption among male-led households was due to reduced gas expenses. Conversely, female-led households exhibited a slight increase in gas consumption during the same period.

[12] According to our data, households in which the breadwinner is a man spent almost twice as much in out of home food as woman-led households before the Covid-19.

Airplane. For the flights category in Column (5), the coefficient of interest is negative, albeit not as significant as for other categories. It is retained in the analysis due to its economic importance. Households with male breadwinners, which initially have higher emissions from air travel, were more impacted by Covid-19 mobility restrictions.

Fuel combustion. In Column (6) of Table 6 representing the fuel category which typically includes personal vehicle use, a higher decrease in emissions for male-breadwinner households is observed compared to female-breadwinner. This aligns with the broader mobility restrictions imposed during the pandemic, which curtailed the use of vehicles, especially for men that tend to have higher car mobility emissions.

When examining the cumulative effect of the pandemic on various household carbon footprint categories, the data distinctly show a negative differential gender effect of Covid-19 on household emissions. While individual categories exhibit varying trends, such as increased food consumption emissions at home and decreased energy and travel-related emissions, the aggregated effect for male-breadwinner households is a larger reduction in overall carbon footprint compared to female-breadwinner households. This overall negative effect emerges from the sum of category-specific changes, where the substantial decreases in emissions across several key areas, particularly those with traditionally higher consumption by male-led households, outweigh the increases in others. The analysis confirms that the gender of the breadwinner is a significant determinant in the household's carbon footprint response to the pandemic, with male-breadwinner households experiencing a more pronounced decline in their carbon footprints. Figure 1 visually summarizes the coefficients of interest $\hat{\beta}_3$ for the six carbon footprint categories analyzed, elucidating the overall negative coefficient in Table 5.

The economic interpretation of this graph is linked to the Covid-19 stringency index. For example, an increase in the stringency index from 20 (beginning of March 2020) to 82 (mid-March 2020) corresponds to an average increase in the in-home food carbon footprint among male-led households of 124 $kgCO_{2e}$ more than female-led households.[13] The difference is most pronounced in fuel-related emissions, where a change of 60 in the Covid-19 stringency index results in an average decrease in the fuel-related emissions among male-led households of 229 $kgCO_{2e}$ more than female-led households.[14] Similar interpretations can be done for restaurant, furniture, energy and flight-related emissions.

The next section shows the validity of our identification strategy and results, by checking that assumptions discussed in Section 3.2 hold.

[13]To put this figure in perspective, 124 $kgCO_{2e}$ represents 3% of the in-home food carbon footprint among male-led households in 2018. Percentages are calculated using average carbon footprints in Tables 3 and 4.

[14]229 $kgCO_{2e}$ represents 16% of the fuel-related emissions among male-led households in 2018.

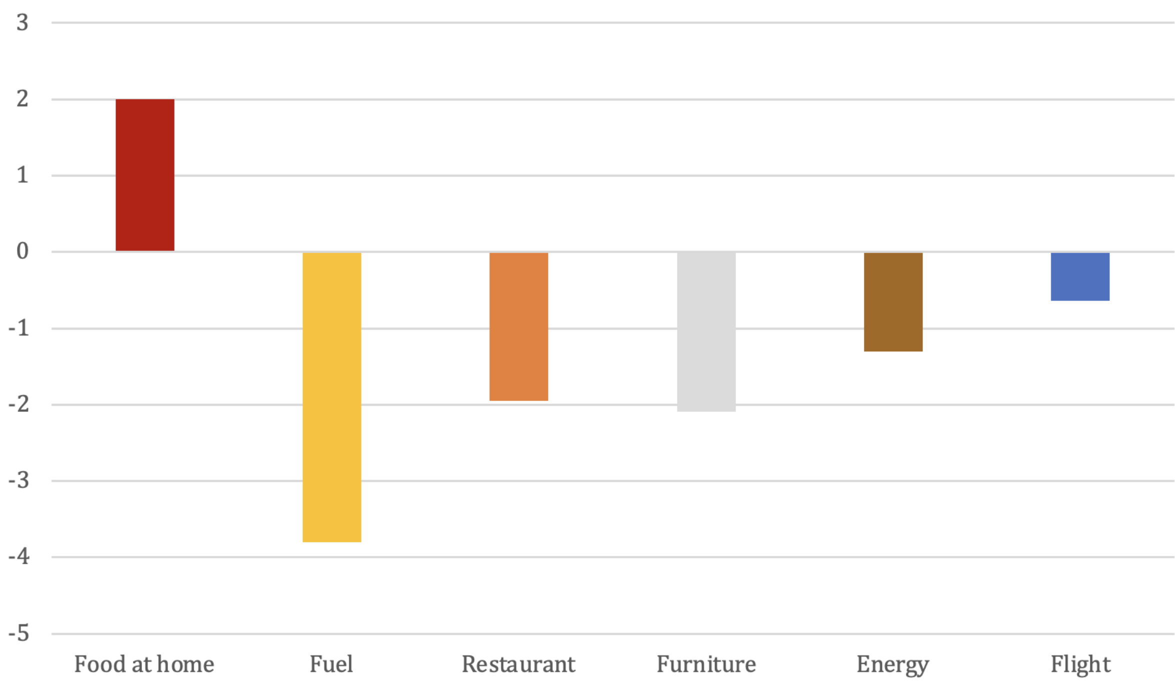

Figure 1: Average difference of the effect of Covid-19 differentiating for gender for different carbon footprint categories (β_3 estimates in $kgC0_{2e}$)

5. Robustness checks

In the next subsections, we test for the parallel trends assumption in subsection 5.1, for the absence of differential shocks in subsection 5.2, for the absence of confounders in subsection 5.3 and for the absence of endogeneity in subsection 5.4.

5.1. Parallel trends

The parallel trends assumption should be discussed for causal inference. It hypothesizes that, in the absence of Covid-19, male and female breadwinner households would have followed similar trajectories. Data leading up to 2020 corroborates this assumption, as the average household carbon footprint for both groups shows a comparable rate of decrease. This similar trend persists even with the onset of the pandemic with a slightly higher rate of decrease for households in which the breadwinner is male.

The trends illustrated in Figure 2 reinforce the reliability of the main analysis. They suggest that any observed post-pandemic differences in carbon footprints between male and female breadwinner households can be reasonably attributed to the impact of the pandemic, rather than to any pre-existing divergent trends.

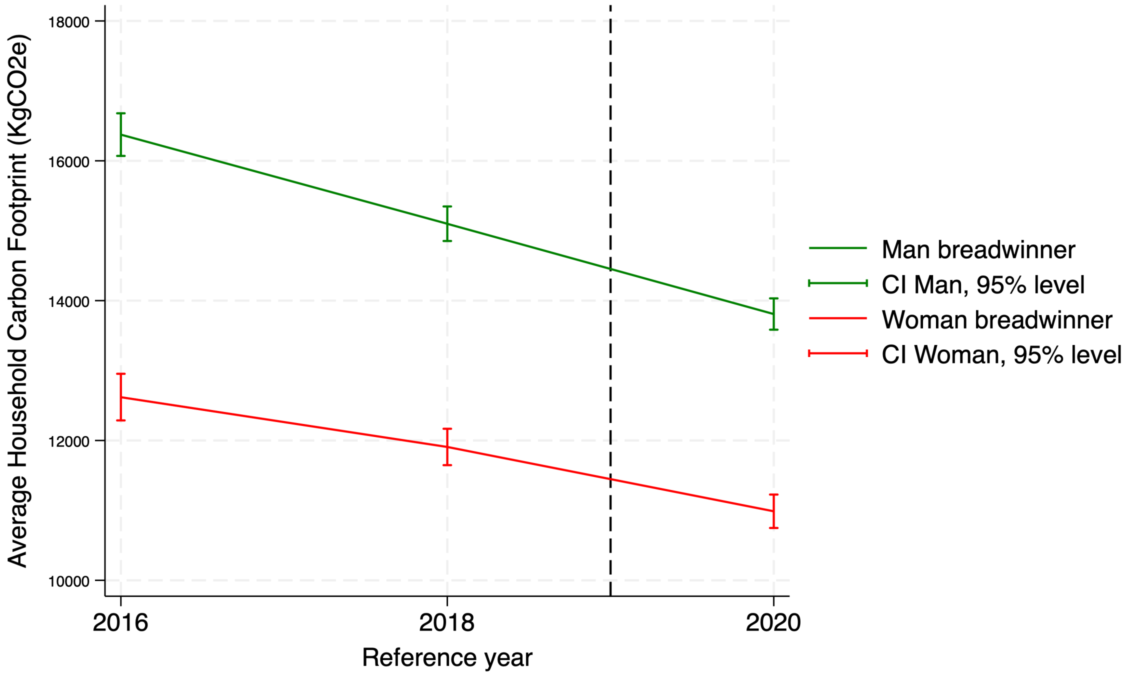

Figure 2: Average Household Carbon Footprint by Gender of the Breadwinner over time

5.2. Absence of differential shocks

The event study approach assumes that no other major shocks, apart from the Covid-19 induced restrictions, differentially influenced households with male and female breadwinners during the study period. To address potential concerns, we use data from households in the BHBS during January and February 2020 as a counterfactual, contrasting them with data from 2018. January and February are chosen as counterfactuals, as no restrictive measures had yet been implemented in Belgium.[15]

This approach is based on the premise that before March 2020, the pandemic had not yet differentially impacted household carbon footprints. Therefore, in the absence of differential shocks, the coefficient of interest, $\hat{\beta}_3$, is expected to show negligible impact during these months.

Notably, February is considered the onset of the Covid-19 period, despite the absence of official restrictions in Belgium then. This is because public awareness of the pandemic was rising, even though restrictions were not yet in place. In our analysis, we replace the stringency index with a binary variable: zero for interviews conducted in 2018 (similar to the main analysis) and one for those in January or February 2020.

[15]In the main analysis, February is taken as a threshold because the Covid-19 stringency index was not equal to zero anymore. This is due to the fact that the awareness of the population about the pandemic had already started, but not clear restrictions had yet been implemented.

We detail results in Appendix I.1. In this refined analysis, examining various household carbon footprint categories, the primary coefficient $\hat{\beta}_3$ does not show statistical significance, contrasting with its significance in the main analysis. Hence, this finding bolsters the conclusion that the observed differences in household emissions are indeed due to the Covid-19 induced restrictions leading to a gender-differentiated impact.

5.3. No observed confounders

The identification strategy assumes that any unobserved factors influencing both Covid-19 and household carbon footprints are captured by the model's observed covariates, eliminating the influence of unobserved household characteristics. To reinforce this, we conduct a synthetic panel analysis, creating cohorts based on region, income and age deciles, and breadwinner gender. This method, accounting for cohort year fixed-effects, controls for unobserved household characteristics that may vary over time and is further explained by Deaton (1985).

Results are available in Table I.12 of Appendix I.2 and align with the main findings. The synthetic panel approach, despite reducing sample size causing some coefficients to lose statistical significance, maintains economic significance and supports the differential impact of the pandemic across household types based on the breadwinner's gender.

Additionally, to address potential income disparities and related characteristics, particularly between households with male and female breadwinners, we employ a matching approach. This method compares carbon footprint disparities between households with similar characteristics, differing only in the breadwinner's gender. The selection of covariates for matching and subsequent balance assessment within matched pairs ensures that observed differences in carbon footprints are attributable to the breadwinner's gender. The selection of covariates for matching—including household income, size, and the age of the breadwinner—is based on their presumed influence on both the gender of the breadwinner and the household's carbon footprint. Post-matching, the covariate balance within matched pairs is assessed to ensure similarity between the groups in each pair. This balance is crucial as it supports the attribution of any observed carbon footprint differences to the gender of the breadwinner.[16] The results, detailed in Table I.13 of Appendix I.2, confirm the main findings, albeit with a slightly lower effect size.

[16]In the matching process, only three observations are off-support. Off-support refers to the region of the propensity score distribution where there is a lack of overlap or common support between the treated and control units. It represents the range of propensity scores where treated and control units have very different distributions, making it challenging to compare their outcomes reliably.

5.4. Absence of endogeneity

The assumption of no endogeneity presupposes that the gender composition of a household's primary income earner (male or female) is not influenced by other factors affecting household carbon footprints, such as income. To address potential income-related endogeneity, we analyze the impact of household income over time on carbon footprints. This is conducted using an augmented version of the identification strategy from equation (1) in Table I.14 of Appendix I.3, which includes an interaction term between household income deciles and a binary pre- and during-Covid-19 variable. This method controls for the temporal effect of income on household emissions.

The findings demonstrate that for the first seven income deciles, income is not the main driver of household emissions during the pandemic. However, for the top three income deciles, a significant reduction in carbon footprints is observed, suggesting a decrease in emissions during the pandemic for higher income households. Despite accounting for income effects over time, the gender disparity in household carbon footprints remains evident. The coefficient $\hat{\beta}_3$ maintains consistent magnitude across income levels, indicating that the gender impact on household emissions is not merely an artifact of income variations but a distinct factor. The robustness of $\hat{\beta}_3$, even with the introduction of income interaction terms, reinforces that gender-based disparities in emissions are not confounded by income. This supports the absence of an endogeneity problem in our analysis.

6. Conclusion

The analysis of household greenhouse gas emissions during the Covid-19 pandemic reveals a clear connection between gender of the household's breadwinner and how household consumption behaviors were influenced by government policies. Our analysis confirms the initial premise that male breadwinner households typically have a higher carbon footprint than their female counterparts, driven predominantly by their greater consumption of carbon-intensive goods and services, such as those associated with private transportation and dining out.

Using Covid-19 related restrictions on individual lifestyles, we shed light on how household's carbon footprints are impacted by constraints on their usual spending patterns across gender of the breadwinner. We find a larger decrease in emissions in male breadwinner households than in their female counterpart.

We then undertake a comprehensive evaluation of the pandemic's impact on various household carbon footprint categories, to undercover the consumption categories driving these gender based differences. Interestingly, while we find that the pandemic restrictions had an negative effect on most household carbon footprint categories, albeit larger for male breadwinner than female breadwinner households, we also shed light on diverging patterns for some categories. Particularly, while both men-led and women-led households increased in home food emissions and decreased out of home food emissions, fuel and traveling emissions, and energy emissions, we find that women increased emissions related to household goods while men decreased them. These gender specific patterns, leading to an overall larger decrease of emissions for male than female-led households, shed light on precise policy interventions opportunities.

In light of these findings, this study proposes a paradigm shift in economic policies aimed at decarbonization, advocating for a gender-sensitive approach that transcends traditional income-centric models. Recognizing the distinct consumption behaviors and carbon footprint contributions of households led by male versus female breadwinners, it becomes imperative for policymakers to devise strategies that are attuned to these gender-specific nuances. By integrating gender considerations into the formulation of economic policies, there is a unique opportunity to devise more effective and inclusive interventions that not only promote environmental sustainability but also contribute to reducing gender inequality in the context of climate change impacts. Such an approach can ensure that efforts to mitigate household carbon emissions are equitable, addressing the distributive nature of carbon footprints. There is also a clear opportunity for crafting targeted educational initiatives and incentives that promote sustainable practices, particularly in the context of transportation and energy use.

Looking ahead, it has become evident that the anticipated rebound effect in carbon emissions following the easing of pandemic restrictions has occurred. Notably, findings from Davis et al. (2022) and Crippa et al. (2022) illustrate a significant resurgence in carbon emissions to pre-pandemic levels or higher, without specifically delineating the impact by gender. This observed rebound underscores the critical need for adaptive policy measures. While these studies do not explicitly analyze gender differences in the rebound effect, the implication for gender-specific policy interventions remains pertinent. The temporary reduction in emissions during the pandemic highlighted the potential for sustainable behavior changes. To capitalize on this, policies should encourage the continuation of practices beneficial during the pandemic, such as remote work and reduced travel. Furthermore, considering the differential impact of the pandemic on gender roles within households, there is a compelling argument for policies that specifically support and promote women's influence in household decision-making related to sustainability. This approach can help to mitigate the rebound effect and contribute to lasting reductions in household carbon emissions.

In essence, the emerging narrative from this analysis is not one of a uniform reduction but a complex landscape of shifts in household carbon footprints during the pandemic, characterized by distinct gender-based heterogeneity. This complexity emphasizes the necessity for customized policy interventions that are aware of the diverse contributions to carbon footprints and are sensitive to the multifaceted factors that shape them, including the pivotal influence of the breadwinner's gender.

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Appendix - The Differential impact of Covid-19 on Household Carbon Footprint: A Gender Perspective

A. Expenditure categories taken into account from the BHBS

1. Bread and cereals
2. Products of meat cattle
3. Products of meat pigs
4. Meat products nec (sheep and lamb)
5. Products of meat poultry
6. Other meat
7. Fish products
8. Milk, cheese and eggs
9. Dairy products
10. Products of Vegetable oils and fats
11. Dairy products
12. Fruit
13. Vegetables
14. Sugar. jam. honey. chocolate and confectionery
15. Food products nec
16. Beverages
17. Tobacco
18. Clothing
19. Footwear
20. Real estate services
21. Maintenance and repair of the dwelling
22. Water supply and miscellaneous services reacting to the dwelling
23. Electricity
24. Gas
25. Liquid fuels

26. Solid fuels
27. Furniture and furnishing
28. Carpets and other floor covering
29. Repair of furniture
30. Household textiles
31. Household appliances
32. Glassware, tableware and household ustensils
33. Tools and equipment for the house
34. Non-durable hh goods
35. Domestic services and hh services
36. Medical products
37. Out patient and medical services
38. Purchase of vehicles
39. Spare parts and accessories for personal transport equipment
40. Diesel
41. Gasoline
42. LPG
43. Lubrificants
44. Maintenance and repair of personal transport equipment
45. Other services in respect of personal transport equipment
46. Passenger transport by railway
47. Passenger transport by road
48. Passenger transport by air
49. Passenger transport by sea and inland waterway
50. Combined passenger transport
51. Other purchased transport services
52. Communication
53. Audio-visual, photographic and information processing equipment
54. Other major durables for recreation and culture
55. Other recreational items and equipment, gardens and pets

56. Recreational and cultural services
57. Newspapers, books and stationery
58. Package holidays
59. Education
60. Catering services
61. Accomodation services
62. Personal care
63. Jewellery
64. Other personal effects
65. Social protection
66. Insurance
67. Other financial services

B. Environmentally Extended Multi Regional Input Output Analysis: Exiobase

Formally, take an economy with n products categories. Each product category i produces x_i monetary units (in millions EUR) of a single homogenous good i. Assume that in order to produce 1 unit, the jth product category must use a_{ij} units from product i. Furthermore, assume that each product category sells some of its output to other product categories (intermediate output) and some of its output to consumers (final output, or final consumption). Call final consumption vector in the i_{th} sector c_i. We can write:

$$x_i = a_{i1}x_i + a_{i2}x_2 + ... + a_{in}x_n + c_i \tag{B.1}$$

where total output equals intermediate output plus final output. If we let A be the matrix of coefficients a_{ij}, x be the vector of total output, and c be the vector of final consumption. The expression for the economy becomes:

$$\mathbf{x} = A\mathbf{x} + \mathbf{c} \tag{B.2}$$

After rewriting, it becomes:

$$\mathbf{x} = (I - A)^{-1}\mathbf{c} \tag{B.3}$$

with c being the vector of final consumption for each good, also seen as final demand. $(I - A)^{-1}$ is known as the 'Leontief matrix' of dimension nxn, capturing intersectoral dependencies. The Leontief matrix helps quantify the direct requirements of one product category to produce one unit of output in another product category. It is then multiplied by the nxn diagonal matrix of emission coefficients S, leading to:

$$C0_2e = S(I - A)^{-1}\mathbf{c} \tag{B.4}$$

with $C0_2e$ being the vector of total requirement of environmental factors of dimension nx1, providing the level of emissions embodied in final consumption.

Applying the method to data sources coming from Exiobase directly provides the matrix $M = S(I - A)^{-1}$ for respective years 2018 and 2020. The M matrix represents the MRIO extension multipliers (total requirement factors of consumption). It is composed of 126 impacts per euro, ranging from environmental to health impacts. In this paper, we use the impact factor 'GHG emissions AR5 (GWP100) | GWP100 (IPCC, 2010)' to convert expenditures into carbon footprint. The choice of this impact factor is motivated by the most recent source from the IPCC (2010), since other global warming potential impact factors provided by Exiobase are less recent. Given that the emission factors are tailored to each individual year, the process of multiplying the expenditures derived from BHBS by the corresponding emission factors for the years 2018 and 2020 facilitates a comparative analysis of the carbon footprints linked to these expenditures across the two specified years. The utilization of accurate emission factors corresponding to their respective years obviates the necessity for adjustments pertaining to inflation or other alterations in prices.

C. Harmonisation of BHBS and Exiobase

A limitation of the concordance table introduced by Ivanova and Wood (2020) pertains to instances where consumption categories are aggregated at a higher level of abstraction, such as in the case of the category 'meat' defined in their research paper. In contrast, Exiobase emission factors offer a more refined and detailed level of granularity, contributing to enhanced precision. This aggregation of consumption categories in the concordance table could be attributed to the authors' focus on facilitating alignment and cross-country comparison across all European Union member states. However, given the specific context of this study focusing solely on Belgium and leveraging the more intricate breakdown of expenditures provided by the BHBS, an endeavor is undertaken to further subdivide consumption categories. By incorporating more precise emission factors from Exiobase, the resulting carbon footprint estimates align more closely with the actual emissions associated with household expenditures. Notably, the adaptations made in this research when compared to the approach by Ivanova and Wood (2020) encompass the following key modifications:

- Rather than having meat as one category, it is subdivided in terms of red meat (beef and calf), porc meat, sheep and lamb meat, chicken meat, fish, and meat that is not elsewhere classified (such as meat from other animals such as rabits and horse, offals, skewers).
- Rather than having just one category for oil and fat, it is subdivided into butter, vegetable oils and other animal fat.
- Rather than having just one category for Fuels and lubricants for personal transport equipment, it is subdivided into diesel, gasoline, LPG and other lubricants.
- Another bridge change that is worth being notified focuses on the initial composition of the bridges for the 'Fuels and lubricants for personal transportation equipment' category in Ivanova and Wood (2020) and the sub-category 'lubricants' that composed it as explained above. When looking at how Ivanova and Wood (2020) built the emission factor for 'Fuels and lubricants for personal transportation equipment' containing lubricants, 1% of emissions in this category are attributed to aviation gasoline and 1% are attributed to gasoline-type jet fuel. This leads to emission factors linked to this category to be much higher than any emission factor from any different consumption category across all expenditures. To provide results that are representative of the Belgian sample, this research paper does not allocate part of the emission factor from the consumption category 'Fuels and lubricants for personal transportation equipment' neither to aviation gasoline nor to gasoline-type jet fuel. When following the same methodology of Ivanova and Wood (2020), the emission factor equaled 257.83 $kgC0_{2e}$ per euro spent in 2018 and 1,21 $kgC0_{2e}$ in 2020. Without considering aviation gasoline and gasoline-type jet fuel, it is equal to 1.13 $kgC0_{2e}$ per euro spent in 2018 and 1,05 in 2020. Excluding the lubricants linked to aviation seems plausible since otherwise the emission factor is too high (the highest among any consumption category of households) and provides biased results in which emissions from consumption of lubricants exceeds any other consumption category. Emissions linked to aviation gasoline and gasoline type jet fuel that are used in the emission factors 'Fuels and lubricants for personal transportation equipment' in Ivanova and Wood (2020) may be due to some households having their own private plane or jet. Looking at expenditures from the BHBS, it is not the case for any household. It thus strengthens the choice not to include it.
- For the bridge allowing to compute emissions related to 'furniture and furnishing expenditures', the composition is 'furniture; other manufactured goods not elsewhere classified'(99% of the composition) and 'secondary raw materials' (1% of the composition). 'Secondary raw materials' is not considered, since it leads to an emission factor of 7.98 $kgC0_{2e}$ per euro spent in 2018 and 7.41 $kgC0_{2e}$ per euro spent in 2020. Put differently, considering the component 'secondary raw materials' in the

carbon footprint of households when calculating their emissions linked to their furniture expenditures lead to an average household carbon footprint of 6000 $kgC0_{2e}$ in 2018 and 5700 $kgC0_{2e}$ in 2020 and outliers. Without considering 'secondary raw materials', the conversion factors equal 0.66 and 0.62 $kgC0_{2e}$ per euro spent in 2018 and 2020 respectively.

D. Descriptive statistics of households in 2018 and 2020 separately

Table D.7: Mean and standard deviation of variables used in the analysis based on different head of households for 2018

	Single adult		Not single adult	
	Male Head	Female Head	Male Head	Female Head
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Household size	1.04	1.21	2.89	2.84
	(0.25)	(0.61)	(1.13)	(1.00)
Number of working individuals	0.46	0.43	1.15	1.17
	(0.50)	(0.49)	(0.95)	(0.77)
Number of retired	0.33	0.37	0.61	0.19
	(0.47)	(0.48)	(0.85)	(0.50)
Number of unemployed	0.17	0.17	0.27	0.32
	(0.37)	(0.37)	(0.54)	(0.57)
Number of students	0.01	0.01	0.22	0.37
	(0.09)	(0.12)	(0.58)	(0.71)
Number of children	0.04	0.21	0.53	0.68
	(0.25)	(0.61)	(0.91)	(0.91)
Income of hh head (€/month)	1961.96	1823.09	2418.61	2166.43
	(1069.50)	(1080.07)	(1344.17)	(1040.03)
Household income (€/month)	1970.47	1855.47	4283.26	3613.49
	(1073.42)	(1117.21)	(2835.87)	(1947.97)
Age hh head	55.05	55.60	54.45	46.39
	(16.05)	(15.99)	(15.23)	(12.79)
Household carbon footprint (kgCO2e)	9420.50	9723.05	16514.08	14195.63
	(5211.46)	(4601.40)	(7858.97)	(6671.37)
Individual carbon footprint (kgCO2e)	9210.19	8797.87	6262.81	5344.82
	(5216.44)	(4458.01)	(3469.28)	(2663.96)
Private car	0.74	0.71	1.28	1.11
	(0.55)	(0.47)	(0.69)	(0.69)
Company car	0.00	0.00	0.16	0.10
	(0.05)	(0.06)	(0.46)	(0.35)
Observations	812	1188	3188	1131

Column 1 and 2 consider household in which there is one single adult, and column 3 and 4 consider household in which there is more than one single adult. Column 1 and 3 consider households in which the primary income earner is a male, and column 2 and 4 considers household in which the primary income earner is a female. Income of the household head represents the monthly income of the primary income earner in €/month, and household income represents the aggregated monthly income of the household in €/month.

Table D.8: Mean and standard deviation of variables used in the analysis based on different head of households for 2020

	Single adult		Not single adult	
	Male Head	Female Head	Male Head	Female Head
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Household size	1.08	1.18	2.86	2.83
	(0.36)	(0.54)	(1.10)	(1.03)
Number of working individuals	0.46	0.43	1.13	1.21
	(0.50)	(0.50)	(0.95)	(0.76)
Number of retired	0.39	0.42	0.67	0.20
	(0.49)	(0.49)	(0.87)	(0.51)
Number of unemployed	0.14	0.13	0.24	0.29
	(0.35)	(0.34)	(0.51)	(0.56)
Number of students	0.00	0.01	0.25	0.41
	(0.06)	(0.11)	(0.62)	(0.68)
Number of children	0.08	0.18	0.54	0.72
	(0.36)	(0.54)	(0.91)	(0.96)
Income of hh head (€/month)	1951.24	1815.65	2293.88	2009.62
	(871.99)	(1010.37)	(1228.99)	(967.23)
Household income (€/month)	1962.74	1820.92	3839.25	3253.97
	(859.66)	(1005.80)	(1682.29)	(1569.86)
Age hh head	56.61	57.05	55.63	46.45
	(16.85)	(16.77)	(15.48)	(13.28)
Household carbon footprint (kgCO2e)	8684.37	9155.99	15106.15	13064.14
	(4581.23)	(4598.32)	(7141.33)	(5947.90)
Individual carbon footprint (kgCO2e)	8345.42	8449.43	5774.31	4971.83
	(4508.62)	(4647.64)	(3030.32)	(2462.76)
Private car	0.83	0.72	1.30	1.07
	(1.06)	(0.56)	(0.73)	(0.69)
Company car	0.01	0.00	0.19	0.12
	(0.11)	(0.00)	(0.49)	(0.41)
Observations	856	1277	3137	1029

Column 1 and 2 consider household in which there is one single adult, and column 3 and 4 consider household in which there is more than one single adult. Column 1 and 3 consider households in which the primary income earner is a male, and column 2 and 4 considers household in which the primary income earner is a female. Income of the household head represents the monthly income of the primary income earner in €/month, and household income represents the aggregated monthly income of the household in €/month.

E. Covid-19 Stringency Index in Belgium

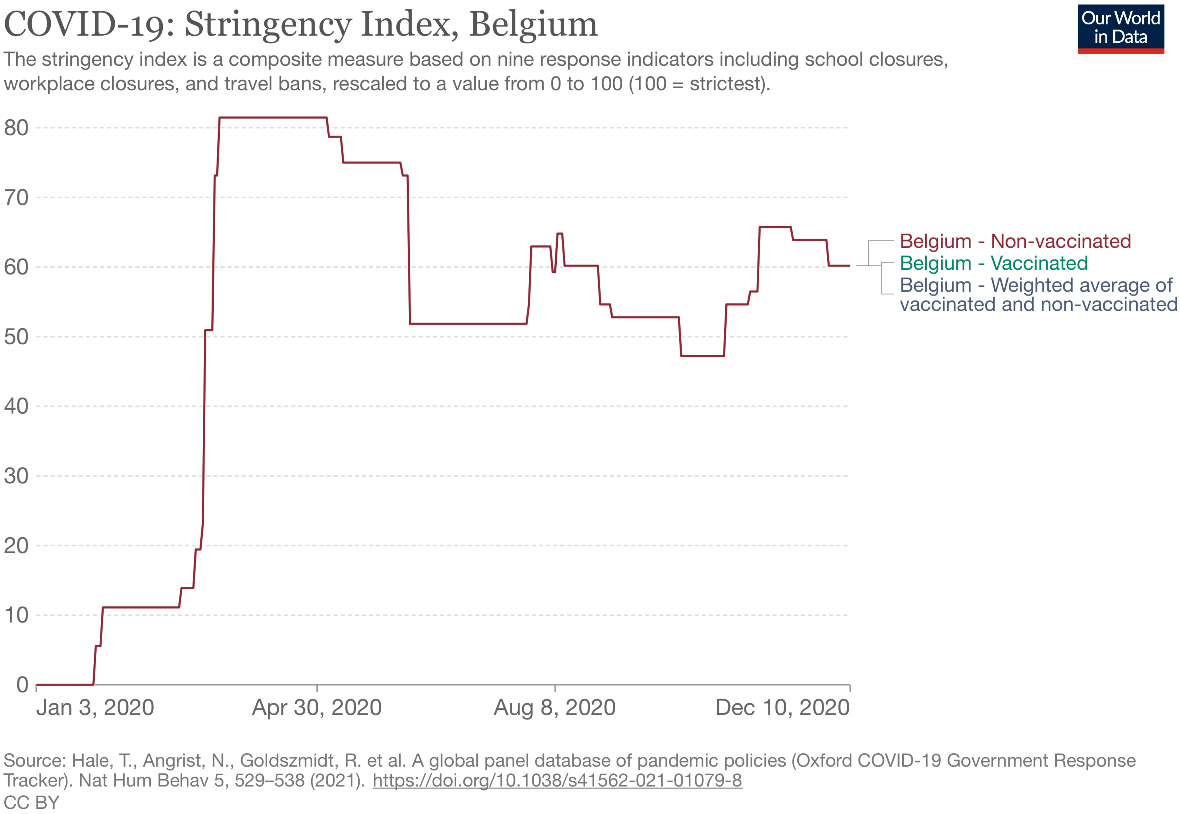

Figure E.3: Covid-19 Stringency Index in Belgium in 2020, Our World in Data

F. Distribution of the Household Carbon Footprint

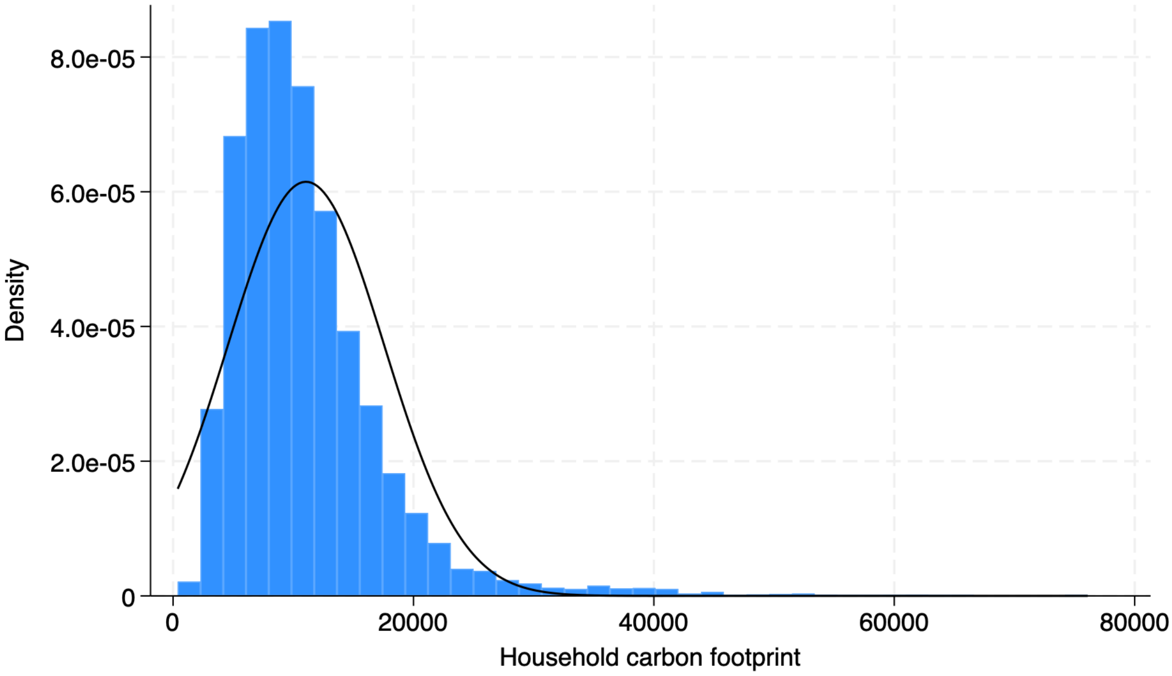

Figure F.4: Distribution of the and household carbon footprint

G. Quantile regression analysis

OLS regression focuses on estimating the mean of the dependent variable conditional on the independent variables. However, when the distribution of the dependent variable is skewed, the mean may not be the best measure of central tendency, as it can be heavily influenced by outliers. Quantile regression, on the other hand, estimates the median (or other quantiles) of the dependent variable, providing a more robust measure in the presence of skewed distributions.

Table G.9: Effect of gender of the breadwinner of the household on household carbon footprint during COVID-19 performing median regressions

	Household carbon footprint			
	(1)	(2)	(3)	(4)
Male	2,691.884***	2,611.488***	593.948***	592.949***
	(145.619)	(146.065)	(121.556)	(126.559)
Covid-19 stringency	-14.618***	-14.173***	-10.719***	-10.387***
	(2.893)	(2.973)	(2.421)	(2.486)
Male × Covid-19 stringency	-5.006	-7.168**	-5.275*	-6.456**
	(3.589)	(3.582)	(2.915)	(2.990)
Wallonia		259.310**	293.634***	331.117***
		(114.371)	(93.491)	(96.255)
Brussels		-986.111***	-56.236	148.845
		(175.491)	(146.416)	(151.897)
Household size			941.159***	1,019.542***
			(42.082)	(45.522)
Household income (€/month)			0.821***	0.777***
			(0.025)	(0.026)
Private car			1,514.792***	1,489.605***
			(66.124)	(68.170)
Company car			353.937***	381.951***
			(123.052)	(127.105)
Age hh head				6.072
				(4.768)
Half-month FE	No	Yes	Yes	Yes
Prof. Status	No	No	No	Yes
Observations	12,241	12,241	12,241	12,208
R^2				

Dependent variable in the four columns is the total household carbon footprint in terms of kg CO2e. Column 4 also controls for different categories of professional status of the primary income earner (Has a job; Has found a job but has not yet started; Student/in training; Homemaker/caring for household; Incapacity to work; Unemployed; On leave prior to retirement or on pre-retirement; Is retired or on early retirement; Other unemployed situation). Household income represents the aggregated monthly income of the household in €/month. Standard errors in parenthesis. Significance: * ($p < 0.10$), ** ($p < 0.05$), *** ($p < 0.01$).

H. Additional categories of the household carbon footprints as dependent variables

Table H.10: Effect of gender of the head of the household on household carbon footprint for tobacco, vehicle purchase, public transport, high-tech, personal belonging, clothing, recreational and water waste-related emissions during COVID-19

	Household carbon footprint categories							
	Tobacco	Vehicle	Public trans.	High-tech	Personal bel.	Clothing	Recreational	Water
Male	9.0887*	258.7134***	-6.0511	15.1177*	-26.2783***	-26.2783***	-3.8488	-23.4301
	(4.8242)	(96.2937)	(7.8087)	(7.9250)	(7.0124)	(7.0124)	(21.7093)	(16.1764)
Covid-19 stringency	-0.0048	-0.4938	-0.3757**	0.4132***	-0.9652***	-0.9652***	-1.4301***	0.1787
	(0.0947)	(1.8912)	(0.1534)	(0.1557)	(0.1377)	(0.1377)	(0.4264)	(0.3176)
Male × Covid-19 stringency	-0.0227	0.5000	-0.1540	-0.0783	0.1814	0.1814	-0.3861	-0.5421
	(0.1140)	(2.2753)	(0.1845)	(0.1873)	(0.1657)	(0.1657)	(0.5130)	(0.3822)
Wallonia	9.0723**	21.7667	-10.2683*	-4.7186	-10.0877*	-10.0877*	27.0625	63.7097***
	(3.6696)	(73.2360)	(5.9389)	(6.0274)	(5.3333)	(5.3333)	(16.5110)	(12.3036)
Brussels	-5.8484	-55.1927	76.8732***	-17.7009*	1.9446	1.9446	-30.4019	390.6769***
	(5.8000)	(115.5718)	(9.3721)	(9.5116)	(8.4163)	(8.4163)	(26.0556)	(19.4694)
Household size	-2.3941	32.2656	3.5035	28.5251***	17.0044***	17.0044***	59.9777***	32.9952***
	(1.7370)	(34.6359)	(2.8087)	(2.8506)	(2.5223)	(2.5223)	(7.8086)	(5.8201)
Household income (€/month)	-0.0038***	0.0297	0.0084***	0.0116***	0.0149***	0.0149***	0.0522***	0.0131***
	(0.0010)	(0.0198)	(0.0016)	(0.0016)	(0.0014)	(0.0014)	(0.0045)	(0.0033)
Private car	1.8493	455.0069***	-12.1227***	23.7344***	16.3064***	16.3064***	63.9512***	-12.2681
	(2.5970)	(51.8674)	(4.2061)	(4.2687)	(3.7772)	(3.7772)	(11.6935)	(8.7090)
Company car	-13.4423***	-154.0751	-26.7533***	8.8484	17.2549**	17.2549**	59.8030***	2.8572
	(4.8382)	(96.7086)	(7.8424)	(7.9592)	(7.0426)	(7.0426)	(21.8029)	(16.2526)
Age hh head	-0.4156**	-8.3215**	-0.3718	0.6211**	-0.6269**	-0.6269**	-1.8305**	0.9750
	(0.1817)	(3.6279)	(0.2942)	(0.2986)	(0.2642)	(0.2642)	(0.8179)	(0.6094)
Half-month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Prof. Status	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	12,111	12,208	12,208	12,208	12,208	12,208	12,208	12,084
R^2	0.019	0.017	0.020	0.050	0.067	0.067	0.070	0.045

Dependent variables in the columns are the household carbon footprint of different consumption goods and services in terms of kg CO2e (tobacco, vehicle purchase and maintenance, public transport, telecommunication and tech device, personal belonging, clothing, recreational and water waste). All columns control for different categories of professional status of the primary income earner (Has a job; Has found a job but has not yet started; Student/in training; Homemaker/caring for household; Incapacity to work; Unemployed; On leave prior to retirement or on pre-retirement; Is retired or on early retirement; Other unemployed situation). Household income represents the aggregated monthly income of the household in €/month. Standard errors in parenthesis. Significance: * ($p < 0.10$), ** ($p < 0.05$), *** ($p < 0.01$).

I. Robustness Checks

I.1. Absence of differential shocks

Table I.11: Effect of gender of the breadwinner of the household on household carbon footprint two months preceding COVID-19

	Household carbon footprint			
	(1)	(2)	(3)	(4)
Male	2,716.123***	2,649.645***	1,049.027***	955.844***
	(169.011)	(170.029)	(156.664)	(159.818)
Covid-19 stringency	-86.835*	-73.542	-21.390	-33.878
	(45.553)	(51.605)	(46.124)	(46.028)
Male × Covid-19 stringency	15.076	12.658	-24.825	-13.483
	(58.011)	(57.874)	(51.725)	(51.616)
Wallonia		223.637	244.273	317.635**
		(167.927)	(150.676)	(150.754)
Brussels		-1,143.178***	-25.177	153.562
		(255.632)	(233.477)	(235.013)
Household size			992.385***	1,069.251***
			(66.852)	(70.475)
Household income (€/month)			0.586***	0.548***
			(0.035)	(0.036)
Private car			1,733.844***	1,637.541***
			(103.922)	(104.459)
Company car			565.442***	520.169**
			(206.650)	(207.624)
Age hh head				14.219*
				(7.519)
Half-month FE	No	Yes	Yes	Yes
Prof. Status	No	No	No	Yes
Observations	7,045	7,045	7,045	7,021
R^2	0.039	0.048	0.241	0.249

Dependent variable in the four columns is the total household carbon footprint. Carbon footprint are given in terms of kg CO2e. Column 4 also controls for different categories of professional status of the primary income earner (Has a job; Has found a job but has not yet started; Student/in training; Homemaker/caring for household; Incapacity to work; Unemployed; On leave prior to retirement or on pre-retirement; Is retired or on early retirement; Other unemployed situation). Household income represents the aggregated monthly income of the household in €/month. Standard errors in parenthesis. Significance: * ($p < 0.10$), ** ($p < 0.05$), *** ($p < 0.01$).

I.2. No observed confounders

Table I.12: Effect of gender of the breadwinner of the household on household carbon footprint during COVID-19 via a pseudo-panel analysis

	Household carbon footprint			
	(1)	(2)	(3)	(4)
Male	3,965.363***	3,965.363***	858.017***	747.129***
	(353.428)	(353.428)	(256.897)	(262.784)
Covid-19 stringency	-5.730	-5.730	-7.444*	-7.255
	(6.897)	(6.897)	(4.480)	(4.471)
Male × Covid-19 stringency	-8.560	-8.560	-7.081	-7.272
	(8.700)	(8.700)	(5.674)	(5.662)
Household size			1,039.719***	1,213.975***
			(144.496)	(170.506)
Household income			0.817***	0.791***
			(0.066)	(0.067)
Private car			2,331.854***	2,296.883***
			(252.820)	(252.913)
Company car			-2,214.094***	-1,981.192***
			(725.837)	(734.356)
Half-month FE	No	No	No	No
Prof. Status	No	No	No	Yes
Observations	599	599	599	599
R^2	0.279	0.279	0.698	0.700

Dependent variable in the four columns is the total household carbon footprint. Carbon footprint are given in terms of kg CO2e. Column 4 also controls for different categories of professional status of the primary income earner (Has a job; Has found a job but has not yet started; Student/in training; Homemaker/caring for household; Incapacity to work; Unemployed; On leave prior to retirement or on pre-retirement; Is retired or on early retirement; Other unemployed situation). Household income represents the aggregated monthly income of the household in €/month. Standard errors in parenthesis. Significance: * ($p < 0.10$), ** ($p < 0.05$), *** ($p < 0.01$).

Table I.13: Matching Estimate of the Effect of gender of the breadwinner of the household on household carbon footprint during COVID-19

	Household carbon footprint			
	(1)	(2)	(3)	(4)
Male	706.003***	663.943***	679.140***	656.414***
	(151.440)	(151.750)	(135.648)	(136.640)
Covid-19 stringency	-21.908***	-24.392***	-14.484***	-14.922***
	(2.705)	(2.806)	(2.515)	(2.514)
Male × Covid-19 stringency	-0.107	-0.214	-5.125	-5.354
	(3.788)	(3.781)	(3.379)	(3.374)
Wallonia		162.315	197.015*	261.346**
		(125.743)	(112.891)	(113.111)
Brussels		-911.805***	82.496	227.787
		(188.667)	(173.516)	(174.486)
Household size			1,017.588***	1,097.823***
			(47.974)	(51.552)
Household income (€/month)			0.604***	0.564***
			(0.028)	(0.029)
Private car			1,664.729***	1,600.317***
			(80.006)	(80.344)
Company car			570.227***	516.991***
			(140.344)	(141.158)
Age hh head				9.535*
				(5.700)
Half-month FE	No	Yes	Yes	Yes
Prof. Status	No	No	No	Yes
Observations	12,236	12,236	12,236	12,203
R^2	0.013	0.022	0.221	0.226

Dependent variable in the four columns is the total household carbon footprint. Carbon footprint are given in terms of kg CO2e. Column 4 also controls for different categories of professional status of the primary income earner (Has a job; Has found a job but has not yet started; Student/in training; Homemaker/caring for household; Incapacity to work; Unemployed; On leave prior to retirement or on pre-retirement; Is retired or on early retirement; Other unemployed situation). Household income represents the aggregated monthly income of the household in €/month. Standard errors in parenthesis. Significance: * ($p < 0.10$), ** ($p < 0.05$), *** ($p < 0.01$).

I.3. Absence of endogeneity

Table I.14: Effect of gender of the breadwinner and income decile of the household on household carbon footprint during COVID-19

	Household carbon footprint			
	(1)	(2)	(3)	(4)
Male	924.656***	899.047***	712.802***	613.353***
	(148.885)	(149.100)	(146.055)	(148.434)
Covid-19 stringency	-5.850	-6.388	-8.841*	-7.436
	(4.813)	(4.862)	(4.772)	(4.791)
Male × Covid-19 stringency	-4.478	-4.961	-5.985*	-6.226*
	(3.700)	(3.694)	(3.612)	(3.616)
2 × Covid-19 stringency	4.014	4.122	3.958	1.464
	(5.637)	(5.632)	(5.510)	(5.546)
3 × Covid-19 stringency	-4.287	-4.361	-2.063	-3.897
	(5.820)	(5.813)	(5.699)	(5.742)
4 × Covid-19 stringency	-0.539	-1.296	2.582	0.458
	(5.772)	(5.767)	(5.668)	(5.709)
5 × Covid-19 stringency	-12.084**	-12.705**	-8.383	-10.679*
	(6.096)	(6.093)	(6.000)	(6.031)
6 × Covid-19 stringency	-6.653	-6.968	-2.200	-4.308
	(6.039)	(6.033)	(5.953)	(5.974)
7 × Covid-19 stringency	-5.188	-5.370	0.006	-1.672
	(6.278)	(6.278)	(6.199)	(6.223)
8 × Covid-19 stringency	-18.341***	-18.829***	-14.619**	-15.772**
	(6.414)	(6.410)	(6.329)	(6.350)
9 × Covid-19 stringency	-14.449**	-14.808**	-8.776	-9.778
	(6.749)	(6.746)	(6.646)	(6.660)
10 × Covid-19 stringency	-14.896**	-14.948**	-13.609**	-15.223**
	(7.024)	(7.019)	(6.869)	(6.880)
Household income decile	1,023.993***	1,024.185***	597.724***	594.691***
	(24.321)	(24.324)	(37.804)	(39.042)
Household size			718.144***	803.502***
			(52.639)	(55.018)
Household income (€/month)			0.171***	0.167***
			(0.041)	(0.041)
Private car			1,346.186***	1,323.220***
			(79.366)	(79.553)
Company car			237.900	274.706*
			(146.613)	(147.320)
Age hh head				6.913
				(5.486)
Half-month FE	No	Yes	Yes	Yes
Prof. Status	No	No	No	Yes
Region FE	No	Yes	Yes	Yes
Observations	12,241	12,241	12,241	12,208
R^2	0.215	0.220	0.255	0.258

Dependent variable in the four columns is the the total household carbon footprint. Carbon footprint are given in terms of kg CO2e. Column 4 also controls for different categories of professional status of the primary income earner (Has a job; Has found a job but has not yet started; Student/in training; Homemaker/caring for household; Incapacity to work; Unemployed; On leave prior to retirement or on pre-retirement; Is retired or on early retirement; Other unemployed situation). Household income represents the aggregated monthly income of the household in €/month. Standard errors in parenthesis. Significance: * ($p < 0.10$), ** ($p < 0.05$), *** ($p < 0.01$).