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Female empowerment and household emissions

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Female Empowerment and Household Emissions*

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Abstract

Existing evidence from surveys and text analysis of social media suggests that women have more pro-environmental attitudes than men. However, there is little evidence of concrete gender differences in patterns of greenhouse gas emissions. We develop a new approach to structurally estimating gender differences in emissions propensity, grounded in a household bargaining model augmented with emissions parameters. Using UK data, we find that women have lower emissions propensities than men, and therefore greater female empowerment is associated with lower household emissions intensity. If the average UK heterosexual working couple transitioned to gender-equal bargaining, its emissions would fall by more than 2%. Our findings suggest that policies aimed at increasing female bargaining power, for instance by narrowing gender pay gaps, may have the additional benefit of reducing household emissions.

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1 Introduction

Households play a crucial role in global greenhouse gas (GHG) emissions. The direct and indirect emissions associated with household consumption account for more than 60% of global GHG emissions (Ivanova et al., 2016), and almost three quarters of the global carbon emissions(Druckman and Jackson, 2016). Policies aimed at mitigating emissions due to household demand could reduce global GHG emissions in end-use sectors by up to 70% relative to the Intergovernmental Panel on Climate Change (IPCC)'s baseline scenarios (IPCC, 2022). Therefore, measuring households' emissions, and understanding its determinants, are crucial to identifying behavior-changing policies to meet urgent climate objectives. Henceforth, we refer interchangeably to "carbon footprint" and "GHG emissions", since our paper follows the standard approach in the literature of converting greenhouse gas emissions into CO2-equivalent emissions using equivalence scales for different gases.

There is a growing literature suggesting that women express greater environmental concern and are more likely to engage in pro-environmental behaviors than men (e.g., Xiao and McCright, 2015; Kennedy and Kmec, 2018; May et al., 2021; De Rock and Le Henaff, 2023; Baraldi and Fosco, 2025).[1] This high-level pattern holds across a range of settings relating to stated attitudes, infrequent decisions, and political choices. However, there are only a few papers that have investigated the degree to which actual individual daily consumption patterns vary by gender (Carlsson Kanyama et al. (2021), Osorio et al. (2024), Toro et al. (2024) and Büchs and Schnepf (2013)). To disentangle gender effects, those papers either focus on singles or perform reduced-form analysis with simple, discrete proxies of whether observed consumption and emissions patterns mostly reflect the preferences of men or women in the household, i.e. whether the household has a female or male "leader" or "head". Even though most of the global population lives in multi-person households, where decisions are taken collectively, we are not aware of any study that has structurally explored the relationship between the distribution

[1] In this paper, any references to men, women, male and female are intended to refer to gender, rather than sex.

of bargaining power within the household and households' carbon footprints.

This paper proposes to fill these gaps. We structurally investigate the relationship between gender and greenhouse gas emissions both by (i) analysing singles data by gender, and by (ii) estimating the relationship between female bargaining power within heterosexual couples, and the household's carbon footprint. To do this, we build on recent developments in household economics, extending them to a setting with emissions. To our knowledge, this is the first paper to use a household bargaining model to answer a question in environmental economics. Our novel approach allows us to contribute to the discussion of gender differences in pro-environmental behaviours, and also to the debate on the potential benefits of policies aimed at empowering women within households. We also contribute to the household literature, by demonstrating the potential for household bargaining models to be applied much more widely than they have to date, including to environmental questions.

We model household bargaining through the widely used static collective household model, and enhance it with a framework to consider the greenhouse gas emissions associated to consumption choices. To estimate bargaining power, we propose an approach which is closely related to that developed in Arduini (2024), building on contributions by Dunbar et al. (2013) and Lechene et al. (2022). Using individual-level variation in time-use data, from the UK Time Use Survey (UKTUS), we estimate bargaining power as a function of household characteristics for UK heterosexual working couples without cohabiting children, as a function of household characteristics. The intuition behind identification is the following. We observe that variation in household budget is associated to more variation in men's expenditure on private leisure (time spent on leisure activities without other household members co-present) than women's. Combined with an identifying assumption that men and women have similarly strong preferences for private leisure,[2] this implies that men have more of a say than women on how to spend incremental household budget, i.e. that they have more bargaining power.

With estimates of bargaining power at hand, our structural model yields estimating equations which we can use to recover men's and women's preference

[2]See Arduini (2024) for a detailed discussion of why this assumption is valid

parameters on different categories of goods, with different associated emissions. To do this, we combine (i) granular household expenditure data for the UK over the period 2001-2014, from the Living Costs and Food Survey (LCF), with (ii) detailed emissions data for different categories of goods in different years published by the Department for Environment, Food & Rural Affairs (DEFRA). The DEFRA emissions data was estimated using Environmentally-Extended Input-Output tables, and is the best available source of information of the total direct and indirect emissions associated to purchasing goods in the UK. Combining expenditure surveys with data on emissions multipliers is the current standard approach in the environmental literature, and is the approach taken by other papers that have attempted to estimate gender differences in emissions propensities (Carlsson Kanyama et al. (2021), Osorio et al. (2024), Toro et al. (2024) and Büchs and Schnepf (2013)).

Taking our estimated bargaining rule (the relationship between household characteristics and bargaining power) from the UKTUS to our merged LCF and DEFRA data, we structurally estimate gender-specific preference parameters for different goods, with different associated emissions. For both singles and couples, we find that women have lower emissions propensities than men. By this, we mean that women's preferences are conducive to lower greenhouse gas emissions from consumption than those of men, per GBP of budget.

We find that if the average UK household transitioned from male-weighted bargaining to equal bargaining, this would reduce emissions from UK couples by 2.1%. On a per-household basis, this is a sizable effect: it is in a similar order of magnitude to estimates of the impact of the average North American household switching to a vegetarian diet (Ivanova et al., 2020). Re-weighting our estimate by the relevant proportion of UK households, and the proportion of UK greenhouse gas emissions which are (directly and indirectly) attributable to households, we estimate that transitioning to equal bargaining could, alone, reduce the UK's overall carbon footprint by 1.1%. This suggests that policies aimed at empowering women within households, such as narrowing gender pay gaps, may have substantial additional benefits in terms of reduced greenhouse gas emissions.

Our more granular findings for specific consumption categories partly differ across household compositions. This is in line with other evidence from the household literature, e.g. Hubner (2020), that preferences are not stable across household compositions. This reinforces the importance of our approach to assessing gender differences in couples, as opposed to inferring these directly from singles data. It is also a strength of our approach relative to papers in the environmental literature, which typically jointly analyse a variety of household compositions.

As a robustness check, we repeat our couples analysis using alternative measures of bargaining power, including simple proxies of whether the household has a female or male lead, following papers in the environmental literature. We still find some partial evidence of women having more environmentally friendly preferences than men, but the findings are weaker, often not statistically significant. This suggests the value of drawing on structural approaches from the household bargaining literature, instead of simple proxies of bargaining.

The remainder of the paper is structured as follows. The next section provides a brief overview of the related literature and underlines our contributions. In Section 3, we set out our model of household decision-making. Section 4 outlines our methodology to estimate bargaining power and gender differences in preferences. In Section 5, we describe the UK data used in this paper. In section 6, we report and discuss the results of our analysis. Section 7 concludes.

2 Related literature

To date, there are very few papers answering the question of whether actual individual daily emissions patterns from consumption vary by gender. One paper, focusing only on Swedish singles data, finds that women have lower total emissions than men (Carlsson Kanyama et al., 2021). Other papers have considered broader household compositions, using simple proxies for the degree to which a household's behaviour should be taken as indicative of the preferences of men or women.

Using Spanish data, Osorio et al. (2024) use as a proxy the female share in households. They define this as the proportion of members older than 13 who are women. This amounts to assuming that bargaining power is divided equally between household members, which has been strongly rejected in the household literature (e.g. Lechene et al. (2022)). Controlling for potential socio-economic confounders, they find that households with a higher female share have (i) lower total household carbon footprints, (ii) lower carbon intensity, (iii) higher emissions on housing and food products, and (iv) lower emissions on restaurant and transport services. Toro et al. (2024) also investigate gender differences in greenhouse gas emissions in Spain, but using a different proxy of female bargaining power. They define the breadwinner in a household as the individual who contributes the most to the household income. They find that female breadwinner households have lower total GHG emissions, primarily driven by lower emissions from private transportation.

Büchs and Schnepf (2013), using UK data, follow a similar approach to proxying for bargaining power: they define the head of the household as the individual financially responsible for accommodation or, in cases of equal financial contribution, the higher earner. Similarly to other studies, they find that female-headed households are less likely to have high emissions associated to their consumption. A more complex picture emerges when they condition on different variables: they then find that female headed households have conditionally higher overall CO2 emissions, but lower emissions for transport, primarily due to reduced motor fuel consumption. As discussed in section 6.2.4, the partial differences between our findings and those of Büchs and Schnepf (2013) are due to differences in our methodological approaches and the emissions data used.

Our findings support the broad consensus in this literature that women have lower emissions propensities that men. Our main contribution relative to previous approaches is that we structurally estimate gender differences using an approach grounded in a general household bargaining model. Instead of using simple, discrete, wage-based proxies, our methodology combines a general theoretical household model, data on observed patterns of time-use, and data on detailed characteristics of household members, including not only wages, but also, for instance, educational attainment. In this way, we provide a more reliable, granular (continuous rather than discrete), theory-consistent, measure of bargaining in the household. This allows us to estimate gender heterogneity in emissions propensity more accurately.

Our work also contributes to the literature on estimating intra-household bargaining. Firstly, by extending the approach in Dunbar et al. (2013), Lechene et al. (2022) and Arduini (2024), we show that it is possible to estimate intra-household bargaining in a manner which is both grounded in a general household model and simple to estimate from widely available data. Secondly, estimates of intra-household bargaining have mostly been applied to estimating individual-level consumption, inequality and poverty measures. For example, see Browning et al. (2013), Dunbar et al. (2013), Lechene et al. (2022), Lise and Seitz (2011), Bargain et al. (2022) and Calvi (2020). There has been little work on how female empowerment relates to different policy-relevant consumption patterns. This has been limited to two applications to date: investment in children's development, e.g. Blundell et al. (2005) and Cherchye et al. (2012) and household portfolio composition (Thörnqvist and Vardardottir, 2014). This paper explores a new question: how does female empowerment relate to the emissions of households? Apart from being interesting in itself, this provides an illustration of how methods to estimate intra-household bargaining may have wider applications than have so far been explored in the literature.

3 Framework

We set out a structural model of household decision-making and augment it with good-specific emissions parameters to formalise how gender differences in preferences translate into different emissions patterns. For singles, household consumption choices take the form of individual utility maximisation. For larger households, we need to additionally consider intra-household bargaining to understand how the preferences of different individual members are mapped onto observed household-level consumptions and emissions patterns.

3.1 Model

This paper is grounded in a static collective model of the household with both private and public goods and both material goods and time-use. The collective model of the household is both more general, and provides a better empirical fit, than alternatives in the literature (e.g. see Browning et al. (2014)). For a more in-depth discussion of this model, and of a more general version of it, see Arduini (2024).

We focus on two household compositions $g = \{S, C\}$:[3]

- **Working singles (S)**. Each single person is categorised as either male or female $t = \{f, m\}$ and is indexed by a household number belonging to the set of single households $h \in H^S$.
- **Heterosexual working couples (C)**. Each of these household has two members, indexed by their type $t = \{f, m\}$ for female and male. Each couple is indexed by $h \in H^C$.

The household purchases both rivalrous (e.g. bread) and non-rivalrous (e.g. heating) material goods on the market. We refer to the conceptually rivalrous goods as private and the conceptually non-rivalrous goods as public, even for single households, where in practice there is no distinction between these types of goods. Additionally, individuals enjoy (i) private leisure, i.e. time spent on leisure activities without other household members co-present (for singles, all leisure time is private leisure), (ii) joint leisure, i.e. time spent on leisure activities with other household members co-present (this is not available to singles), and (iii) a domestic good produced by household members' domestic work. Individuals also spend time on paid work, but this is assumed not to directly enter the utility function.

Denote the consumption vector of a person of type t in household h of composition g by: $q^j_{t,h,g} \in \Omega^Q$. The price of each good j is $p^j_{t,h,g}$. For most goods, the price does not vary within the sample, so we often write simply p^j and omit the indices. However, some prices vary at the household or individual level, notably

[3] Note that we do not claim that these two groups are "comparable", e.g. we do not focus only on heterosexual singles (it is not possible in the data) nor do we require people to have stable preferences across household compositions: this is why we conduct the analysis separately for the two groups.

for time-use. The price of an individual's time is their wage $w_{t,h,g}$.[4]

Time is continuous,[5] and each individual has time-endowment normalised to 1, so each individual has labour endowment equal to $w_{t,h}$. In addition, each member can be endowed with non-labour income $y_{t,h}^{NL}$, or alternatively the household as a whole can have non-labour income y_h^{NL}. The household's endowment (or full income) is $y_h = y_h^{NL} + \sum_{t\epsilon h} w_{t,h}$. We refer to this as the household budget.

Preferences are heterogenous in two dimensions: sex and household composition. Single men and women have different preferences from each other. Men and women in couples have different preferences from each other, and also have different preferences from singles. This allows us to capture the key dimension of preference heteorogeneity of interest to us, i.e. the difference between men and women, without assuming preference stability across household composition, which has been rejected empirically by other papers e.g. by Hubner (2020). Therefore an individual has preferences of one of four types: $u_{f,S}$, $u_{m,S}$, $u_{f,C}$, or $u_{m,C}$.

All preferences and domestic production functions are modelled as Cobb-Douglas, so that an individual's utility takes the form:

$$u_{t,g} = \sum_{j\epsilon\Omega^Q} \left(\alpha_{t,g}^j \ln(q_{t,h,g}^j)\right) \tag{1}$$

This widely used, tractable, specification has several advantages in this context. Firstly, it enables estimation of bargaining weights even from data with small sample sizes, which are prevalent in the household bargaining literature, including in the application to environmental preferences in this paper. Secondly, the parsimonious direct utility representation and demand equations lend themselves to the environmental extension in this paper and enable transparent interpretation of estimates. The price of these advantages is that Cobb-Douglas imposes homotheticity and separability, which are strong assumptions.

[4] For non-participants in the labour market, the price of their time is higher than their (unobserved) wage, and would require estimating. For this reason, we restrict our attention to working couples without cohabiting children.

[5] By examining UK time-use data used for the application in this paper, this modelling assumption appears realistic.

As explained in the methodology section, to estimate bargaining weights we focus only on data on private leisure. Hence, in effect, we are only imposing the restrictions of Cobb-Douglas on this specific good. As discussed in Arduini (2024), in this context the Cobb-Douglas assumption does not seem problematic. For instance, UK time-use data on singles shows homothetic patterns for expenditure on private leisure.

However, for our environmental analysis we need to draw more heavily on parametric form of preferences. This introduces complexities because some goods, such as food and clothing, exhibit strong non-homotheticity. To keep our approach simple and easy to interpret, we use Cobb-Douglas utility functions, but only make comparisons between people with similar budgets. This is akin to taking a linear approximation of expenditure functions which is local to a specific budget.

3.2 Singles

For singles, Cobb-Douglas utility functions yield very simple expenditure functions:

$$E^j_{t,h} = q^j_{t,h} p^j = \alpha^j_{t,S} y_h$$

Expenditure on a subset of goods Ω^X is:

$$E^X_{t,h} = \sum_{j \in \Omega^X} \left(q^j_{t,h} p^j \right) = \left(\sum_{j \in \Omega^X} \alpha^j_{t,S} \right) y_h$$

These expenditure functions yield simple structural estimating equations that allow us to directly recover the preference parameters of singles.

3.3 Couples

3.3.1 Bargaining in the household

In a household with multiple members, the constituent individuals bargain over how to divide resources. In the context of this paper this only applies to couples, so we drop the household category subscripts g. Depending on the bargaining process, and on the outside options of the individuals, the different individuals will have different bargaining power and the resulting household-level consumption patterns will be a closer reflection of the preferences of one or the other member. Individuals have a vector of characteristics $\pi_{t,h}$ (e.g. age, educational attainment) and their households have a vector of characteristics ζ_h (e.g. the gender ratio in the region).

The collective model of the household does not restrict bargaining to any specific solution, and only requires that this process be Pareto efficient.[6] Relative bargaining power will in general depend on a variety of variables, including prices (e.g. hourly wages of all members), individual characteristics (e.g. age and educational attainment of all members) and household characteristics (e.g. local area the household is located in). We refer to the vector of variables that affect bargaining power as z_h. Note that a specific member's bargaining power will depend not only on their own characteristics, but also on the characteristics of all other household members, hence the household-level subscript.

A key result from the existing literature (see Browning et al. (2014)) is that the problem solved by any collective household, regardless of the underlying bargaining process and outside options, can be represented as an optimisation problem where the maximand is the weighted sum of the members' utility functions. Each member's utility function is weighed by their Pareto weight $\mu_{t,h}(z_h)$ normalised so that $\sum_{i\epsilon h} \mu_{t,h}(z_h) = 1$. The higher an individual's Pareto weight, the more weight the collective household gives their utility in determining its choices. The household's optimisation problem is therefore to maximise $\sum_{i\epsilon h} (\mu_{t,h}(z_h) u_{t,g}(q_{t,h}))$.

Because the pareto weights could take any form, we linearly approximate

[6] As opposed to models with specific bargaining solutions e.g. McElroy and Horney (1981), for which there is little consensus in the literature.

them as:

$\mu_{t,h} = \mu_t^0 + \sum_z \mu_t^z \left(z_h - \bar{z}\right)$

- μ_f^0 is the average pareto weight of women and μ_m^0 is the average pareto weight of men in the sample. This is the pareto weight evaluated at the average characteristics in the sample. By definition, the average resource share of men and women sum to one: $\mu_f^0 + \mu_m^0 = 1$.

- μ_f^z (μ_m^z) captures the impact on sharing of a household's characteristic z_h deviating from the sample average $(z_h - \bar{z})$ on women's (men's) bargaining power. For instance, a higher-than-average wage for the woman might increase the woman's pareto weight, so that she would have a higher-than-average-for-women bargaining power. Since pareto weights must sum to one within the household, this implies her partner must have a correspondingly lower-than-average-for-men pareto weight: $\mu_f^z + \mu_m^z = 0$. We can interpret μ_t^z as the marginal impact of characteristic z_h on the resource share on people of type t.

Given the properties of Pareto weights, in the rest of the paper we write $\mu_{f,h}$ for women's bargaining power and $(1 - \mu_{f,h})$ for the man's.

3.3.2 Household-level expenditure functions for couples

In this context, the household-level expenditure functions for couples are a weighted sum of the preferences of members, where the weights represent their relative bargaining power:

$$E_h^j = \mu_{m,h}\alpha_{m,C}^j y_h + \mu_{f,h}\alpha_{f,C}^j y_h$$

Using the fact that bargaining weights sum to one, we can re-write this as:

$$E_h^j = \alpha_{m,C}^j y_h + \left(\alpha_{f,C}^j - \alpha_{m,C}^j\right) \mu_{f,h} y_h$$

Note that here the interpretation of expenditure on a private good is that part of it is consumed by the man and part of it by the woman, while for public expenditure, the whole consumption is enjoyed by both household members. In expenditure data, we only observe household expendturue on a good such as food E_h^{food}, but that is an aggregate of the expenditure on food for the woman $\mu_{f,h}\alpha_{f,C}^{food}y_h$ and food for the man $\mu_{m,h}\alpha_{m,C}^{food}y_h$.

Expenditure on a subset of goods Ω^X is:

$$E_{t,h}^X = \sum_{j\in\Omega^X} E_h^j = \left(\sum_{j\in\Omega^X} \alpha_{m,C}^j\right) y_h + \left(\sum_{j\in\Omega^X} \left(\alpha_{f,C}^j - \alpha_{m,C}^j\right)\right) \mu_{f,h} y_h$$

We first estimate bargaining weights, and then substitute them into these structural equations, allowing us to directly estimate these equations to recover the preference parameters of men and women in couples.

3.4 Environmental extension

For consistency with emissions data, we model emissions per GBP of expenditure as a good-specific constant ϕ^j, called conversion factor or emission multiplier.

A household's expenditure on a specific good therefore has associated emissions:

$$\epsilon_h^j = \phi^j E_h^j$$

Similarly, a household's expenditure on a subset of goods X has associated emissions:

$$\epsilon_h^X = \sum_{j\in\Omega^X} \phi^j E_h^j$$

The total emissions (carbon footprint) of a household are:

$$\epsilon_h^Q = \sum_{j\in\Omega^Q} \phi^j E_h^j$$

We would expect higher budget households to emit more than lower budget households in absolute terms (because most consumption has associated emissions), so rather than looking at absolute emissions, we focus on emissions relative to budget, which depends on how money is spent. For single households, we define their **emissions propensity** as their emissions-to-budget ratio:

$$\pi^Q_{h,S} = \frac{\epsilon^Q_h}{y_h} = \sum_j \alpha^j_{t,S}\phi^j$$

or, for a subset of goods:

$$\pi^X_{h,S} = \frac{\epsilon^X_h}{y_h} = \sum_{j\in\Omega^X} \alpha^j_{t,S}\phi^j$$

For couples, we define emissions propensity of a member as the emissions-to-budget ratio that the household would have under a dictatorship of that individual:[7]

$$\pi^Q_{h,C} = \sum_j \alpha^j_{t,C}\phi^j$$

And for a subset of goods:

$$\pi^X_{h,C} = \sum_{j\in\Omega^X} \alpha^j_{t,C}\phi^j$$

We are interested in whether women or men have a higher emissions propensity, i.e. comparing $\pi^X_{f,g} \lesseqgtr \pi^X_{m,g}$. Note that lower emissions propensity on a subset of goods X is driven by two factors:

1. Consuming less of X: spending a lower proportion of budget on goods in subset X and spending a larger proportion on some other subset of goods.

2. Consuming more environmentally friendly products within X: keeping the

[7] We define male dictatorship as a household where decisions are fully shaped by the male preference parameter. In this case, the female bargaining weight is equal to zero. Similarly, under female dictatorship, the female bargaining weight is equal to one. In our analysis, we also consider an equal household, where each members' preferences are weighted equally.

proportion of budget spent on X constant, a higher proportion is spent on goods with lower associated emissions.

Lower emissions propensity overall indicate exclusively the second effect.

To disentangle between these two effects, we also consider the **carbon intensity of choices**. For singles, this is defined as the emissions propensity on category X, divided by the share of the budget that is spent on category X. For a member of a couple, this is defined as that person's emissions propensity on category X, divided by the share of the budget that would be spent on that category under the dictatorship of that member:

Overall:

$$CI_{t,C} = \frac{\sum_j \alpha^j_{t,g} \phi^j}{\sum_j \alpha^j_{t,g}}$$

For a subset of goods X:

$$CI^X_{t,C} = \frac{\sum_{j \in \Omega^X} \alpha^j_{t,g} \phi^j}{\sum_{j \in \Omega^X} \alpha^j_{t,g}}$$

4 Methodology

We begin by estimating household-specific bargaining weights from UK time-use data, based on observable household characteristics—our bargaining rule.[8] These estimates are then applied to expenditure data (specifically the LCF) to calculate household-specific bargaining weights within that dataset. To analyse emissions patterns, we integrate emissions data from DEFRA into the LCF, creating an emissions-augmented expenditure dataset. Within this dataset, we compare the consumption and emissions behaviours of single men and women with similar

[8]Note that the bargaining rule may well vary between countries and over time. In this paper, we focus only on the UK in the period 2001-14, and hence do not allow the bargaining rule to vary itself.

budgets. We then examine couples, using the estimated bargaining weights, again focusing on comparisons between households with similar financial means.

4.1 Estimating bargaining weights

4.1.1 Estimating bargaining weights from time-use data

Estimating structural parameters for multi-person households is complicated by substantial data limitations. In general, we only observe aggregate household expenditures, and cannot directly observe how these are split between members, or what process the household underwent to arrive to this choice. In order to get under the hood of household decision-making, and uncover differences in bargaining power and in preferences between members, we require some identifying variation in the data - something that varies at the individual, rather than household, level, and which we observe for all household members.

Dunbar et al. (2013) shows that we can recover resource sharing (the way that expenditures are split between household members overall, not on each specific good) in quite a general setting, as long as we observe individual-level expenditure on a single private good, the ‘assignable good’, for all members of a household. Lechene et al. (2022) shows that the approach proposed by Dunbar et al. (2013) can be estimated simply by OLS. Building on those results, Arduini (2024) proposes a new approach to estimating resource sharing from time-use data.

We use a similar approach, but (i) estimate bargaining weights instead of resource sharing, and (ii) apply our structural estimates to explore gender differences in terms of emissions, rather than individual-level consumption. We set out our approach below.

First, we use individual time diaries (collected for all members of a household) to obtain individual-level expenditure on private leisure ℓ for both men and women in working heterosexual couples. Private leisure is time spent on leisure activities without other household members co-present. For instance, one of the members may be reading a book on their own, or having a coffee with a friend but without their partner. Expenditure on private leisure is the amount of time spent on private leisure multiplied by the price of time, which for our sample is the observed wage from paid market work. From our structural model we obtain the equations:

$$E^{\ell}_{f,h} = w_{f,h}\ell_{f,h} = \alpha^{\ell}_{f,C}\mu_{f,h}y_h$$

$$E^{\ell}_{m,h} = w_{m,h}\ell_{m,h} = \alpha^{\ell}_{m,C}\left(1-\mu_{f,h}\right)y_h$$

Substituting in the approximation of the Pareto weight, we obtain the following structural estimating equations:

$$E^{\ell}_{f,h} = \alpha^{\ell}_{f,C}\mu^{0}_{f}y_h + \alpha^{\ell}_{f,C}\sum_{z}\mu^{z}_{f}\left(z_h-\bar{z}\right)$$

$$E^{\ell}_{m,h} = \alpha^{\ell}_{m,C}\left(1-\mu^{0}_{f}\right)y_h - \alpha^{\ell}_{f,C}\sum_{z}\mu^{z}_{f}\left(z_h-\bar{z}\right)$$

Re-writing this in terms of observables and regression coefficients:

$$E_{f,h} = \beta^{0}_{f}y_h + \sum_{z}\beta^{z}_{f}y_h\left(z_h-\bar{z}\right)$$

$$E_{m,h} = \beta^{0}_{m}y_h + \sum_{z}\beta^{z}_{m}y_h\left(z_h-\bar{z}\right)$$

where:

- $\beta^{0}_{f} = \alpha^{l}_{f,C}\mu^{0}_{f}$
- $\beta^{z}_{f} = \alpha^{l}_{f,C}\mu^{z}_{f}$
- $\beta^{0}_{m} = \alpha^{l}_{m,C}(1-\mu^{0}_{f})$
- $\beta^{z}_{m} = -\alpha^{l}_{m,C}\mu^{z}_{f}$

To identify the bargaining weight parameters, we:

1. Run linear regressions[9] of leisure expenditure for men and women with the restriction that $\beta_f^z + \beta_m^z = 0$.

2. We make the identifying assumption that men and women have similar preferences for private leisure so that $\alpha_{t,C}^l = \alpha_C^l$.

3. Estimate each type's average bargaining weight as $\hat{\mu_{t,C}^0} = \frac{\hat{\beta_{t,C}^0}}{\hat{\beta_{f,C}^0} + \beta_{m,C}^0}$.

4. Estimate the marginal impact of different characteristics as follows. First, estimate $\hat{\alpha^l} = \frac{\hat{\beta_t^0}}{\hat{\mu_t^0}}$. Then, we estimate $\hat{\mu_t^z} = \frac{\hat{\beta_t^z}}{\hat{\alpha^l}}$.

The intuition for the identification result is as follows. The man's expenditure on private leisure may be more or less responsive to changes in the household budget for one of two reasons, or a combination of them. The first possibility is that the man has more bargaining power, and hence more of a say on how additional household budget is spent, and therefore more of it is spent on his own private consumption, as opposed to the woman's. This is the channel we wish to estimate. The second possibility is that the man's preferences for private leisure are stronger relative to the woman's, so that even if they have equal say in how additional budget is used, the man may choose to spend additional budget on his private leisure while the woman may choose to spend additional budget on her clothing. This is a potentially confounding factor.

In order to disentangle these two channels, we shut down the preference channel through the identifying assumption, allowing us to identify bargaining power. Under our identifying assumption, men and women have the same preferences for their own private leisure, so differences in responsiveness to changes in y_h identify differences in bargaining weights. This identifying assumption is consistent with UK singles' time-use data, in which we observe similar patterns of expenditure on private leisure between men and women.[10]

[9] We run the two regressions jointly, as seemingly unrelated regressions, because the error terms are likely correlated across equations.

[10] While this does not guarantee that men and women *in couples* will also have similar preferences on leisure, we are not able to test our identifying assumption directly. We note that this is also the case for similar papers in the household literature.

4.1.2 Estimating bargaining weights in the expenditure dataset

Having estimated the bargaining rule, we can apply our estimates to a separate but comparable dataset, the LCF. Note that both the UKTUS and LCF are representative of the UK population and we use data for the same time period. This allows us to estimate bargaining weights for the households in our expenditure data as a function of those households' characteristics.[11]

4.2 Estimation of emissions propensities

4.2.1 Singles

The first part of our analysis focuses on singles, to directly elicit gender differences from observed consumption patterns. For singles, the structural estimating equations for greenhouse gas emissions from category X are:

$$\epsilon^X_{f,h} = \left(\sum_{j \in \Omega^X} \alpha^j_{f,S} \phi^j \right) y_h$$

$$\epsilon^X_{m,h} = \left(\sum_{j \in \Omega^X} \alpha^j_{m,S} \phi^j \right) y_h$$

Therefore, we linearly regress:

$$\epsilon^X_{t,h,S} = \beta^X_{f,S} y_h I_f + \beta^X_{m,S} y_h I_m \tag{2}$$

Where I_t is an indicator function which takes value 1 for individuals of type t and 0 for individuals who are not of type t. We conduct the singles analysis separately for households in different budget groups to ensure we are comparing

[11] To do so, we calculate how household characteristics in the expenditure dataset deviate from the averages in the time-use data, and use these deviations $(z_h - \bar{z})$ to estimate household-specific bargaining.

single men and women with similar budgets.[12]

Our estimated coefficients are: $\beta^X_{t,S} = \pi^X_{t,S}$ and $\beta_{t,S} = \pi_{t,S}$. Hence, if $\beta^X_{f,S} < \beta^X_{m,S}$ we conclude that women have a lower emissions propensity than men for category of goods X. Then, to obtain the carbon intensity of choices, we run an additional regression on expenditures, rather than emissions:

$$E^X_{t,h,S} = \gamma^X_{f,S} y_h I_f + \gamma^X_{m,S} y_h I_m \tag{3}$$

Here the estimated coefficients are: $\gamma^X_{t,S} = \sum_{j \in \Omega^X} \alpha^j_{t,S}$, so we recover the share of budget spent on category X from these coefficients directly. We then obtain the carbon intensity of choices for single men and women as:

$$CI_{t,S} = \frac{\beta_{t,s}}{\gamma_{t,s}}$$

4.2.2 Couples

For couples, the structural estimating equation for greenhouse gas emissions for category X is:

$$\epsilon^X_h = \left(\sum_{j \in \Omega^X} \alpha^j_{m,C} \phi^j \right) y_h + \left(\sum_{j \in \Omega^X} \left(\left(\alpha^j_{f,C} - \alpha^j_{m,C} \right) \phi^j \right) \right) \mu_{f,h} y_h$$

Therefore, we linearly regress:

$$\epsilon^X_h = \beta^X_{m,C} y_h + \beta^X_{\Delta,C} \mu_{f,h} y_h \tag{4}$$

For couples, we also conduct our analysis separately for people with similar budgets. To do so, we focus our analysis on households which (i) are in the middle

[12] We divide singles into categories where the budget varies by no more than 100GBP per week, and conduct our analysis on buckets which contain at least 200 households.

50% of the distribution of total household budget, and (ii) have bargaining weights between 0.4 and 0.6. This means that, between households, we are comparing households with budgets that are not too dissimilar and, within households, we are comparing men and women who have a reasonably similar split of their household budget at their disposal.

For men, we estimate the emissions propensity as:

$$\pi^X_{m,C} = \beta^X_{m,C}$$

And for women, we estimate it as:

$$\pi^X_{f,C} = \beta^X_{m,C} + \beta^X_{\Delta,C}$$

To estimate the carbon intensity of choices, we additionally run a regression on expenditure, rather than emissions, to recover further structural parameters:

$$E^X_h = \gamma^X_{m,C} y_h + \gamma^X_{\Delta,C} \mu_{f,h} y_h \tag{5}$$

Using these estimates we obtain shares of the budget that would be spent on category X under dictatorship of men:

$$\sum_{j \in \Omega^X} \alpha^j_{m,C} = \gamma^X_{m,C}$$

And for women:

$$\sum_{j \in \Omega^X} \alpha^j_{f,C} = \gamma^X_{m,C} + \gamma^X_{\Delta,C}$$

Hence, we estimate men's carbon intensity as:

$$CI^X_{m,g} = \frac{\beta^X_{m,C}}{\gamma^X_{m,C}}$$

And for women:

$$CI^X_{f,g} = \frac{\beta^X_{m,C} + \beta^X_{\Delta,C}}{\gamma^X_{m,C} + \gamma^X_{\Delta,C}}$$

5 Data

In this section, we present the data sources used in our analysis. We begin by using the UK Time-Use Survey to estimate bargaining power among working couples in the UK, based on household characteristics (the bargaining rule). These estimates are then applied to the Living Costs and Food Survey (LCF), a comparable expenditure dataset, to compute household-specific bargaining. We enrich the expenditure data with emissions multipliers from Environmentally-Extended Input-Output tables, enabling us to estimate the emissions associated with the spending patterns of different households.

5.1 UK Time-use Survey

The UK Time-Use Survey (UKTUS 2001, 2014)[13], is a high-quality time-use survey, representative of the UK population. It is a national household-based study composed of: (i) a household questionnaire, (ii) an individual questionnaire, and (iii) individual time diaries. A single household representative answered the household questionnaire, including questions on household characteristics such as composition, dwelling type, and location. The other components were answered by the individual in question. This is likely to substantially increase the quality of the data relative to datasets where a single member answers on behalf of all individuals. The individual questionnaire asks about individual characteristics including age, educational attainment and earnings. Each member completed a weekday and weekend time diary identifying primary and secondary activities for each 10-minute interval over the two days.

The time-use data is extremely detailed, including very granular activities, location, and co-presence of others (distinguishing between household and non-household members). A full list of activities can be found on the UKTUS webpage (it is not included due to its length), but examples of activities include "shopping for and ordering food via the internet", "repairing dwelling", "ironing", "cleaning

[13] Office for National Statistics. (2019b). United Kingdom Time Use Survey [data series] 2nd Release. https://doi.org/http://doi.org/10.5255/UKDA-Series-2000054.

yard", and "working".

To the end of identifying bargaining weights, we require information on how much time people spend doing leisure activities without other household members co-present (private leisure). This variation is used to identify bargaining weights, as explained in Section 4. The activities included in our definition of private leisure include, for instance: "reading books", "walking and hiking", "watching a film on TV", "listening to sport on the radio", "visiting and receiving visitors", and "sleeping".[14]

The time diaries are constructed carefully to minimise measurement error, for instance with the possibility of writing a simple sign to signify the same activity for multiple time intervals. The quality of the data is very high, with approximately 95% of observations having more than 5 distinct activities recorded in a day, and less than 90 minutes of unrecorded time.

5.2 LCF

The Living Costs and Food Survey (previously FES) is a nationally representative UK expenditure survey. It is a high-quality, large-scale survey that is used to estimate official government statistics, and has been widely used in academic papers. The LCF is a repeated cross-section available yearly since 1978. We focus on the years 2001-2014 for comparability with the time-use data used to estimate bargaining within couples.[15] The survey has three components:

1. A household survey recording household characteristics and retrospective questions on infrequent expenses (rent, vehicles, house repairs...). These infrequent expenditures are transformed to an equivalent weekly value to make them comparable to other categories. The household survey is answered by the reference person (potentially jointly with other household members).

[14] The full list of activities is chosen to be consistent with the approach outlined in detail by Arduini (2024). Results are robust to alternative definitions of leisure activities

[15] The expenditure survey changes from 2000 to 2001 and is available in its current form only from 2001, hence we exclude 2000. For the years 2004 and 2006, coding problems led to the detailed diary data not being reliable. The data files with more aggregate expenditure categories for those years are high quality but are not sufficient for our purposes.

2. An individual questionnaire, answered by each member, with information including educational attainment, hours worked and sources of income.[16]

3. A detailed two-week expenditure diary, completed individually by each member. For our purposes, who purchased a good is not relevant, so our analysis is based on overall household expenditure, summed across different members' diaries.

After restricting the pooled LCF data (2001-14) to working singles and working heterosexual couples, and cleaning the data, our sample ('main' sample) comprises 13,913 households, of whom 7,448 are couples and 6,465 are working singles. Table 1 provides summary statistics for the 'main' sample, which we use to understand high-level patterns and to interpret our findings relative to the population. For our regression analysis, we further restrict our sample to compare only people with similar budgets. Table 2 provides summary statistics for the regression sample, which is composed of 4,141 singles and 3,149 couples.

Hourly pay is obtained by dividing labour income by actual hours worked, rather than contractual hours.[17] Household budget is full income: the sum of the labour endowment of members (hourly wage multiplied by 24 hours, multiplied by 7 days).[18] On average, despite having higher educational attainment,[19] women command lower hourly wages than men. Single women are sligthly older than single men, and the opposite is the case for couples.

5.3 DEFRA emissions multipliers

To translate GBP expenditures into GHG emissions, we make use of emissions multipliers provided by the Department for Environment Food and Rural Affairs

[16] In rare instances, income is top-coded. We adjust top-coded values using data on after-tax income percentiles from HM Revenue & Customs (HM Revenue & Customs, 2023).

[17] This, together with self-employed labour, explains the lower end of hourly wages (which are sometimes lower than the official minimum hourly wage).

[18] Accurate non-labour income data is not available in UKTUS and hence is also excluded in LCF for comparability.

[19] We divide qualifications into three categories: 2 for undergraduate degrees, equivalent or higher; 1 for school-leaving qualifications, such as A-levels, or equivalent; and 0 for any lower qualifications.

Table 1: Summary statistics for LCF main sample

(a) Singles

Variable	(1) Female	(2) Male	(3) Difference
Household Budg.	1,938.387	2,133.766	195.380***
	(1,154.741)	(1,442.175)	(32.700)
Hourly pay	11.538	12.701	1.163***
	(6.873)	(8.584)	(0.195)
Age	46.616	44.586	-2.030***
	(12.857)	(11.917)	(0.308)
Qualification score	0.929	0.830	-0.099***
	(0.834)	(0.841)	(0.021)
Observations	3,079	3,386	6,465

(b) Couples

Variable	(1) Female	(2) Male	(3) Difference
Household Budg.	3,982.508	3,982.508	0.000
	(1,942.905)	(1,942.905)	(31.838)
Hourly pay	10.933	12.773	1.840***
	(5.758)	(8.178)	(0.116)
Age	43.066	45.086	2.020***
	(12.956)	(13.004)	(0.213)
Qualification score	0.922	0.809	-0.113***
	(0.847)	(0.848)	(0.014)
Observations	7,448	7,448	14,896

Notes: Standard deviation in parenthesis in Columns (1) and (2), Standard errors of two-sample t-test in parenthesis in Column (3). Column (3) provides the difference between single females and males for selected variables in Sub-table (a), and the difference between female and male members of two-person households in the main sample for selected variables in Sub-table (b).
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 2: Summary statistics for LCF regression sample

(a) Singles

Variable	(1) Female	(2) Male	(3) Difference
Household Budg.	1,535.653	1,555.116	19.463*
	(327.737)	(324.261)	(10.134)
Hourly pay	9.141	9.257	0.116*
	(1.951)	(1.930)	(0.060)
Age	46.560	44.339	-2.221***
	(13.121)	(12.177)	(0.394)
Qualification score	0.801	0.654	-0.148***
	(0.800)	(0.783)	(0.025)
Observations	2,099	2,042	4,141

(b) Couples

Variable	(1) Female	(2) Male	(3) Difference
Household Budg.	3,540.823	3,540.823	0.000
	(468.824)	(468.824)	(11.815)
Hourly pay	10.376	10.700	0.324***
	(2.388)	(2.512)	(0.062)
Age	40.963	42.745	1.782***
	(12.627)	(12.606)	(0.318)
Qualification score	0.965	0.696	-0.269***
	(0.836)	(0.809)	(0.021)
Observations	3,149	3,149	6,298

Notes: Standard deviation in parenthesis in Columns (1) and (2), Standard errors of two-sample t-test in parenthesis in Column (3). Column (3) provides the difference between single females and males for selected variables in Sub-table (a), and the difference between female and male members of two-person households in our regression sample for selected variables in Sub-table (b).
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

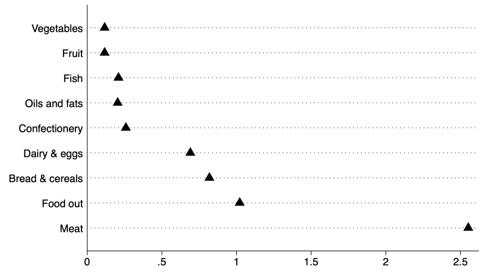
(DEFRA). These quantify the GHG emissions associated with one GBP spent in a given year on a given good category, in the UK. Emissions of different GHGs are converted into CO_2 equivalent to provide a single emissions multiplier per GBP expenditure on a category of goods.

These multipliers are derived from the UK Multi-Regional Input-Output model (UKMRIO model) (DEFRA, 2024), which is an environmentally-extended multi-regional input-output database. This approach takes into account all direct and indirect emissions associated with expenditures by any UK end-consumer (households, national and local government, and charities) regardless of where those emissions actually happened. For instance, household emissions include direct emissions from burning wood in a fireplace, indirect emissions from a local restaurant using energy to cook food purchased by the household, and indirect emissions abroad involved in a foreign firm producing a technological device purchased by the household.

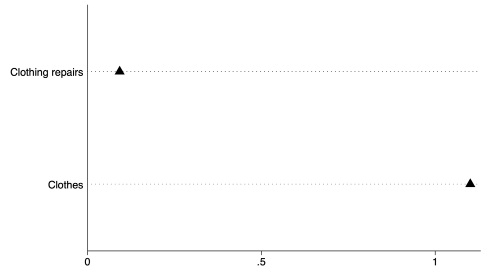
The DEFRA emission multipliers are available at the COICOP level (Classification of Individual Consumption by Purpose). This includes 108 product categories - see Appendix A for a full list, as well as additional information about the DEFRA multipliers. Figure 1 depicts the average GHG emissions for one GBP spent on selected goods, in the period 2001 - 2014. Two opposite forces are driving emissions multipliers: the price of a good drives the multiplier down, while its associated emissions drive it up.

Emissions multipliers from environmentally-extended multi-regional input-output databases are widely used and viewed as the best approach to estimate consumption-based emissions (e.g. Christis et al. (2019); Kilian et al. (2023); Osorio et al. (2024); Owen and Büchs (2024). It is worth noting that they suffer from two main limitations. Firstly, at the time of writing, they are available only at a somewhat granular level. For instance, in the DEFRA data, while we can distinguish between meat and vegetable products, we cannot distinguish between red and white meat. Secondly, being based on expenditure data, carbon footprint estimates inherit some limitations of expenditure surveys. For instance, there is no way of accounting for whether a product was purchased at a discounted price. If there were gendered patterns in purchasing discounted products, this could affect

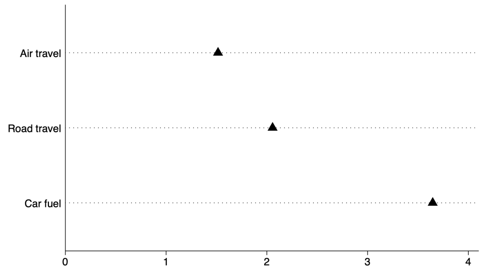
Figure 1: Average Emission factors, kgCo2eq/£, 2001-2014



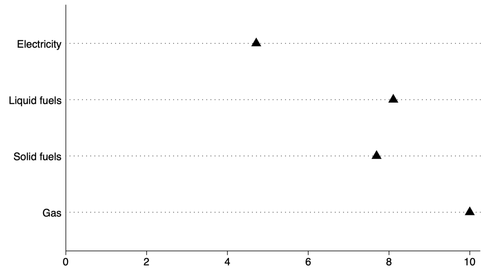
(a) Food



(b) Clothing



(c) Transport



(d) Energy

Notes: Graphical depiction of the average GhG multipliers in kgCo_2eq/£ from 2001 to 2014 for selected consumption categories. Yearly multipliers provided by DEFRA (2024).

our estimates.

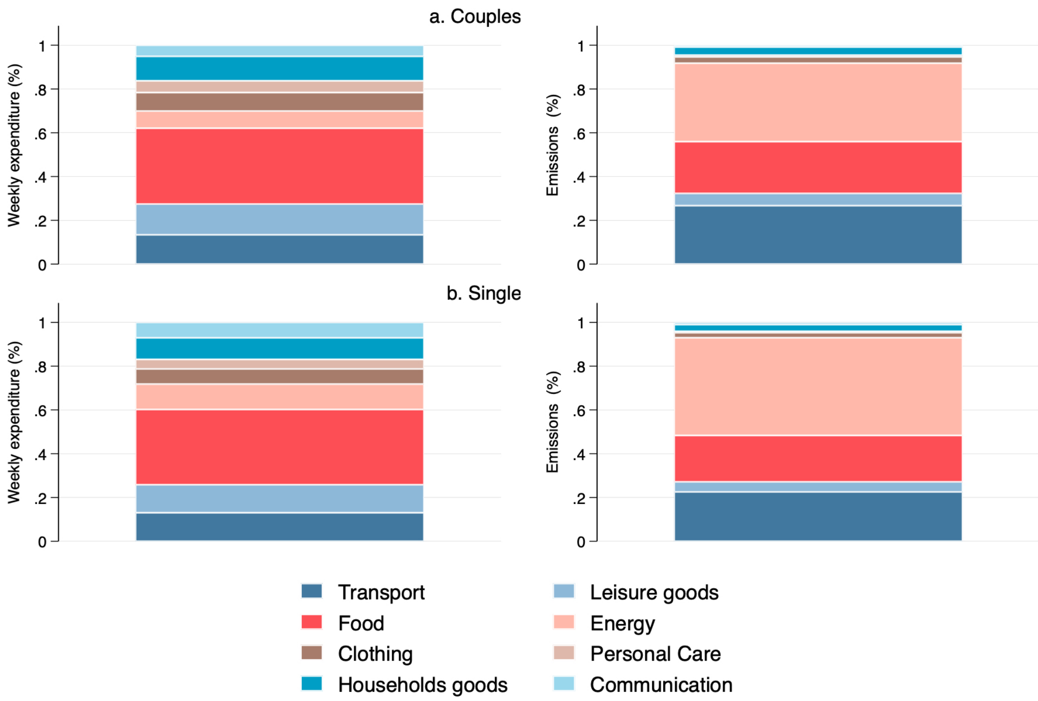
5.3.1 Bridging LCF and DEFRA data

We merge the DEFRA data into LCF by COICOP category. This gives us category-specific emissions per GBP expenditure alongside the information on how much our households spend on those categories. Our analysis focuses on the following categories of expenditure: food, energy, transport, clothing, and an overall expenditure measure including these categories and other expenditures (e.g. on toiletries). Our selection of consumption categories aligns with our objective of analyzing daily individual behavior and follows common practices in the literature.[20]. We exclude from the analysis expenditure categories that have almost no immediate consumption value and cannot easily be squared with the static model underlying the methodology in this paper. This includes: savings, insurance, investments, purchase and lease of vehicles, major house works including renovation (minor repairs are included), financial gifts, bets, gambling, and expenditure on education (the latter is minor for working couples without cohabiting children). We exclude expenditure on accommodation because it is too noisy a measure of emissions associated with building that accommodation in the first place. Similarly, we exclude medical expenditures, which map very inaccurately onto emissions in the UK context because of the complex pricing structure for treatment and medication in the UK. The average contribution of each consumption category to spending and emissions for households in the 'main' sample is illustrated in Figure 2.

Our overall expenditure measure captures a very large proportion of household expenditure. It represents on average 90.54% of the measure of total consumption in the LCF data (the ONS total consumption measure). The remaining proportion of expenditure can be ascribed to the excluded categories, particularly rental and mortgage costs. We note that our overall expenditure measure is a much smaller proportion of household budget. This is because household budget in this paper is defined as full income, rather than realised income or disposable income, i.e. it includes income that would have been earned if household members worked 24 hours a day, 7 days a week. People spend a substantial proportion of their time, and hence of their full income, on leisure and domestic activities.

[20] For instance, Carlsson Kanyama et al. (2021) examine only food, furnishing, and holiday-related expenses, while Osorio et al. (2024) incorporate both consumption and non-consumption expenditures in their carbon footprint calculations.

Figure 2: Budget and carbon footprint shares by good categories.



Notes: The Figure depicts the share of weekly household budget dedicated to each good category (left bars) and the share of emissions out of the total weekly emissions these goods represent (right bar) for the singles and couples in our sample.

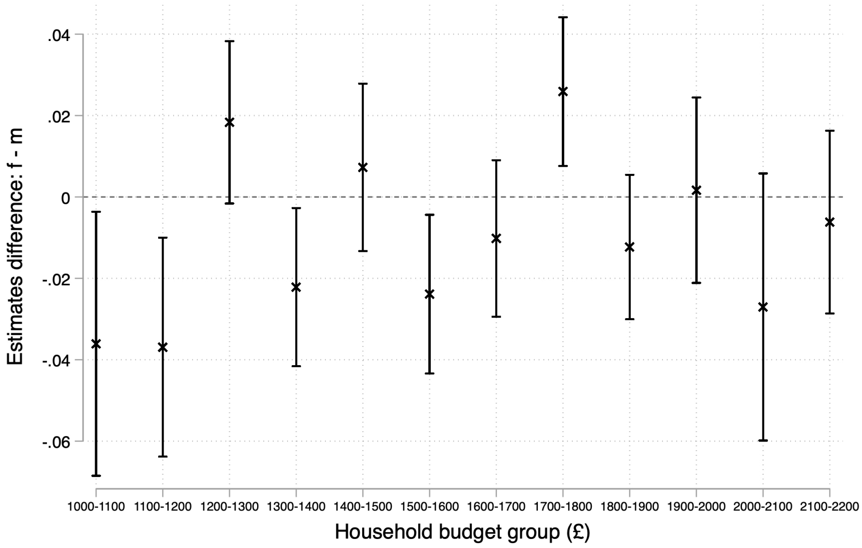
6 Findings

6.1 Findings for singles

Table 3 outlines the regression results and structural estimates for overall consumption. Each column refers to a particular household budget bucket: Column (1) to households with a budget between 1000 and 1100£ per week, column (2) to households with 1100 to 1200£ per week, etc. The first two rows of the table provide the coefficients estimated from Equation 4, i.e. the regression on household emissions. Together with results from the regression on household expenditure, this allows us to recover the estimated emissions propensities (π_t), Cobb-Douglas preference parameters (α_t) i.e. the share of budget spent on those goods, and carbon intensity of choices (CI_t) for single men and women separately. We can then disentangle the budget share (α_t) from the carbon intensity (CI_t) channels, to explain gender differences in propensities. These are reported in the rows below. We additionally report for each estimate whether the difference between genders is statistically significant (significant diff.). Tables 4, 5, 6, and 7 are built similarly, but for specific categories of consumption. For each category of consumption (overall, food, transport, energy and clothing), we graph the difference between single men's and women' emission propensities together with its confidence interval in Figures 3, 4, 5, 6 and 7.

Overall environmental preferences. In our singles regression sample, the average weekly greenhouse gas emissions of single women are $330kgCo_2eq$ per week, and $346kgCo_2eq$ per week for single men, i.e. 4.85% lower for women than men. Moreover, as detailed in Figure 3 the overall pattern across budget categories suggests that single women have somewhat lower emissions propensities π than single men. These differences are mostly driven by men preferring goods that are more carbon intensive within the basket of goods included in our analysis, and are partly counteracted by women wishing to spend more of their budget on the categories of goods included in our analysis. Computing the weighted average for the regression sample, women's Cobb-Douglas preference parameter α on overall consumption is

Figure 3: Gender difference in singles' emissions propensities on overall consumption: Women's - Men's.



Notes: The graph depicts the differences between single women's and men's emission propensities, estimated via Equation 2, and their confidence intervals at the 90% confidence level.

4.3% larger than men's, while the carbon intensity (CI) of women's choices is 7.4% lower than men's.

Table 3: Emissions Propensities and Carbon Intensities for singles: overall consumption

	Household budget groups(in 1000£)											
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	1-1.1	1.1-1.2	1.2-1.3	1.3-1.4	1.4-1.5	1.5-1.6	1.6-1.7	1.7-1.8	1.8-1.9	1.9-2	2-1.2	2.1-2.2
Fem. Budg.	0.269***	0.251***	0.250***	0.219***	0.229***	0.208***	0.207***	0.222***	0.185***	0.201***	0.173***	0.180***
	(0.013)	(0.011)	(0.008)	(0.008)	(0.009)	(0.009)	(0.008)	(0.008)	(0.007)	(0.010)	(0.014)	(0.010)
Mal. Budg.	0.306***	0.288***	0.231***	0.241***	0.221***	0.232***	0.217***	0.196***	0.198***	0.200***	0.200***	0.186***
	(0.015)	(0.012)	(0.009)	(0.008)	(0.009)	(0.008)	(0.008)	(0.008)	(0.008)	(0.009)	(0.014)	(0.010)
π_m	0.306	0.288	0.231	0.241	0.221	0.232	0.217	0.196	0.198	0.200	0.200	0.186
π_f	0.269	0.251	0.250	0.219	0.229	0.208	0.207	0.222	0.185	0.201	0.173	0.180
Significant diff.	yes	yes	no	yes	no	yes	no	yes	no	no	no	no
α_m	0.165	0.159	0.130	0.142	0.129	0.143	0.133	0.119	0.113	0.124	0.133	0.111
α_f	0.159	0.151	0.147	0.140	0.140	0.141	0.138	0.149	0.121	0.130	0.121	0.127
Significant diff.	no	no	yes	no	no	no	no	yes	no	no	no	yes
CI_m	1.849	1.813	1.780	1.694	1.712	1.623	1.629	1.641	1.743	1.615	1.505	1.668
CI_f	1.694	1.659	1.700	1.558	1.629	1.478	1.500	1.492	1.535	1.550	1.434	1.415
Significant diff.	yes	no	no	yes	no	no	no	yes	yes	no	no	yes
N	310	403	447	450	435	381	340	314	309	256	272	224
R-squared	0.736	0.731	0.781	0.773	0.750	0.786	0.797	0.821	0.805	0.771	0.568	0.765

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

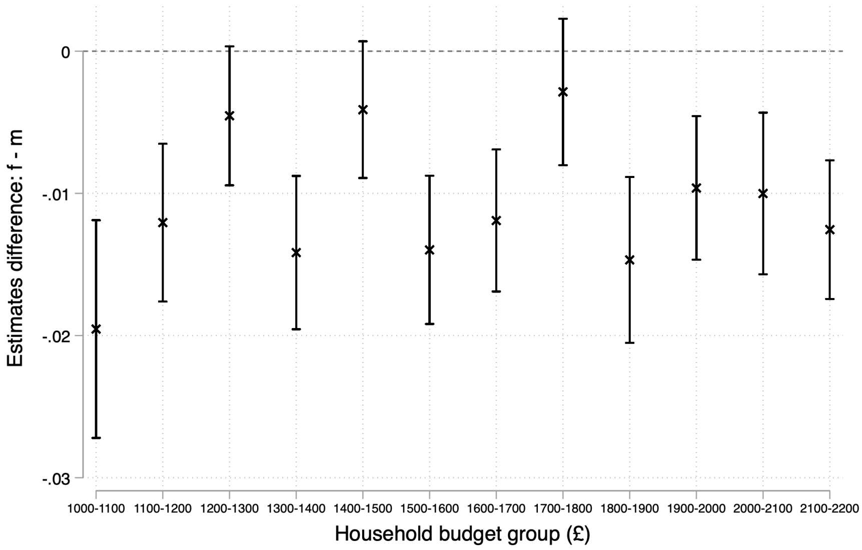
Notes: The sample is divided into 12 subsamples of at least 200 households, whose budgets vary by no more than 100 pounds per week within the subsample. Each column refers to a distinct subsample: column 1 to the subsample including households whose weekly budget is between 1000 and 1100 pounds per week, column 2 to households whose weekly budget is between 1100 and 1200 pounds, etc. Fem. Budg. and Mal. Budg are the regression estimates of Equation 2. π_m and π_f are the emission propensities (retrieved from the regression estimates), α_m and α_f are Cobb Douglas preferences parameters (retrieved by estimating Equation 3, CI_m and CI_f give the carbon intensities of consumption. Significant diff. indicates whether differences between the estimates for men and women are statistically significant at the 90% confidence level.

Environmental preferences for food, transport, energy, and clothing. We then go on to look at gender differences in emission propensities and carbon intensity of consumption for specific good categories. We can see from Figure 4 that single women's food preferences exhibit a lower emission propensity than single men's. These gender differences are driven by both lower shares of budget dedicated to food consumption for single women, and less carbon-intensive food choices. Similar conclusions can be drawn for transportation, although the gap between single men's and women's emission propensities is lower, and rarely statistically significant.

As shown in Figure 6, we observe the opposite trend for energy. Although the differences in emission propensity are not statistically significant, the point estimates suggest that women's emission propensities may be higher than men's. Table 6 shows that single women tend to allocate a larger share of their budget to energy, in line with previous findings (notably Büchs and Schnepf (2013)). The results for carbon intensity are mixed, consistent with the fact that individuals have limited control over the type of energy used in their accommodation.

For clothing, as depicted in Figure 7, single women have substantially higher emissions propensity than single men. As illustrated in Table 7, this is driven almost fully by the substantially higher budget share that single women assign to clothing. The carbon intensity of clothing choices is similar for single men and single women - this is unsurprising since clothing is divided into a small number of, not very granular, categories in DEFRA emissons data.

Figure 4: Gender difference in singles' emissions propensities on food: Women's - Men's.



<u>*Notes:*</u> The graph depicts the differences between single women's and men's emission propensities, estimated via Equation 2, and their confidence intervals at the 90% confidence level.

Table 4: Emissions Propensities and Carbon Intensities for singles: Food

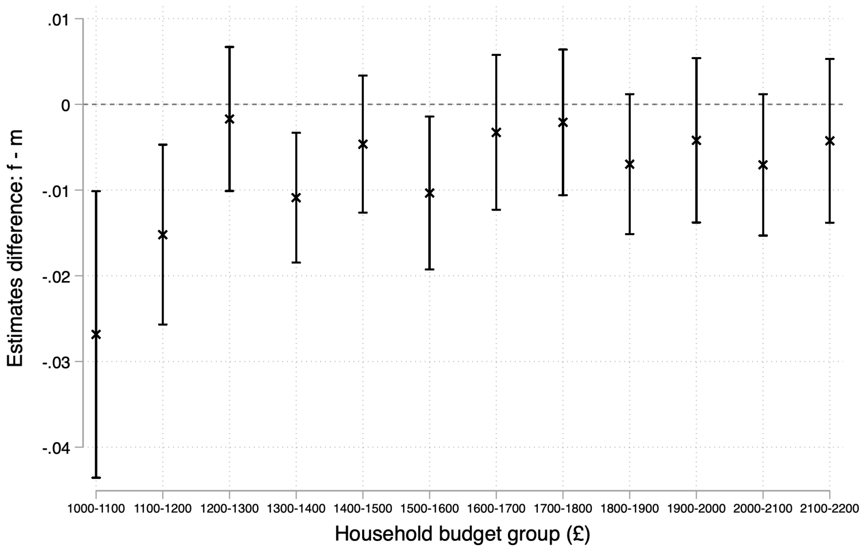
	Household budget groups(in 1000£)											
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	1-1.1	1.1-1.2	1.2-1.3	1.3-1.4	1.4-1.5	1.5-1.6	1.6-1.7	1.7-1.8	1.8-1.9	1.9-2	2-1.2	2.1-2.2
Fem. Budg.	0.045***	0.041***	0.042***	0.037***	0.038***	0.033***	0.035***	0.036***	0.030***	0.032***	0.032***	0.025***
	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Mal. Budg.	0.064***	0.053***	0.046***	0.051***	0.042***	0.047***	0.047***	0.039***	0.044***	0.042***	0.042***	0.038***
	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)	(0.002)	(0.002)
π_m	0.064	0.053	0.046	0.051	0.042	0.047	0.047	0.039	0.044	0.042	0.042	0.038
π_f	0.045	0.041	0.042	0.037	0.038	0.033	0.035	0.036	0.030	0.032	0.032	0.025
Significant diff.	yes	yes	no	yes	no	yes	yes	no	yes	yes	yes	yes
α_m	0.053	0.046	0.041	0.045	0.037	0.040	0.040	0.034	0.037	0.038	0.036	0.033
α_f	0.045	0.040	0.039	0.037	0.036	0.033	0.034	0.036	0.030	0.031	0.031	0.027
Significant diff.	yes	yes	no	yes	no	yes	yes	no	yes	yes	yes	yes
CI_m	1.209	1.152	1.128	1.147	1.125	1.173	1.166	1.123	1.215	1.108	1.147	1.128
CI_f	0.996	1.028	1.083	1.011	1.044	0.994	1.018	0.999	0.980	1.047	1.019	0.921
Significant diff.	yes	yes	no	yes	yes	yes	yes	yes	yes	no	yes	yes
N	310	403	447	450	435	381	340	314	309	256	272	224
R-squared	0.642	0.665	0.665	0.629	0.635	0.638	0.684	0.647	0.594	0.711	0.629	0.681

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

<u>*Notes:*</u> The sample is divided into 12 subsamples of at least 200 households, whose budgets vary by no more than 100 pounds per week within the subsample. Each column refers to a distinct subsample: column 1 to the subsample including households whose weekly budget is between 1000 and 1100 pounds per week, column 2 to households whose weekly budget is between 1100 and 1200 pounds, etc. Fem. Budg. and Mal. Budg are the regression estimates of Equation 2. π_m and π_f are the emission propensities (retrieved from the regression estimates), α_m and α_f are Cobb Douglas preferences parameters (retrieved by estimating Equation 3, CI_m and CI_f give the carbon intensities of consumption. Significant diff. indicates whether differences between the estimates for men and women are statistically significant at the 90% confidence level.

Figure 5: Gender difference in singles' emissions propensities on transport: Women's - Men's.



Notes: The graph depicts the differences between single women's and men's emission propensities, estimated via Equation 2, and their confidence intervals at the 90% confidence level.

Table 5: Emissions Propensities and Carbon Intensities for singles: Transport

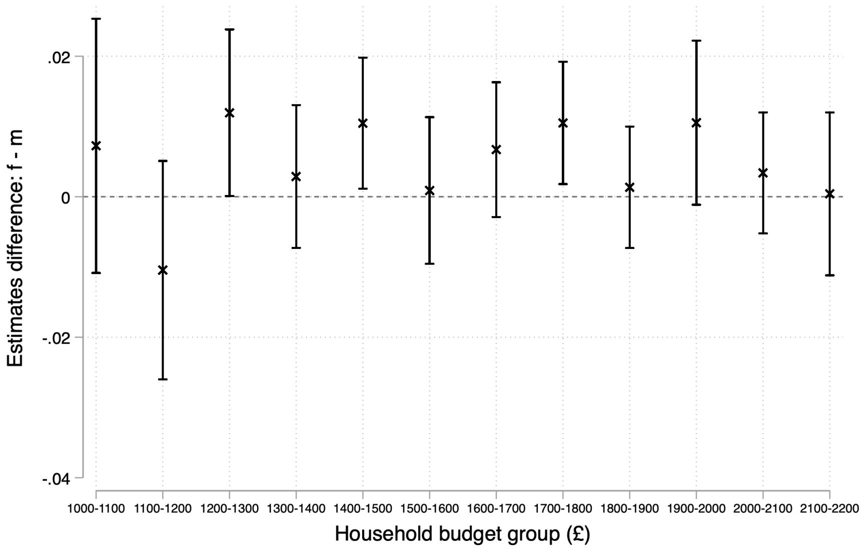
	Household budget groups(in 1000£)											
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	1-1.1	1.1-1.2	1.2-1.3	1.3-1.4	1.4-1.5	1.5-1.6	1.6-1.7	1.7-1.8	1.8-1.9	1.9-2	2-1.2	2.1-2.2
Fem. Budg.	0.043***	0.045***	0.047***	0.043***	0.050***	0.047***	0.047***	0.049***	0.040***	0.046***	0.040***	0.044***
	(0.007)	(0.004)	(0.004)	(0.003)	(0.003)	(0.004)	(0.004)	(0.004)	(0.003)	(0.004)	(0.004)	(0.004)
Mal. Budg.	0.070***	0.060***	0.049***	0.054***	0.054***	0.057***	0.050***	0.051***	0.047***	0.050***	0.047***	0.049***
	(0.008)	(0.005)	(0.004)	(0.003)	(0.003)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
π_m	0.070	0.060	0.049	0.054	0.054	0.057	0.050	0.051	0.047	0.050	0.047	0.049
π_f	0.043	0.045	0.047	0.043	0.050	0.047	0.047	0.049	0.040	0.046	0.040	0.044
Significant diff.	yes	yes	no	yes	no	yes	no	no	no	no	no	no
α_m	0.022	0.018	0.015	0.016	0.016	0.016	0.015	0.014	0.014	0.015	0.015	0.015
α_f	0.013	0.015	0.014	0.013	0.015	0.014	0.014	0.014	0.012	0.013	0.012	0.015
Significant diff.	yes	no	no	yes	no	no	no	no	no	no	no	no
CI_m	3.197	3.401	3.351	3.323	3.406	3.476	3.378	3.570	3.407	3.429	3.206	3.313
CI_f	3.209	3.019	3.359	3.288	3.264	3.352	3.298	3.399	3.367	3.437	3.211	2.987
Significant diff.	no	yes	no	no	no	no	no	no	no	no	no	yes
N	310	403	447	450	435	381	340	314	309	256	272	224
R-squared	0.290	0.408	0.446	0.500	0.515	0.499	0.481	0.547	0.503	0.526	0.529	0.538

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: The sample is divided into 12 subsamples of at least 200 households, whose budgets vary by no more than 100 pounds per week within the subsample. Each column refers to a distinct subsample: column 1 to the subsample including households whose weekly budget is between 1000 and 1100 pounds per week, column 2 to households whose weekly budget is between 1100 and 1200 pounds, etc. Fem. Budg. and Mal. Budg are the regression estimates of Equation 2. π_m and π_f are the emission propensities (retrieved from the regression estimates), α_m and α_f are Cobb Douglas preferences parameters (retrieved by estimating Equation 3, CI_m and CI_f give the carbon intensities of consumption. Significant diff. indicates whether differences between the estimates for men and women are statistically significant at the 90% confidence level.

Figure 6: Gender difference in singles' emissions propensities on energy: Women's - Men's.



Notes: The graph depicts the differences between single women's and men's emission propensities, estimated via Equation 2, and their confidence intervals at the 90% confidence level.

Table 6: Emissions Propensities and Carbon Intensities for singles: Energy

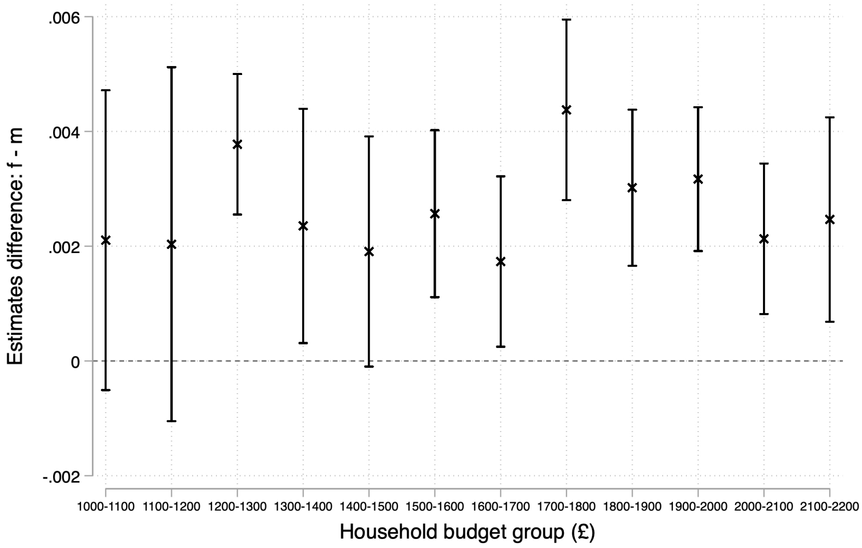
	Household budget groups(in 1000£)											
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	1-1.1	1.1-1.2	1.2-1.3	1.3-1.4	1.4-1.5	1.5-1.6	1.6-1.7	1.7-1.8	1.8-1.9	1.9-2	2-1.2	2.1-2.2
Fem. Budg.	0.138***	0.120***	0.116***	0.097***	0.097***	0.089***	0.088***	0.088***	0.079***	0.082***	0.065***	0.067***
	(0.007)	(0.006)	(0.005)	(0.004)	(0.004)	(0.005)	(0.004)	(0.004)	(0.004)	(0.005)	(0.004)	(0.005)
Mal. Budg.	0.131***	0.130***	0.104***	0.094***	0.086***	0.088***	0.082***	0.077***	0.078***	0.071***	0.062***	0.066***
	(0.008)	(0.007)	(0.005)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.005)	(0.004)	(0.005)
π_m	0.131	0.130	0.104	0.094	0.086	0.088	0.082	0.077	0.078	0.071	0.062	0.066
π_f	0.138	0.120	0.116	0.097	0.097	0.089	0.088	0.088	0.079	0.082	0.065	0.067
Significant diff.	no	no	yes	no	yes	no	no	yes	no	no	no	no
α_m	0.016	0.015	0.013	0.012	0.011	0.010	0.010	0.010	0.009	0.008	0.008	0.008
α_f	0.017	0.015	0.014	0.012	0.012	0.011	0.011	0.010	0.010	0.009	0.008	0.009
Significant diff.	no	no	no	no	yes	no	yes	no	no	yes	no	no
CI_m	8.168	8.413	7.877	8.022	7.864	8.385	8.253	7.878	8.216	8.589	7.668	8.359
CI_f	8.140	7.743	8.443	7.826	7.948	7.858	7.886	8.381	7.839	8.618	8.170	7.553
Significant diff.	no	yes	no	no	no	no	no	no	no	no	no	yes
N	310	403	447	450	435	381	340	314	309	256	272	224
R-squared	0.666	0.636	0.680	0.681	0.709	0.673	0.718	0.759	0.745	0.649	0.689	0.616

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: The sample is divided into 12 subsamples of at least 200 households, whose budgets vary by no more than 100 pounds per week within the subsample. Each column refers to a distinct subsample: column 1 to the subsample including households whose weekly budget is between 1000 and 1100 pounds per week, column 2 to households whose weekly budget is between 1100 and 1200 pounds, etc. Fem. Budg. and Mal. Budg are the regression estimates of Equation 2. π_m and π_f are the emission propensities (retrieved from the regression estimates), α_m and α_f are Cobb Douglas preferences parameters (retrieved by estimating Equation 3, CI_m and CI_f give the carbon intensities of consumption. Significant diff. indicates whether differences between the estimates for men and women are statistically significant at the 90% confidence level.

Figure 7: Gender difference in singles' emissions propensities on clothing: Women's - Men's.



Notes: The graph depicts the differences between single women's and men's emission propensities, estimated via Equation 2, and their confidence intervals at the 90% confidence level.

Table 7: Emissions Propensities and Carbon Intensities for singles: Clothing

	Household budget groups(in 1000£)											
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	1-1.1	1.1-1.2	1.2-1.3	1.3-1.4	1.4-1.5	1.5-1.6	1.6-1.7	1.7-1.8	1.8-1.9	1.9-2	2-1.2	2.1-2.2
Fem. Budg.	0.007***	0.007***	0.006***	0.006***	0.006***	0.005***	0.005***	0.007***	0.005***	0.005***	0.005***	0.005***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Mal. Budg.	0.005***	0.005***	0.002***	0.004***	0.004***	0.003***	0.003***	0.003***	0.002***	0.002***	0.003***	0.003***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
π_m	0.005	0.005	0.002	0.004	0.004	0.003	0.003	0.003	0.002	0.002	0.003	0.003
π_f	0.007	0.007	0.006	0.006	0.006	0.005	0.005	0.007	0.005	0.005	0.005	0.005
Significant diff.	no	no	yes	yes	no	yes	yes	yes	yes	yes	yes	yes
α_m	0.010	0.010	0.006	0.009	0.007	0.006	0.008	0.006	0.005	0.005	0.007	0.006
α_f	0.014	0.015	0.013	0.013	0.013	0.012	0.012	0.016	0.012	0.011	0.011	0.011
Significant diff.	no	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
CI_m	0.466	0.472	0.404	0.467	0.559	0.454	0.444	0.411	0.451	0.431	0.435	0.521
CI_f	0.478	0.460	0.455	0.486	0.423	0.452	0.449	0.438	0.451	0.465	0.453	0.480
Significant diff.	no	no	no	no	no	no	no	no	no	no	no	no
N	310	403	447	450	435	381	340	314	309	256	272	224
R-squared	0.161	0.093	0.261	0.143	0.127	0.187	0.227	0.282	0.254	0.290	0.277	0.227

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: The sample is divided into 12 subsamples of at least 200 households, whose budgets vary by no more than 100 pounds per week within the subsample. Each column refers to a distinct subsample: column 1 to the subsample including households whose weekly budget is between 1000 and 1100 pounds per week, column 2 to households whose weekly budget is between 1100 and 1200 pounds, etc. Fem. Budg. and Mal. Budg are the regression estimates of Equation 2. π_m and π_f are the emission propensities (retrieved from the regression estimates), α_m and α_f are Cobb Douglas preferences parameters (retrieved by estimating Equation 3, CI_m and CI_f give the carbon intensities of consumption. Significant diff. indicates whether differences between the estimates for men and women are statistically significant at the 90% confidence level.

6.2 Findings for couples

6.2.1 Bargaining weights

The results of our bargaining regressions are reported in Table 8. By our identifying assumption, and the simple steps discussed in the methodology section, we are able to recover the structural parameters of the bargaining rule. Applying these estimates to households in the LCF, we find that women have lower bargaining power than men on average: the mean bargaining weight for women is 0.46 and 0.54 for men in our main sample (the median is 0.45 and 0.55). Household-specific bargaining weights vary substantially with different characteristics of the couples. The direction of these estimated marginal effects is consistent both with bargaining theory and with previous findings in the literature. Women's (men's) bargaining power is higher (lower) for households characterised by: a higher female hourly pay and educational attainment, and a lower male hourly pay, average age, age gap between the man and the woman, and male educational attainment. For instance, an increase in female hourly pay by 1 GBP is associated with a 1.3% increase in her bargaining weight.

6.2.2 Environmental preferences

For couples, our findings confirm the high-level conclusion that women have more environmentally friendly preferences than men. As shown in Table 7, for overall consumption, men have a statistically significantly higher emission propensity than women: the total emissions of a household with a male dictator would be 67% higher than those of a household with a female dictator, and the same household budget; a very substantial impact.[21] The gender difference in carbon intensities is also significantly estimated: under male dictatorship, the carbon intensity of the basket of chosen goods is 45% higher than under female dictatorship; a stark difference.[22]

[21] This number is obtained as the gap between male and female emissions propensities, divided by the female emissions propensity

[22] Obtained as the difference between the carbon intensity for men and women, divided by the carbon intensity for women.

Table 8: Regressions ran on pooled UKTUS data to estimate bargaining

VARIABLES	(1) Male Leisure Exp.	(2) Female Meisure Exp.
hhBudget	0.243***	0.198***
	(0.00262)	(0.00236)
hhBudget * (female wage - average female wage)	-0.00559***	0.00559***
	(0.000198)	(0.000198)
hhBudget * (male wage - average male wage)	0.00215***	-0.00215***
	(6.87e-05)	(6.87e-05)
hhBudget * (female educ - average female educ)	-0.00295	0.00295
	(0.00253)	(0.00253)
hhBudget * (male educ - average male educ)	0.0154***	-0.0154***
	(0.00237)	(0.00237)
hhBudget * (average hh age - average age)	0.000905***	-0.000905***
	(0.000151)	(0.000151)
hhBudget * (hh age gap - average age gap)	0.000481	-0.000481
	(0.000338)	(0.000338)
hhBudget * (regional wealth p.c. - UK wealth p.c.)	-5.44e-07**	5.44e-07**
	(2.19e-07)	(2.19e-07)
Observations	711	711
R-squared	0.937	0.931

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 9: Emissions Propensities and Carbon Intensities, couples

	(1) Overall	(2) Food	(3) Transport	(4) Energy	(5) Clothing
HH Budget	0.209***	0.034***	0.045***	0.086***	0.003**
	(0.015)	(0.004)	(0.007)	(0.007)	(0.001)
Female share	-0.084***	0.004	0.000	-0.072***	0.003
	(0.032)	(0.008)	(0.015)	(0.015)	(0.003)
π_m	0.209	0.034	0.045	0.086	0.003
π_f	0.125	0.038	0.045	0.014	0.006
Significant diff.	yes	no	no	yes	no
α_m	0.125	0.037	0.013	0.012	0.007
α_f	0.109	0.029	0.014	0.001	0.014
Significant diff.	no	no	no	yes	no
CI_m	1.667	0.917	3.397	7.455	0.487
CI_f	1.144	1.304	3.274	24.661	0.442
Significant diff.	yes	yes	no	no	no
N	3,149	3,149	3,149	3,149	3,149
R-squared	0.825	0.764	0.612	0.688	0.316

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: The sample is restricted to households belonging to the middle 50% of the household budget distribution, and in which inequality between members is reasonable (the female resource share is constrained between 40 and 60% of the household's budget) HH Budg and Female share are the estimated coefficients of Equation 4 π_m and π_f are the emission propensities (retrieved from the regression estimates), α_m and α_f are Cobb Douglas preferences parameters (retrieved by estimating Equation 5, CI_m and CI_f give the carbon intensities of consumption. Significant diff. indicates whether differences between the estimates for men and women are statistically significant at the 95% confidence level.

To understand some more concrete implications of these estimates, let us consider a household with a weekly household budget of £3,983, which is the mean in the main sample[23]. If this household had a female bargaining weight of 0.46, which is the main sample mean, then we would predict the household's overall level of emissions to be 679 $kgCo_2eq$ per week.[24] We can repeat the same calculation for an equal household, where the bargaining weights are both set to 0.5, and then we obtain a predicted level of overall emissions of 665 $kgCo_2eq$ per week. This is a 2.1% fall in household consumption emissions.[25] For comparison, Ivanova et al. (2020) find that transitioning to a vegetarian diet could reduce the average North American citizen's annual per capita carbon footprint by 3.7%. To consider the impact relative to total GHG emissions, we weight our estimate by the proportion of relevant households in the UK, and the proportion of UK GHG emissions associated to households as opposed to other end-consumers (the government and non-profit organisations). As explained in Appendix B, we estimate that transitioning to gender equal bargaining would reduce total direct and indirect GHG emissions by UK end-consumers by 1.1%.

Within narrower categories of goods, a somewhat different picture emerges relative to what we saw for singles. For food, while women continue having a lower preference parameter than men on the overall category, women in couples prefer a basket of goods with a statistically significantly higher carbon intensity than men in couples (while for singles, women also had lower carbon intensity for food). These two opposite effects lead to no statistically significant difference in emissions propensity on food for men and women in couples.

For transport, men and women in couples have similar emissions propensities. This appears to be due to the canceling out of two opposite forces: women preferring to spend slightly more than men on this category (the reverse of the finding for singles), but choosing statistically less carbon intensive goods within this basket (similarly to singles).

[23]Recall that this is full income rather than disposable income, i.e. it is what the household would earn if both members worked 24 hours a day

[24]This is obtained by multiplying the household budget by the weighted average of the male and female emissions propensities

[25]Calculated as the difference between the emissions of the average household and the counterfactual equal household, divided by the emissions of the average household.

For energy, women in couples have a much lower emissions propensity than men, driven by a much lower preferred share of budget assigned to this category of consumption. At the same time, for couples, women's preferred basket of goods within energy is much more carbon intensive than the preferred basket of goods for men, although the latter is not statistically significant. This is a reversal of each of the findings for singles on energy. We note that it is particularly challenging to interpret findings for energy because a substantial component of observed emissions patterns from energy may be attributable to heterogeneity between the available energy sources in different UK homes during the period being considered. Part of the reversal in findings between singles and couples on energy may also be related to the fact that singles and couples often consider different sets of potential homes from each other, which may have different profiles in terms of energy systems and the possibility of upgrading or not.

For clothing, we find similar emissions propensities for men and women, with noisy measurement.

The partial divergence between findings for singles and couples is consistent with previous findings in the literature, e.g. Hubner (2020), that preferences are generally not stable across household compositions. This makes it particularly important to develop approaches, such as the one proposed in this paper, to uncover gender differences in preferences of men and women in couples directly from couples data, combined with estimates of bargaining power, rather than relying on findings from singles data. There are numerous reasons why preferences may differ between household compositions, including sample selection effects and a genuine transformative effect of becoming part of a couple. Future work may extend our analysis to other household compositions.[26]

6.2.3 Alternative proxies of bargaining power

We compare our baseline findings to what would happen if we were to use alternative estimates of bargaining power. We consider three options:

[26]we have not attempted this here due to substantial additional complications when dealing with members who don't do paid work, and children.

1. **Breadwinner approach**, as sometimes used in the environmental literature. The breadwinner (the household member with the highest weekly pay) is assumed to have full control over all the consumption decisions of the household (i.e. is a dictator).

2. **Wage ratio**, i.e. the hourly wage of the woman divided by the sum of the hourly wages of the woman and the man in the household. This is a commonly used proxy of bargaining power in the household economics literature because it captures an important aspect of the difference in earnings potential of men and women if they were to separate and live on their own individual income.

3. **Income ratio**, i.e. the actual income of the woman divided by the sum of her income and the man's. This is a half-way approach between the breadwinner proxy from the environmental literature and the wage ratio proxy from the household literature. Like the wage ratio, it is a continuous measure rather than a binary, but like the breadwinner approach, it focuses on earned income rather than potential earnings.

Using the breadwinner approach, for couples we do not find any statistically significant gender differences in terms of emissions propensity, as reported in Table 10. The direction of effects is suggestive of overall somewhat lower emissions propensities for women on all categories apart from clothing. Using this proxy, women in couples are estimated to have significantly lower carbon intensity than men in couples for all categories of expenditure but energy.

Using the wage ratio proxy, we find similar results on emissions propensity: nothing is statistically significant, but the directions indicate lower emissions propensity for women on all categories except clothing. As shown in Table 11, this is driven by both lower budget share spent on these categories, and lower carbon intensity of choices, except for transport and clothing, although none of these gender differences are statistically significant. The latter finding for transport is in contrast with most evidence from the literature.

Using the income ratio, as outlined in Table 12, we find that women have statistically significantly lower emissions propensity overall, but not for any specific category of goods. Carbon intensity of choices is never statistically significantly lower for women than men. The overall findings are similar to our baseline ones qualitatively, but using this proxy, we estimate a substantially lower average bargaining power for women than in our baselines: 0.43 instead of 0.46. Driven by this, the impact of moving to equal bargaining (equal earnings here) is estimated to be a 3.2% decrease in emissions, which is higher than our baseline estimate of a 2.1% reduction.

6.2.4 Comparison to other findings in the literature

The closest study to ours is Büchs and Schnepf (2013), which also uses UK data, but finds that female-led households have higher emissions propensities than male-led households, conditional on other household characteristics. Our results are more in line with other findings in literature, including from Sweden and Spain. The differences between our paper and Büchs and Schnepf (2013) are likely due to differences in our methodological approaches and the emissions data used.

Firstly, we employ a structural estimate of household bargaining rather than a binary variable for whether the house is female-headed or male-headed. This explains part of the difference in our results: when we repeat our analysis using a similar proxy to theirs, we find no statistically significant different emissions propensities for female and male headed households. However, in our robustness analysis, using a variety of proxies of bargaining, we never find that women have overall higher emissions propensities.

The remaining difference in our findings is likely due to improvements in data over time. Similarly to us, Büchs and Schnepf (2013) combine LCF data with DEFRA emissions multipliers. However, while we use DEFRA's 2023 emissions data release, that was not yet available at the time of writing of Büchs and Schnepf (2013), who instead had to rely on the 2011 release, which has been revised repeatedly in more recent releases. It is also useful to keep in mind that, while both of our papers contain applications to the UK, we focus on different samples, including different time periods and household compositions, so that the results

Table 10: Proxy of bargaining power with gender of the breadwinner

	(1) Overall	(2) Food	(3) Transport	(4) Energy	(5) Clothing
Fem. Budg.	0.167***	0.035***	0.045***	0.052***	0.005***
	(0.002)	(0.001)	(0.001)	(0.001)	(0.000)
Mal. Budg.	0.171***	0.036***	0.045***	0.054***	0.004***
	(0.002)	(0.000)	(0.001)	(0.001)	(0.000)
π_m	0.171	0.036	0.045	0.054	0.004
π_f	0.167	0.035	0.045	0.052	0.005
Significant diff.	no	no	no	no	no
α_m	0.117	0.033	0.013	0.006	0.010
α_f	0.119	0.033	0.014	0.007	0.010
Significant diff.	no	no	no	no	no
CI_m	1.467	1.082	3.352	8.239	0.458
CI_f	1.408	1.060	3.265	7.909	0.457
Significant diff.	yes	yes	no	yes	no
N	3,724	3,724	3,724	3,724	3,724
R-squared	0.815	0.750	0.596	0.688	0.298

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: The sample is restricted to households belonging to the middle 50% of the household budget distribution. Fem. Budg. and Mal. Budg are the regression estimates of Equation 2. π_m and π_f are the emission propensities (retrieved from the regression estimates), α_m and α_f are Cobb Douglas preferences parameters (retrieved by estimating Equation 3, CI_m and CI_f give the carbon intensities of consumption. Significant diff. indicates whether differences between the estimates for men and women are statistically significant at the 95% confidence level.

Table 11: Proxy of bargaining power with hourly wage ratios

	(1) Overall	(2) Food	(3) Transport	(4) Energy	(5) Clothing
HH Budget	0.187***	0.041***	0.045***	0.054***	0.004***
	(0.015)	(0.004)	(0.007)	(0.007)	(0.001)
Female share	-0.034	-0.011	-0.001	-0.003	0.000
	(0.031)	(0.008)	(0.014)	(0.014)	(0.003)
π_m	0.187	0.041	0.045	0.054	0.004
π_f	0.152	0.030	0.044	0.052	0.005
Significant diff.	no	no	no	no	no
α_m	0.124	0.037	0.014	0.006	0.010
α_f	0.111	0.030	0.013	0.007	0.010
Significant diff.	no	no	no	no	no
CI_m	1.504	1.110	3.242	8.910	0.433
CI_f	1.371	1.019	3.373	7.417	0.486
Significant diff.	no	no	no	no	no
N	2,321	2,321	2,321	2,321	2,321
R-squared	0.826	0.763	0.604	0.704	0.297

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: The sample is restricted to households belonging to the middle 50% of the household budget distribution, and in which inequality between members is reasonable (the female hourly wage ratio is constrained between 40 and 60%) HH Budg and Female share are the estimated coefficients of Equation 4 π_m and π_f are the emission propensities (retrieved from the regression estimates), α_m and α_f are Cobb Douglas preferences parameters (retrieved by estimating Equation 5, CI_m and CI_f give the carbon intensities of consumption. Significant diff. indicates whether differences between the estimates for men and women are statistically significant at the 95% confidence level.

Table 12: Proxy of bargaining power with weekly pay ratios

	(1) Overall	(2) Food	(3) Transport	(4) Energy	(5) Clothing
HH Budget	0.208***	0.040***	0.048***	0.062***	0.003**
	(0.018)	(0.004)	(0.008)	(0.008)	(0.002)
Female share	-0.077**	-0.010	-0.004	-0.021	0.003
	(0.036)	(0.009)	(0.016)	(0.017)	(0.003)
π_m	0.208	0.040	0.048	0.062	0.003
π_f	0.131	0.031	0.044	0.041	0.006
Significant diff.	yes	no	no	no	no
α_m	0.134	0.034	0.013	0.007	0.007
α_f	0.103	0.033	0.016	0.006	0.014
Significant diff.	no	no	no	no	no
CI_m	1.549	1.182	3.834	9.383	0.480
CI_f	1.276	0.941	2.818	6.759	0.444
Significant diff.	no	no	no	no	no
N	1,860	1,860	1,860	1,860	1,860
R-squared	0.812	0.764	0.604	0.647	0.304

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: The sample is restricted to households belonging to the middle 50% of the household budget distribution, and in which inequality between members is reasonable (the female weekly pay ratio is constrained between 40 and 60%.) HH Budg and Female share are the estimated coefficients of Equation 4 π_m and π_f are the emission propensities (retrieved from the regression estimates), α_m and α_f are Cobb Douglas preferences parameters (retrieved by estimating Equation 5, CI_m and CI_f give the carbon intensities of consumption. Significant diff. indicates whether differences between the estimates for men and women are statistically significant at the 95% confidence level.

should be compared with care.[27]

6.3 Discussion of findings

Policy implications. Policy-makers can intervene in a variety of ways to empower women within households, for instance by pursuing policies to narrow gender pay gaps and providing free childcare to all children. This paper suggests an additional, novel, rationale for such policie: they are likely to substantially lower household consumption emissions, and thus overall GHG emissions at a national level.

Limitations. It is important to recall that the data used in this paper has some limitations, including the limited degree of granularity of categories for which we can obtain emissions multipliers. Moreover, our analysis does not encompass some consumption goods which are difficult to analyse with our expenditure and emissions data, such as the emissions associated to building and renovating homes, and pharmaceuticals. When more granular and extensive emissions data becomes available in future years, it would be important to repeat a similar analysis using it. Moreover, this paper focuses on the period 2001-2014. It would be interesting to check whether gender differences in emissions propensities have remained stable, or become more or less pronounced, over time, with growing overall environmental consciousness.[28]

We also note that further work is needed to rule out potential counfounding factors that are not addressed in this paper. In particular, we do not allow for preference heterogeneity within genders. In reality, this is likely to exist, for instance by age. Moreover, it is possible that couples form in a way that is assortatively matched so that couples tend to either involve two environmentally friendly people or two individuals who are not concerned about the environment (even though on

[27] Firstly, we cover a longer time period (they focus only on 2006-9). Secondly, we focus only on working singles and heterosexual working couples, while they consider all different household compositions in aggregate.

[28] We do not have appropriate data to perform this analysis - in particular we cannot estimate bargaining power reliably for years after 2014.

average women may be more environmentally friendly than men). This in itself is not an issue for our analysis, unless environmental preferences are correlated with factors that also affect the distribution of bargaining power in the household. If that were the case, that could introduce bias into our results. For instance, it may be that some of our estimated gender differences are in fact driven by some couples being more left-wing and/or younger, and these couples being characterised by both higher female empowerment and greater environmental consciousness of both members of the couple. We do not allow for more heterogeneity in preference parameters in our approach because the data that we use to estimate bargaining power is too small to conduct the exercise separately for granular groups (e.g. younger people in left-wing regions vs older people in right-wing regions), and we leave it to future work to investigate these possibilities.

Finally, we note that findings are sensitive to the chosen measure of bargaining power, and that we obtain somewhat different conclusion in our baseline, using structural bargaining estimates, and using each of three alternative proxies of bargaining. This suggests the importance of carefully modeling and estimating bargaining power, rather than relying on a proxy. The approach we use itself makes substantial simplifications and assumptions, and it will be important for future work to use whichever methods emerge from the household economics literature as being more reliable. Currently, there is a gap in that literature when it comes to systematically assessing the predictive success of different approaches, but we hope that gap will be filled in the coming years, allowing applications to a range of contexts, including the environmental literature, to rely on best-performing approaches.

7 Conclusion

This paper contributes to the environmental literature by investigating gender as a determinant of carbon footprints of consumption both for singles and couples by using a revealed preference approach, rather than relying on reported attitudes. Moreover, this is the first paper to structurally estimate intra-household bargaining power to examine gender differences in emissions in two-person households. In so doing, this paper also contributes to the household economics literature, by exploring a new application of intra-household bargaining power estimates.

Consistent with the literature to date, our findings suggest that women in general have more environmentally friendly preferences than men. For single women, this is driven by a lower carbon intensity of the chosen basket of goods. For women in couples, this is driven both by a lower carbon intensity of preferred baskets of goods, and a preference to spend a lower proportion of the budget on goods considered in this analysis.

We do not attempt to explore the psychological mechanisms driving gender differences in preferences. However, our results, combined with existing evidence in the literature that women have stronger pro-environmental attitudes than men, are suggestive that awareness of environmental issues and concerns about them translates into concrete differences in emissions. Further work is needed to draw this link more strongly and explore potential avenues for policy to leverage this link to combat climate change.

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Appendix A: Emission multipliers

A.1. UKMRIO methodology

Take Z to be a transaction matrix, where the row $z_{i.}$ reveals output sold by industry i, and column $z_{.j}$ reveals input bought by industry i. Total output produced x_i produced by industry i can thus be expressed as

$$x_i = z_{i1} + z_{i2} + ... + z_{ij} + y_i$$

where y_i is final output demanded by consumers, and $z_{i.}$ output sold to other industries. One can reformulate the final output of industry i as

$$x_i = a_{i1}x_1 + a_{i2}x_2 + ... + a_{ij}x_j + y_i$$

where a_{ij} is the requirement of inputs from industry i for industry j to produce 1 pound of output. Take A to be the matrix of coefficients a_{ij}, X to be the vector of total output, y to be the vector of final consumption, and I to be the identity matrix. We can rewrite in matrix notation: $X = AX + y$. Solving for x, we get

$$X = (I - A)^{-1}y \tag{6}$$

$L = (I - A)^{-1}$ is known as the Leontief Inverse: it provides the inter-industry requirements for a given sector to produce one unit of output to final demand. Call F the vector of greenhouse gas emissions generated by each sector in a given year. The emission intensity vector e is thus:

$$e = FX^{-1}$$

and represents the emissions associated with the production of one unit of output x. Multiplying both sides of Equation 6 by the emission intensity vector e thus gives the GhG emission matrix, which provides the emissions embodied in the final consumption for each sector. Conversion multipliers used to convert expenditures from the LCF to carbon footprints are obtained as $M = eL$: this vector is a conversion factor for indirect emissions on the whole supply chain.

A.2. UKMRIO good categories

Table 13: Expenditures categories included in the UKMRIO (COICOP-level)

COICOP	Expenditure category
1.1.1	Bread and cereals
1.1.2	Meat
1.1.3	Fish and seafood
1.1.4	Milk, cheese and eggs
1.1.5	Oils and fats
1.1.6	Fruit
1.1.7	Vegetables
1.1.8	Sugar, jam, honey, chocolate and confectionery
1.1.9	Food products n.e.c.
1.2.1	Coffee, tea and cocoa
1.2.2	Mineral waters, soft drinks, fruit and vegetable juices
10.1.1	Pre-primary and primary education
10.2.1	Secondary education
10.3.1	Post-secondary non-tertiary education
10.4.1	Tertiary education
10.5.1	Education not definable by level
11.1.1	Restaurants, cafes and the like
11.1.2	Canteens
11.2.1	Accommodation services
12.1.1	Hairdressing salons and personal grooming establishments
12.1.2	Electrical appliances for personal care
12.1.3	Other appliances, articles and products for personal care
12.3.1	Jewellery, clocks and watches
12.3.2	Other personal effects
12.4.1	Social protection
12.5	Insurance
12.6.2	Other financial services n.e.c.
12.7.1	Other services n.e.c.
13	Non-profit instns serving households
14	Central_x000D_ government
15	Local_x000D_ Authorities

Table 13 continued from previous page

COICOP	Expenditure category
16	Gross fixed_x000D_ capital_x000D_ formation
17	Valuables
18	Changes in inventories
2.1.1	Spirits
2.1.2	Wine
2.1.3	Beer
2.2.1	Tobacco
3.1.4	Cleaning, repair and hire of clothing
3.1.1	Clothing materials
3.1.2	Garments
3.1.3	Other articles of clothing and clothing accessories
3.2.1	Shoes and other footwear
3.2.2	Repair and hire of footwear
4.1.1	Actual rentals paid by tenants
4.1.2	Other actual rentals
4.2.1	Imputed rentals of owner occupiers
4.3.1	Materials for the mainenance and repair of the dwelling
4.3.2	Other services for the maintenance and repair of the dwelling
4.4.1	Water supply
4.4.2	Refuse collection
4.4.3	Sewage collection
4.4.4	Other services relating to the dwelling n.e.c.
4.5.1	Electricity
4.5.2	Gas
4.5.3	Liquid fuels
4.5.4	Solid fuels
4.5.5	Heat energy
5.1.1	Furniture and furnishings
5.1.2	Carpets and other floor coverings
5.1.3	Repair of furniture, furnishings and floor coverings
5.2.1	Household textiles
5.3.1	Major household appliances whether electric or not
5.3.2	Small electric household appliances
5.3.3	Repair of household applicances
5.4.1	Glassware,tableware and household utensils
5.5.1	Major tools and equipment
5.5.2	Small tools and miscellaneous accessories

Table 13 continued from previous page

COICOP	Expenditure category
5.6.1	Non-durable household goods
5.6.2	Domestic services and household services
6.1.1	Pharmaceutical products
6.1.2	Other medical products
6.1.3	Therapeutic appliances and equipment
6.2.1	Medical services
6.2.2	Dental services
6.2.3	Paramedical services
6.3.1	Hospital services
7.1.1	Motor cars
7.1.2	Motor cycles
7.1.3	Bicycles
7.1.4	Animal drawn vehicles
7.2.1	Spare parts and accessories for personal transport equipment
7.2.2	Fuels and lubricants for personal transport equipment
7.2.3	Maintenance and repair of personal transport equipment
7.2.4	Other services in respect of personal transport equipment
7.3.1	Passenger transport by railway
7.3.2	Passenger transport by road
7.3.3	Passenger transport by air
7.3.4	Other transport services
8.1.1	Postal services
8.2.1	Telephone and telefax equipment
8.3.1	Telephone and telefax services
9.1.1	Equipment for the reception, recording and reproduction of sound and pictures
9.1.2	Photographic and cenematographic equipment
9.1.3	Information processing equiment
9.1.4	Recording media
9.1.5	Repair of audio-visual, photographic and information processing equipment
9.2.1	Major durables for outdoor recreation
9.2.2	Musical instruments and major durables for indoor recreation
9.2.3	Maintenance and repair of other durables for recreation and culture
9.3.1	Games, toys and hobbies
9.3.2	Equipment for sport, camping and open-air recreation
9.3.3	Gardens, plants and flowers
9.3.4	Pets and related products
9.3.5	Veterinary and other services for pets

Table 13 continued from previous page

COICOP	Expenditure category
9.4.1	Recreational and sporting services
9.4.2	Cultural services
9.4.3	Games of chance
9.5.1	Books
9.5.2	Newspapers and periodicals
9.5.3	Miscellaneous printed matter
9.5.4	Stationery and drawing materials

Appendix B: From Household Emissions to Total UK Emissions

Structural estimation of gender-based emission propensities within heterosexual couples indicates that achieving equal bargaining power would reduce household consumption emissions by approximately 2.1%. To assess how this impact translates to total UK emissions, two key adjustments must be considered.

First, households are not the sole contributors to final demand emissions. Other sectors—such as non-profit institutions, central and local governments, and investment-related components—also play a role. Data from DEFRA, which provides annual breakdowns of UK emissions by final demand category, allow us to quantify the household sector's relative contribution (DEFRA, 2024). On average, between 2001 and 2014, households accounted for 73.3% of total GHG direct and indirect emissions due to UK demand.

Second, the equal bargaining counterfactual is only relevant for multi-person households in which decisions are made collectively by couples. It does not apply to single-person households or households without couples. To adjust for this, we use yearly data from the Office for National Statistics (ONS) on family and household composition (ONS, 2024). These figures show that, on average, 72.6% of individuals lived in multi-person households with couples over the same 2001–2014 period.

Although we only consider childless couples in the analysis, we do not exclude household with children in the re-weighting of our estimated effect. There is evidence from the household literature that couples with children tend to have lower female bargaining than those without cohabiting children (e.g. see Bargain et al. (2022). Therefore, here we apply our estimates to families with children, considering this is likely to yield a conservative, lower bound, estimate.

Taking both adjustments into account, we re-weight the initial 2.1% estimated reduction in household emissions. The resulting estimate of the impact on total UK emissions is:

$$2.1\% \times 73.3\% \times 72.6\% = 1.1\%$$

This suggests that equalizing bargaining power within couples would lead to an estimated 1.12% reduction in total UK emissions, once both the sectoral scope of household demand and the relevant household types are taken into account.