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Uncovering consumption inequalities by integrating household activity patterns in UK input-output tables

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Abstract

Understanding inequality through the lens of what households do – and the products and time their activities require – offers a richer perspective than conventional income-based inequality metrics. The study demonstrates this by analysing detailed consumption activities for the UK (2005, 2015) and their total (direct and upstream) use of household-produced products, market products, and human time. We expanded the national input-output tables with household production and detailed final consumption activities, the latter receiving product flows from market and household production activities. Household production outputs were preferentially valued by a market-equivalent value. For household types differentiated by income and composition, the tables include time use across the full 24-hour day, divided on 129 market production, 22 household production, and 33 consumption activities. The subsequent analyses provide a comprehensive understanding of households' products and time use, with policy-relevant findings to promote more equitable consumption patterns. E.g., including the value of household production reduces inequality in consumption, although household production time and value are increasing with income. Furthermore, consumption activities differ in their total input requirements and in the degree to which these requirements vary by household type. Community activities (e.g., socialising) shows relatively equal uses of products across household types while the use in outgoing leisure (e.g., dining out) increases notably more with income. The upstream production time required for one minute of consumption increases notably with income across consumption activities, excluding basic consumption (e.g., sleeping). Considering household and market input requirements of distinct consumption activities can refine policies promoting more equitable consumption.

Keywords Household production · Consumption inequality · Output-based method · Input-output analysis · Time use survey · Expenditure data

JEL codes C67 · C81 · D13 · D63 · J22 · Z13

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1 Introduction

The debate on valuing and viewing household production in line with market production has persisted since the early academic contributions, including those by Hildegarde Kneeland in 1929 and Margaret Reid in 1934, while not leading to regular integration of household production into standard economic frameworks. With the recognition of household production as an important factor to welfare, major societal challenges can be addressed. These include explaining economic growth (Bridgman et al., 2012; Bridgman et al., 2022) and the concurrent role of technological development (Coyle & Nakamura, 2019), explaining and expanding the view on between-household inequality (Gautham & Folbre, 2024; Folbre et al., 2013; Frick et al., 2012; Ragnarsdóttir et al., 2023), and understanding the gender-division of labour, care provision, and intrahousehold bargaining (Folbre, 2006; Lundberg & Pollak, 1993). With the current development of the 2025 version of the System of National Accounts (SNA), the inclusion of household production to complete national overviews of economic activities is again debated (Hoekstra, 2020). A common thread in studies on household production – whether within households, across households, or across countries or time – is the divergence in income and power relations, requiring consistent accounting to make household production comparable to market production. However, there is still a limited understanding of the role of household production as consumer of market products and time and as contributor of inputs to *actual* final consumption activities. This makes it difficult to assess how household production shapes overall consumption patterns, resource allocation, and economic well-being, in broader economic and policy contexts. Gronau and Hamermesh (2006) calculated the time vs. expenditure requirement in an exhaustive number of activities, showing that leisure activities (or "final consumption activities", using our terminology) were comparably more time-intensive, and proportionally more for disadvantaged households. While this consumption view can provide a first insight to "*how goods and income taxation interact*" (p.1), it misses the upstream use of time and household-produced products by each final consumption activity.

This study raises the central research question: *How does incorporating the upstream use of time and products (being produced by the household or market) for specific consumption activities contribute to our understanding of consumption inequality?* To answer this question, the study refines and extends traditional measures of between-household inequality by focusing on detailed consumption activities, explicitly accounting for their use of household-produced products, market products, and time. The study goes beyond traditional inequality analyses by not only presenting statistics on direct inequality in income or total consumption but also analysing the total (direct and upstream) use of products and time. To enable these analyses, it develops input-output tables with a detailed modelling of households and their activities, presented after an extensive discussion of methodological choices. Incorporating upstream use of time and products into inequality measures can reveal hidden disparities in access to goods and work time that traditional measures overlook, offering valuable insights for social policies. Detailed modelling of final consumption activities helps identify the aspects of daily life with the largest disparities, enabling more targeted and

effective policy interventions. While the study primarily focuses on the UK in 2015 (due to better data quality), we compare the results to 2005 (deploying UK time-use evidence from 2000/1 as explained in Section 3.1).

Household production activities are traditionally, and in the current context, defined as activities that you could pay a third party to do without losing the possibility for consumption that results from it (Reid, 1934). In the UK, an average working-age person spent more than 8 h in production activities in 2015, of which household production, such as meal preparation or cleaning, constituted 50% and 30% for women and men, respectively (Gershuny & Sullivan, 2019). This stresses the important contribution of household production to current consumption levels in the UK society.

Studies investigating the effect of including household production in inequality measures have focused on income and predominantly valued household production time using fixed market-based wages (e.g. Gautham & Folbre, 2024; Frick et al., 2012; Ragnarsdóttir et al., 2023). Their examinations of the contribution of household production to income are in line with the commonly applied input-based methods to value household production outputs (Eurostat, 2003; Cushing & Rosenbaum, 2012). However, valuing time in household production by a fixed market wage is not consistent with national accounting practices and does not account for the diminishing return to time spent in household production activities, that market and household production activities use different compositions of labour time and technology, and the varying value of produced outputs (Eurostat, 2003; Cushing & Rosenbaum, 2012; Goldschmidt-Clermont & Pagnossin-Aligisakis, 1999). Therefore, it has long been argued that household production ideally should be valued based on its outputs though this is more demanding (Fitzgerald & Wicks, 1990; Ironmonger, 1996). An output-based valuation of household production can more accurately capture the contribution by household production to both income and consumption. Further, compared to income, consumption is a better measure of well-being and living standards (Brewer & O'Dea, 2012; Carver & Grimes, 2019; Brown & Gathergood, 2020). A study from the UK (Brewer & O'Dea, 2012) and undergoing work by the US Bureau of Labor Statistics (Garner et al., 2023) have developed consumption measures that includes the service flow from homes and vehicles, showing less inequality and lower poverty rates when these flows are included. While current studies on including household production in inequality measures do not distinguish different household production activities and their contributions to different consumption activities, such a detailed approach can further extend our understanding of inequality and how outputs from household production contribute to everyday life.

In many countries, household production satellite accounts created by statistical agencies address the limited detail to household production activities. These accounts are "satellites" to the central national accounts and show the monetary value of household production in an economy, grouped into up to ten household production activities. See as examples the work for the UK (Holloway et al., 2002), USA (Bridgman et al., 2012), Finland (Statistics Finland, 2025), France (Poissonnier & Roy, 2017), Spain (Casero & Angulo, 2008), and Switzerland (Federal Statistical Office, n.d.). Most accounts do not detail households by their

characteristics and therefore cannot contribute to inequality analysis. Among the mentioned, only the US, Swiss, and Finnish satellite accounts detail the household production by population characteristics – by income, sex, and age and member composition, respectively. Only the UK satellite accounts value the outputs of the household production rather than the input of time, thus making the household production comparable to market production. As the word "satellite" indicates, the household production accounts are separated from the market accounts. This implies they function well as a descriptive tool but have limitations for further analysis of the relationship between the market and the household spheres (Carrasco & Serrano, 2011). Further, from a purely descriptive point of view, household satellite accounts do not show how an output from household production, for example commuting to work, can be an input to market activities. Nevertheless, the theoretical traditions that are reflected in the international guidelines, including the SNA 2008 and the EU guidelines (Eurostat, 2003), recommend the use of household satellite accounts. This may have discouraged more widespread use of less conventional and more integrated approaches with larger analytical capabilities. Also, approaches to integrate the household activities are more demanding in terms of data and analytical complexity; they require not only individual time use and household expenditure data, but also knowledge on the use and value of products as inputs to specific household activities.

To our knowledge, Stahmer & Ewerhart (1999), later built upon by Schaffer (2007) and Stahmer (2010), are the only studies integrating flows of outputs from household production activities as inputs to more than one final consumption activity into a national input-output table. Among these, Schaffer (2007) is the only study that has distinguished population groups (here by sex) in an investigation of the upstream use of market and household-produced products in (a few) consumption activities. Therefore, given our aim to analyse inequalities in the total use of products and time across detailed consumption activities, it is relevant to combine insights from studies on direct income inequality that account for household production (e.g., Frick et al. 2012, Ragnarsdóttir et al. 2023) with the input-output approach.

This study makes three key contributions. First, it extends work on consumption inequality beyond a single, uniform measure by revealing how inequality takes different shapes across final consumption activities that use the inputs from both household and market production. Second, it demonstrates an inequality measure that takes the total (upstream) use of products and time into account, reflecting the draw on common resources in the economy. Last, the study develops and demonstrates a set of methods used to structure, detail, and complete activity data in an economy and to value the outputs of household production in the input-output structure. To do this, it uses the UK economy in the years 2005 and 2015. The developed methods can be used for analyses with several other purposes. By modelling the flows of money and time within the market economy, and between the market economy and the households, a complete picture of the economy is provided.

The significant amount of time devoted to household production activities (Gershuny & Sullivan, 2019) and the economic contribution of this (Bridgman et al., 2022; ONS, 2018) highlight a major underreporting of production in traditional production measures. We expect that this underreporting extends to the consumption

within different activities, likely varying between activities and household types, in until now unexplored ways. Furthermore, considering total (direct and upstream) use in consumption activities, rather than just direct use in consumption activities, contributes to a more varied perspective for shaping distributional policies, as it captures consumption throughout the entire life cycle of products. Household production constitutes a persistent, though slightly declining, factor in production over a 50-year period (Bridgman et al., 2012; 2022). While the declining role can partly be attributed to the shift of women from household production to market activities, the rise of digitalization and self-service (e.g., online banking or self-checkout) may counterbalance this trend, making it crucial to continue to analyse the development. From a well-being perspective, such shifts are important, especially since welfare policies are typically tied to formal market work. The work required to do this analysis is extensive, requiring the construction of input-output tables with detailed household activities and the flows of products between these and the market. It requires data on expenditures, time use, end use of products from the literature and well-founded assumptions. In times of changed world order and, in the UK case, demonstrated changes in time use and expenditure patterns associated with COVID-19 (Gershuny et al., 2021; Croudace, 2022) and Brexit (Fleissig & Swofford, 2023), and increasing income disparities (ONS, 2023c), it appears particularly urgent to develop methods to provide a more nuanced and exhaustive picture of inequality.

The remainder of the paper is structured in the following way: Section 2 presents the conceptual foundation for the research and explains its application in the current investigation. Section 3 presents the developed set of methods. Section 4 presents the results, first presenting the completed input-output tables, and then the detailed analysis of household consumption patterns and inequality. Section 5 discusses the results, and Section 6 concludes.

2 Conceptual foundations

2.1 Input-output approaches to modelling household activities

Traditional input-output tables, more precisely referred to as direct requirement tables, show a comprehensive record of product flows between activities in the economy (Miller & Blair, 2009; Weidema et al., 2009). Input-output tables are double-entry accounts that ensure balanced product flows. Using this structure provides both the direct requirement of intermediate material, capital, and services in the production of each product and enables the calculation of the indirect (upstream) requirements, including the entire life cycle of each product. An input-output table detailing household activities will show the flows of human time and products between production activities and to final consumption activities. For example, the direct requirements for the final consumption of a meal are the meal, eating time, a plate, etc. Upstream requirements include the meal ingredients, meal production time, kitchen tools, inputs to the production of meal ingredients and kitchen tools, etc. Together, the direct and upstream requirements constitute the total requirements. When input-output tables built in accordance with the SNA refer to households' market expenditures as "final consumption" or "final demand", this is a misnomer,

since it rather represents households' market demand. Besides the misleading name, it implies that the value-added from the household production is excluded.

The first input-output structures of household production activities were developed for Australia, 1975 (Ironmonger & Sonius, 1989), inspiring tables for Finland, 1990, Norway, 1991, and the US, 1985 (Aslaksen et al., 1995; Ironmonger, 1997; Vihavainen, 1995). These did commendable work to estimate the direct contribution to the economy by household production, showing both time and expenditure flows, but showing no details to the market activities. While these first tables did not show the flow of household-produced products within households, Landefeld & McCulla (2000) illustrated this in an input-output table for the US 1992 but only specified one broad final consumption activity. Concurrent with this, Stahmer & Ewerhart (1999) (see Stahmer (2010) in English) developed an input-output table for Germany for 1990, that detailed market production, household production, and broad consumption activities in monetary, time, and physical units. The input-output structure modelled in our current study takes inspiration from the German (Stahmer & Ewerhart, 1999) in representing market activities in detail and the inputs of more household production activities to more consumption activities and with added rows of time use.

This *integrated* input-output approach deviates from the Household Satellite accounts created by the UK Office of National Statistics (ONS) from 2005 and onwards by including household production in the core part of the input-output tables.

2.2 Household production and inequality

As the next paragraphs demonstrate, the existing literature on the contribution of household production to inequality has focused on income inequality as opposed to consumption inequality. The income from household production have been estimated based on opportunity costs or generalist wages, or variations thereof (Bonke, 1992; Gautham & Folbre, 2024; Folbre et al., 2013; Frazis & Stewart, 2011; Frick et al., 2012; Gottschalk & Mayer, 2002; Ragnarsdóttir et al., 2023). These methods can imply differentiated wages e.g., for women and men (Frick et al., 2012), transferring inequalities in the market to the household sphere. Further, the methods ignore diminishing returns to the time spent in a household production activity and can thereby overestimate the value of household production for households that have fewer time constraints from market work (Goldschmidt-Clermont & Pagnossin-Aligisakis, 1999).

The current study's focus on consumption makes the output value of household production central. Therefore, it estimates the output value of household-produced products preferentially by the value of an equivalent market product (see methods section). The output-based approach is superior to the input-based approach where the output value is calculated as the sum of input values, including wages. This is because the output-based method aligns with market pricing, follows national accounting practices, and avoids dependency of the value on the effectiveness of the producer (Eurostat, 2003; Goldschmidt-Clermont & Pagnossin-Aligisakis, 1999; National Research Council, 2005). For example, in a restaurant, the price of a meal is set per dish, regardless of how quickly the staff work. Moreover, differences in the composition of labour time, equipment, and technology between household and

market production suggest that using market wages may not fully capture the value-added from household production (Cushing & Rosenbaum, 2012). In the context of creating UK household production satellite accounts, Holloway et al. (2002) developed a detailed methodology for estimating household production values using an output-based method. This inspired what follows here. Often, the unit reflecting the product output is the number of instances or episodes of an activity rather than the duration of that activity, e.g., the number of washing loads or meals as opposed to the minutes spent washing clothes or cooking. When using the output-based method, wages are implicitly calculated as the difference between the output value and the sum of intermediate input values.

Theoretically, individuals with higher incomes would spend less time in household production since they have a higher opportunity cost of time (Gronau, 1986). In reality, income and household production time are positively related in many cases (Frick et al., 2012). Still, most of the studies from the 1970s to the mid-2000s and recent repeated cross-sectional and multi-country studies found the addition of household production wages to the market wages to be inequality-reducing because the inequality in the household production wages was smaller than the market income inequality (Gautham & Folbre, 2024; Frick et al., 2012; Ragnarsdóttir et al., 2023). Gottschalk & Mayer (2002) found that including household production reduced income inequality in all years between 1976 and 1988, though it did not change the pattern of increasing inequality during the period. The substitutability between specific household-produced products and market products was investigated by a study that used the Great Recession (2007–2009) as a natural experiment, showing that a 10% decrease in market expenditures increased the value of household production by 6.5% (Been et al., 2020). This suggests that household production indeed plays an important market expenditure compensating role and that a detailed view of household production activities or outputs is important for the analysis.

2.3 Towards a more comprehensive approach to household activities and inequality

Our construction of the input-output structure for household activities is based on best practices outlined in a systematic literature review on the input-output modelling of household behaviour (Madsen & Weidema, 2023) and a conceptual foundation for creating national accounts based on time-use data, consistent with the SNA input-output tables (Gershuny, 2025). This study operationalises and demonstrates the relevance of the approaches proposed by Gershuny (2025) and Madsen & Weidema (2023), extending them beyond accounting into analytical application. It demonstrates how the detailed input-output structure contributes to a much more nuanced view of consumption inequality when including the direct and upstream use of time and money.

Within the field of household production, a substantial body of research has focused specifically on care work and the role of women. Notably, in this millennium, contributions by Nancy Folbre (e.g., Folbre, 2006 and Suh & Folbre, 2016) have been instrumental in advancing this area of study. Our study includes all household production activities rather than focusing on specific ones. It relies

on high-quality time-use diary data as opposed to the anticipated general time distribution of respondents used in other studies (Frick et al., 2012; Gottschalk & Mayer, 2002) or last-week references as in Been et al. (2020). It covers the entire UK household population of 2005 and 2015 in contrast to other studies that were limited to certain household types (Been et al., 2020; Bonke, 1992; Frazis & Stewart, 2011; Ragnarsdóttir et al., 2023). We detail the input-output tables for 2005 and 2015, because the relatively large time gap can be interesting to investigate, since the provision of some products has changed in the meantime. For example, the total time in paid care of children under 5 (substituting household childcare) increased by 27.4% between 2005 and 2014 in the UK (Webber & Payne, 2016). In the same period, the use of digital solutions like online banking has increased notably (Eurostat, 2024), potentially substituting paid work.

Expanding on Schaffer (2007), who introduced more population groups (distinguished by sex), we introduce multiple income groups and household compositions in our input-output table. Our study investigates four different household compositions (see Section 3.2), which is important because the number of adults affects the available time for household production (Ragnarsdóttir et al., 2023). Further, our breakdown of final consumption activities is highly detailed. In our analysis, we detail 33 consumption activities for which we can analyse the inequality in expenditures and time use. In the presentation of the results, we aggregate the final consumption activities into four categories, thereby merging and separating out some of the categories of wants identified by Gershuny (2025). We exclude regular schooling, homework, and looking for jobs from the presentation of results since these formally belong to the production activities. We also exclude the provision of products to other household members or persons outside the household, and investments since these activities have no associated time use in the underlying data. The four final consumption activity categories are the following with the number of detailed final consumption activities (specified in Appendix A) in parenthesis after each activity name.

a. *Basic consumption activity* (4): Fulfilling basic, physiological, needs, such as sleeping, eating, and hygiene. As many people consume more than needed from a physiological perspective the word "basic" might be misleading. The activities are usually undertaken in the home sphere. Basic consumption is hypothesised to be the activity with the least variation in time use and little variation in expenditures; everyone needs a minimum amount of this.
b. *Home leisure activity* (12): The consumption of home leisure, including hobbies and relaxation such as playing music, crafts, watching television etc. While these activities are often also social, this is not their main purpose. The activities are usually undertaken in the home sphere or locally. Consumption of home leisure covers a broad range of activities that often require specific equipment to perform. Therefore, the expenditures in this category are expected to be income-dependent. Home leisure is also expected to include activities that less time-constrained households, like retired households, spend much time in, e.g., watching TV.

c. *Community activity* (5): The consumption of time for establishment, enjoyment, and maintenance of social community networks, i.e., activities done in interaction with others, such as meeting with friends. The activities are undertaken either in the home or public sphere. Community activity does not as such require any specific equipment or conditions and is therefore expected to be a more income-neutral activity time and expenditure-wise.
d. *Outgoing leisure activity* (6): The consumption of market services out of the home, such as theatre, sporting events, museums, and personal care services, only requiring limited inputs of household-produced products. Outgoing leisure is expected to be the most luxurious and therefore with the largest variation both in time and expenditures. Lower-income and more time-restricted households, such as households with children, are expected to spend less time in outgoing leisure than other household types.

3 Methods

The detailing of household activities in the input-output tables implies adding new columns, representing each household production and final consumption activity, and new rows for each household-produced product, for time use, and for value-added (wage) from household production (Fig. 1). The wage part of the value-added is the gross income, including income taxes which are zero in household production. After a data description in Section 3.1, the creation of the new structure is explained: Section 3.2 describes the detailing by household type, Section 3.3 the detailing of household products and activities, Section 3.4 the valuation of household-produced products, Section 3.5 the allocation of product inputs to activities, and Section 3.6 the detailing of wages and work time, and the estimation of imported time. Section 3.7 introduces the methods used for the input-output analysis to obtain the total use in consumption activities by different household types.

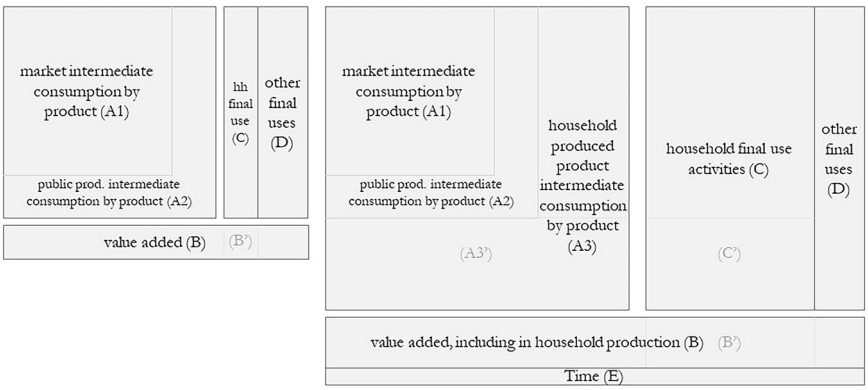

Fig. 1 Original UK input-output (left) and the complete input-output table (right). The intermediate consumption of household-produced products occurs within the same household and only by others if voluntary work is produced

3.1 Household data and input-output tables

The UK national product-by-product input-output tables from 2005 and 2015 were detailed using the UK Time Use Survey (TUS) from 2000/2001 (N = 16,898) and 2014/2015 (N = 14,844) (Gershuny & Sullivan, 2017) and the UK Living Cost and Food Survey (LCF) from 2004 (N = 6,798), 2005 (N = 6,785), 2006 (N = 6,645), 2014 (N = 5,133), 2015 (N = 4,912), and 2016 (N = 5,041) (ONS, 2024c) converted to 2015-prices by COICOP (Classification of Individual Consumption according to Purpose, 1999) category-specific deflators obtained from the UK Office of National Statistics (ONS). The adjacent years were included to increase the sample size. For the LCF expenditure data, the N refers to the number of households, while for the TUS data, it refers to person-days after removing observations with missing income information. The TUSs are diary-based and collect time use in primary and secondary activities in 10-minute time intervals for one weekday and one weekend day for all household members aged 8 and above. The LCFs collect expenditures at the household level based on interviews and diaries, rescaled to cover one week. Both surveys also collect household characteristics such as income and member composition. In addition to the flows of market products, the UK input-output table from 2015 includes a detailed structure of the flow of products from public production and non-profit institutions serving households (NPISH).

The study uses the TUS from 2000/2001 even though a TUS exists for 2005. The 2005 TUS has a small sample size compared to the 2000/2001 and 2014/2015 surveys, it did not include people younger than 16 years and a household identifier. Further, it used pre-coded activities, that in some instances were not directly comparable with the ones used in the 2000/2001 and 2014/2015 surveys (Lader et al., 2006). It was deemed better to linearly interpolate the primary time use in the 2000/2001 TUS to 2005 using the 2015 TUS for individuals in the same household composition and age group.

3.2 Detailing household types by income and composition

Each household in the sample belongs to an equivalised disposable income group, by decile for 2015 and by quintile for 2005 (ONS, 2019). The equivalisation uses the OECD modified scale (Hagenaars et al., 1994), giving a two-adult household the value of 1, summed from a value of 0.667 for the first adult household member and 0.333 for all additional members aged 14 and above. All younger children are given the value 0.2. Throughout the paper, decile and quintile refer to the equivalised disposable income. In the 2000/2001 TUS, households were asked to report their disposable income as one of 11 income intervals rather than their exact income. In the 2005 model, households were only divided into quintiles for this reason. Still, only 40% of the TUS observations were unambiguously associated with one income quintile; the rest were assigned an income decile based on the mean value in their income interval. Within each income group, four different household compositions were distinguished: retired households (defined as households where at least 50% of income comes from the retired members in the LCF and where at least 50% of the members are retired in the TUS, which does not specify the income source), single adult households, potentially plus children, multiple adult households without

children, and multiple adult households with children. For the one adult (plus children) group, income deciles 2–5 and 6–10 were merged for the 2015 model and income quintiles 3–5 for the 2005 model to increase the individual-level sample size in the TUS. It resulted in 33 household types in 2015 and 18 in 2005 (number of observations in each group in Appendix B). Each household type is based on observations from at least 126 person-days from the TUS and 174 households from the LCF (Appendix B).

Observations were weighted to ensure representativeness of the UK population at the household and individual levels of the TUS. On the household level, data were weighted to be representative of equivalised income and household composition. On the individual level, data were weighted to be representative of sex and age group. The weights were created from ONS's (2019) income-specific household compositions that distinguish the sex of adults in most household types but neither sex nor age of children. Therefore, when not specified, the age or sex distributions were assumed to follow the national distribution (UN Population Division, 2023). To create the weights of single-adult households with children, it was further assumed that an adult is a man in 10% of the households and that 57%, 31%, and 12% of households have one child, two children, and three or more children, respectively (ONS, 2015). To create the weights for the households with more adults and children, it was assumed that three adults with children refer to one child, two children, and three or more in 45%, 40%, and 15% of the cases respectively, and that three or more adults refer to 3.54 adults and three or more children refer to 3.53 children (ONS, 2015). Retired households with multiple members were assumed to have equal gender distribution.

3.3 Detailing household products and activities

In total, 22 different household production activities and products were distinguished (some of them are aggregated in Table 1). Since household-produced products are consumed within the same household as they are produced, except for voluntary work, each product-household type combination is represented in a separate row in the input-output table. For each household type, household production includes six categories of transport, detailed by travel purpose, and a secondary care activity. The 129 market products, classified by the CPA (Classification of Products by Activity, 2008), from the original 2015 input-output table were maintained. The 2005 input-output table used a classification called IOG. In some instances, this did not comply with the level of aggregation used in the 2005 CPA – COICOP Converter for Household Consumption, published by the ONS and used to convert from the COICOP classification in the LCF to the CPA classification in the input-output tables. It was therefore necessary to aggregate the original 123 market products in the 2005 input-output table to 94.

In total, 33 final consumption activities, such as sleeping and reading, were specified for each household type. These include four consumption activities not appearing in the time use data: the consumption of the performed voluntary work, the consumption of the performed care (by children, dependent adults, or pets usually within the same household), smoking time, and the consumption of banking, insurance, and savings. Because the latter reflect future consumption, the activity has

Table 1 Methods used to estimate values of the outputs of household production

Activity	Unit	Estimation method
Food and dining table preparation	/meal	The estimation of a cost per meal is based on the UK restaurant expenditures from the LCFs and the number of restaurant visits from the TUSs for each household type. The larger variation in the quality of a meal compared to what is expected for other household-produced products makes this the only product where the value is household-type-dependent. The number of household-produced meals is estimated as the total number of times people consume a meal minus the number of times they consume a restaurant meal, rather than the number of meal production episodes since the number of meals produced from each episode is unknown. The value is split between food preparation and setting the table, proportional to the households' time spent in the two activities. Results when instead using the national average restaurant meal price for all household types are in Appendix I and J.
Cleaning	/hour	The hourly price of a domestic cleaner obtained from the ONS is used.
Laundry	/wash	The price of a laundry load in 2005 and 2015 including relevant ironing from the ONS (Webber & Payne, 2016) is used. The total number of laundry loads per year from the same report is assumed to be washed by household types proportional to their size.
Home maintenance	/hour	An average hourly price of a decorator and carpenter from the ONS is used.
Household accounting and management	/hour	The average hourly wage of an administrative and secretarial position from ONS (2023b) plus the value of other inputs are used, i.e. an input-based method.
Shopping	/hour	The same value is used as for paperwork. Hiring a shopping assistant (who could do physical or online shopping) is the alternative to doing the shopping yourself.
Gardening	/hour	The hourly price of a gardener was calculated as the wage of a gardener (obtained from the ONS) plus the average difference between the hourly price and wage of a decorator and carpenter.
Pet care	/pet(s)	A price equivalent to the daily kennel cost obtained from the ONS is assigned to households where a member reports doing pet care. Members could be taking care of more pets. We do not adjust for that.
Childcare	/hour	Products that are not specific to childcare have not been allocated to the childcare activities (see Section 3.5). Therefore, the hourly price of a childminder obtained from the ONS plus childcare-specific product values are used rather than the cost of out-of-home childcare.
Adult care	/hour	For the same reason as for childcare, the hourly price of a home care assistant obtained from the ONS is used.
Voluntary work	/hour	As the TUS provides no information on the voluntary activity output, a replacement cost used by the ONS (Foster, 2013) is used, including clerical and secretarial, professional, and personal and protective voluntary activities.
Person transport	/km	When a household member is transported to a consumption activity, the transport requires the presence of the household

Table 1 continued

Activity	Unit	Estimation method
		member. This contrasts with other household productions activities as they can be performed solely by a third party. Still, there is a market equivalent price of transport. The average transport cost per km is imputed as the average minicab fare obtained from the ONS when people report transporting by car, walking, or cycling. The cost per km was converted to a cost per hour from the average speed of each transport mode calculated from the National Travel Survey (Department of Transport Statistics, 2023). When households reported using public transport, which is a market alternative, the cost (from the LCF) per hour (from the TUS) of public transport was used to value the activity output. The output value of each transport activity therefore depends on the composition of transport modes. The activities are valued from the point of view of the household member. Therefore, when two household members transport together for 2 × 1 h, the total value to the members is also 2 × the value of the transport service. As transport mode data is unavailable in the 2001 TUS, the modes are assumed to be the same in each transport activity as in 2015.
Transport for shopping	/trip	The alternative to transporting for shopping is product delivery. For the 2015 model, a cost per delivery is estimated by dividing the total UK expenditures on delivery from the LCFs by the total number of online purchases estimated based on the TUS. Online shopping is assumed to occur when ICT is used during the shopping activity in the TUS, when transport does not precede the activity, and when the household member does not shop simultaneously with other household members not using ICT. For the 2005 model, when online shopping was less common, the delivery cost of a 6 kg parcel was used. Results when instead using the same valuation method as for other transport activities are in Appendix I and J.

no assigned time use. While education and job search are similarly investments in future jobs (Madsen & Weidema, 2023), the activities were for simplicity modelled as current consumption activities.

3.4 Valuing household-produced products

The economic values of household-produced products were, to the extent possible, determined by an output-based method. This approach calculates the cost of replacing services or products provided by households with market services or products (Cushing & Rosenbaum, 2012). The value of household production time is imputed as the output value minus the value of all other inputs. By counting episodes e.g. of eaten meals or laundry loads, time use data provide important information on the outputs, as argued in Table 1 and first demonstrated by Ironmonger (1996) and Harvey & Mukhopadhya (1996) (cited in Ironmonger & Soupourmas, 2009). However, in our valuation, outputs of cleaning, household management, maintenance, and gardening were dependent on the time input as we found no obvious uniform output (Table 1). This is a well-known issue which is ideally solved by

valuing by the hourly price of the service rather than by the wage of the activity performer to account for the different compositions of labour, equipment, and technology in the market and household activities (Cushing & Rosenbaum, 2012). Further, the outputs of care activities were valued by summing the price of a child minder with other inputs values because the outputs arguably are dependent on the used amount of time (see discussion). Table 1 provides an overview of how the value was determined for each product. Market-equivalent output values were mostly obtained from the ONS (ONS, 2023d, 2023a).

While the original input-output tables are in basic prices, the prices used to impute the value of the household-produced products are purchaser's prices. Since household-produced products are mainly services where the differences between basic and purchaser's prices are low, this is not considered a major source of error. VAT was subtracted from the prices of products where it was included.

3.5 Creating the input-output structure for household activities

As a first stage of constructing the household input-output structure, household supply and use tables were constructed for each household type. The supply table shows the value of household-produced products made by each household activity, and the use table shows the corresponding inputs of time, market, and household-produced products. Since the supply table shows the outputs of products, most entries are on the diagonal (Miller & Blair, 2009). Off-diagonal values show the production of secondary products from joint production. Among the production activities, care activities seem to be the only ones that can be performed concurrently with other activities. Therefore, we include care as a secondary product. As the relative amount of care can be varied independently of the activity that it is secondary to, the co-production of care is a combined production. Therefore, the supply of care is modelled on the diagonal in a separate secondary care production activity. The input of time used in secondary production was kept in a separate row of the use table for time in primary activities to sum to 24 h per day × 365 days per year.

While many market products only have one dominant household use, others require assumptions regarding their distribution over several household activities (Table 2). The most used assumption here, and also in previous studies, both old and new, e.g. Ironmonger & Sonius (1989) and Yu et al. (2019), is that products are consumed in proportion to the time used in the relevant activities. For combined production, activity-specific inputs (such as transport or childcare equipment) were distributed in proportion to the total time (primary + secondary) spent in the relevant activities since secondary production will still draw on those inputs. Inputs that are not activity-specific, e.g., light or clothes, were distributed with half to the primary and half to the secondary activity since the combined production does not require twice the amount. The same distribution keys were applied across household types.

The LCFs include actual dwelling rents for renters and dwelling capital investments for owners but do not convert the investments to imputed rents. In contrast, the UK input-output tables include both actual and imputed rents. From the number of households paying rent and based on the assumption that the average rent in each household type is representative of the value flow from owner-occupied dwellings in the same household type, imputed rent was distributed across the household types.

Table 2 Rules applied for distribution of household-produced inputs to household activities

Household-produced products from	
Food preparation and setting table	Distributed to eating, excl. restaurant meals, in proportion to the time use.
Cleaning and laundry	Cleaning is distributed proportional to time used in indoor activities, and laundry in proportion to time use in all activities where clothes are worn.
Maintain home and vehicle	This activity covers a variety of maintenance tasks. Maintenance-related expenditure categories from the LCF indicate whether the use of material inputs in maintenance contributes to the repair of cars, leisure products, support household production activities, or activities in general. Each of the groups of material inputs is distributed across their relevant activities in proportion to time use (except cars which are slightly more complicated, see below). The value of the household production of maintenance is distributed in proportion to the market input values.
Household management, and accounting	Distributed to household production activities and schooling in proportion to time use.
Shopping	Distributed in proportion to expenditures of all household activities.
Child, adult, and pet care	Allocated to consumption by others in the household. Based on the TUS, we are not able to say whether the consumer is another individual in the TUS or an individual who was unable (e.g. due to age) to fill out the TUS.
Voluntary work	Allocated to consumption by others outside the household activity.
Gardening	In 2021, 28% of UK garden owners had vegetable patches (Statista Research Department, 2021). It is assumed that 28% of the gardening is an input to food production and the remainder to relaxing. Food products might be produced in other ways and vegetable patch owners might spend time in other garden activities, thus it is a crude estimate.
Travel	Leisure travel is distributed across out-of-home leisure in proportion to time use. Walking and cycling without a specified purpose are assumed to be leisure. Other travel purposes are specified in the diaries which enable us to distribute travel time to the right activities.
Market products	
Food, beverages, and tobacco.	All food is allocated to meal preparation. All alcohol is distributed to meal consumption and being with friends in proportion to time use in the activities.
Tobacco	Smoking products are allocated to a smoking activity. This was not included in the TUS but was estimated based on the number of cigarettes purchased according to the LCF and assuming 7 minutes of smoking time. The smoking time is subtracted from relaxing.

Table 2 continued

Young children's and adult care products	Products specific to young children (e.g., prams) are allocated to childcare activities. Purchased childcare services are allocated to the consumption by others mostly in the same household as it does not require the involvement of the producing household members. Though other products (e.g., food) are also consumed by the dependent child or adult, they are considered to be consumed together with the adults in their activity (e.g., eating meals) rather than in a separate childcare activity.
Clothes, footwear, accessories	Distributed across activities where worn, in proportion to time use.
Rent, housing	Distributed to home activities in proportion to time use.
Energy and water	Energy and water consumption are distributed based on end-use statistics (Environmental Agency 2005 cited in Sustainable Development Commission (2006) and ONS (2022a)). E.g., the statistics show the proportion of natural gas used in space heating, thus it is further assumed that space heating is consumed in indoor activities in proportion to time use. There are no expenditures on what corresponds to sewage service in the LCF, but the input-output table shows household final demand expenditures on it. Sewage service is distributed to activities in proportion to their water consumption.
Tools, maintenance and cleaning materials	Distributed to maintenance and cleaning in proportion to time use in the relevant activities. E.g., battery water is only relevant to transport activities.
Furniture	Distributed to indoor activities in proportion to time use; room or garden-specific things to activities occurring in that space.
Health and hygiene	Services were allocated to personal care services and goods to self-care.
Transport, transport fuels, and trade services	The mode of transport for each activity stated in the 2015 TUS makes it possible to allocate each transport expenditure to its right transport purpose. Wholesale and retail trade services are allocated to shopping in proportion to total expenditures.
Phones, leisure equipment such as TVs, and leisure activity payments	Studies on the use of smartphones and the proportion of smartphone users (Andone et al., 2016; Deng et al., 2019; Ofcom, 2015) were used to distribute phone use across activities in 2015. For other mobile phones, 2/3 is distributed to conversation and the remaining to correspondence. Landline phones as well as all phones in 2005 are allocated to conversation. Computers are distributed to paperwork, homework, and relevant consumption activities in proportion to time use. Equipment repair expenses are allocated to maintenance. Other products are allocated to a single relevant consumption category.
Holiday packages and holiday accommodation	Distributed in proportion to the time used in leisure activities, like museum visits and sports games, that are expected to be reasons for people to travel.

Table 2 continued

Pets and accessories	Allocated to pet care.
Education	All education expenditures are distributed to school and homework in proportion to time use.
Prepared meals	School and work meals are allocated to meals at school and work, takeaway and meals and drinks consumed off-premises to meals in other places, and restaurant/café meals and drinks to the restaurant and café activity.
Insurance, pensions, savings, and bank charges	Savings, bank charges, and most insurances are allocated to a banking and investment category without time use. Specific insurances, such as for vehicles or pets, are allocated to pet care and transportation activities.
Money given to people outside the household	Allocated to the consumption by others outside the household.
Unspecified expenditures	Distributed across activities in proportion to the rest of expenditures.

As with other expenditures, actual and imputed rents were scaled to the totals in the national input-output tables. The total rent reported in the LCF and scaled to the national level underestimated the actual rent relative to the national input-output table. The number of renters was underrepresented in the 2015 LCF compared to the English Housing Survey 2015–2016. It is assumed that the lower rent reported in the LCF is due to the underrepresentation of renters and therefore that the average value per rented dwelling in each household type is representative.

Market expenditures in basic prices for each product (from the final demand in the original input-output tables) were distributed between the household types in proportion to that group's LCF expenditures on each product. The CPA – COICOP converters for 2005 and 2015 were used to translate from the COICOP classification in the LCF and the initial supply and use tables to the CPA in the input-output table. The converters did not distinguish whether the consumption was provided by the market, government, or NPISH. The same conversion rates were applied for all three. The conversion from COICOP to CPA reduced the level of detail compared to the original household use tables. The LCF is one of the main sources for the creation of final demand in the input-output table, but it underestimates the total household consumption of most products, and several other survey and administrative sources are used for non-food expenditures (ONS, 2022b).

For each household type, the developed supply table (V) and use table (U) were transformed into a direct requirements input-output table (Z) using the by-product technology construct, splitting V into its diagonal and its off-diagonal parts:

$$Z = (U - V'_{off_{diag}})(V'_{diag}{}^{-1})$$

In this household modelling, there are no off-diagonal values because all co-production is combined production. The new rows of household-produced products, time use, and household production wages were added to the original input-output tables. The money value of household production time makes it comparable to the value-added obtainable in the national input-output table. Inputs and outputs still balance after the detailing of households.

Product taxes paid by households according to the original input-output tables were distributed across household activities in proportion to the expenditures since no further information was provided in the input-output tables from the ONS. Imports use tables provided by the ONS along with the input-output tables were used to distribute household imports to household activities based on the activities' consumption of products. In the input-output tables in basic prices, wholesale and retail trade services were not distributed over the products. We applied a simplified distribution of wholesale and retail trade services as inputs to shopping, in proportion to each household type's expenditures.

It should be noted that while the expenditures cover all individuals in the UK, the time use row covers the time use patterns of people aged 8 and above as data did not exist for younger people. It seems unlikely that this has a notable effect on the production side. When results are presented per person, it refers to people aged 8 and above (see also the discussion section).

3.6 Detailing other rows in the input-output tables

After detailing the traditional household final demand, the original compensation of employees (wages) was distributed over the different household types based on their income and the number of working people, assuming the same household type composition of employees across all market activities.

Market employee compensation was converted to work hours by dividing by hourly earnings obtained from the ONS's statistics on average earnings and work hours (ONS, 2024a, 2024b). The earnings per hour data distinguishes 24 industries for earnings and 15 different industries for work hours using the 2007 Standard Industrial Classification (SIC), making the money-time conversion crude compared to the 129 industries in the 2015-input-output table. For the 2005 model, we first needed to convert the 2007 SIC classification to the 2003 SIC classification which is consistent with the 2002 CPA used in the input-output table. The conversion of compensation of employees to hours results in a 10.2% (2015) and 7.8% (2005) higher estimate of work hours compared to what is reported in the TUS. Some of this difference may be explained by people working fewer hours than they get paid for, e.g. due to breaks during work, which are separately accounted for in the TUS, and sickness absence. The formal work hours were rescaled to fit the numbers reported in the TUS. This better reflects actual work hours and makes each person's day sum to 24 h but gives a slightly higher hourly wage than in the official wage statistics. The time used in producing products for export was estimated by multiplying the export value by the calculated ratio of time use to output value for each industry. Imported time was estimated assuming the same hourly wage and the same share of employee compensation in the total product value as in domestic production.

While the original 2005 input-output table only shows the government and NPISH as part of the final demand, the 2015 input-output table also shows their service outputs as consumed by other market activities and households. The newer version is a much better reflection of the real destination of production and consumption of the services provided by the government and NPISH. To improve comparability, we distributed the government and NPISH services in the 2005 table with the same proportions as in the 2015 table.

Our expanded 2015 (2005) input-output table contains as rows and columns 129 (94) market products, including government and NPISH products, and 726 (396) household-produced products from the 33 (18) household types × 22 household-produced products, and 1089 (594) final consumption activities from the 33 (18) household types × the 33 final consumption activities. Further, it includes 33 (18) primary time rows, a joint secondary time row, 33 (18) employee compensation rows, two rows for imports (in monetary value and in time, imputed from the time spent for production of equivalent domestic products), and the remaining original value-added rows and final use (NPISH, government, stock changes, and exports) columns. The 2005 input-output table was converted to 2015 GBP by the consumer price index.

3.7 Calculating direct and upstream use of time and products in final consumption activities

The entries in the input-output table show the *direct* use of a product (row name) in the production of a product in a final consumption activity (column name). The *total* consumption required to produce one unit of each output is calculated from the Leontief inverse:

$$L = (I - A)^{-1}$$

Here $A = Z\hat{x}^{-1}$ is the technical coefficients, i.e., the input-output ratio, and I is the identity matrix. The hat over the output vector transforms it into a matrix with the vector elements along the diagonal. Multiplying by a vector of final consumption of interest, e.g., the consumption during home leisure on an average day for an individual in a low-income retired household, gives the total upstream production needed to perform that consumption activity. The model is open with respect to households, implying that household final consumption demand is kept exogenous and labour inputs are kept in the value-added part of the model. To obtain the total consumption of time and value-added for each output, the vector of final consumption of interest is multiplied on the Leontief inverse and the resulting vector of scaling factors is multiplied on the matrix of primary factors (value-added and time) normalised by the total output.

4 Results

4.1 Presentation of the extended 2005 and 2015 input-output tables

This section presents descriptive results from the extended input-output tables, focusing on the inclusion of household production. By including household production and its outputs (area A3' + C' in Fig. 1) in the production side of the economy, the intermediate consumption (area A in Fig. 1) is increased by more than two-thirds compared to the traditional input-output table in both 2005 and 2015 (Table 3). Further, the value-added (area B in Fig. 1) increased by 57% and 45% from the inclusion of imputed household wages in 2005 and 2015, respectively (Table 3). Out of the total value-added from household production, in both years,

Table 3 Summary statistics of the traditional and extended input-output tables, bn. 2015-GBP

	Traditional, 2005	New, 2005	Traditional, 2015	New, 2015
Intermediate consumption (A)	1108	1862	1164	2064
Value of household production (A3' + C')[a]	0	1787	0	1933
Value-added (B)	1963	3083	2442	3551
Total household final consumption (B' + C)	946	1874	1179	2068
Household-produced products in final consumption (C')	0	1305	0	1413
Time (E), in bn. hours	–	492	–	517

Letters refer to areas in Fig. 1. The prime (') refers to specific areas of the preceding letter as specified in Fig. 1

[a]As inputs and outputs balance it is the same as the column sum of household production activities

approximately 80% were from activities where the wage was determined by the output-based method, i.e. as the difference between the output and input values (Table 4). This gives an average hourly wage of 14.5 £ in 2005 and 13.4 £ in 2015 for activities where the wage was determined by the output-based method and 8.8 £ for activities where the wage was determined by the input-based method in both years. Appendix C and D contain the detailed input-output tables for 2005 and 2015, respectively.

In both years, when also accounting for the value that households generate in the production activities, total final consumption (area B' + C in Fig. 1) is closed to doubled compared to in the traditional input-output tables (Table 3). Both in the new and original input-output tables, the area B' does not include wages but only the value of imports and taxes. A small part of household production, specifically transport to work and some clothes maintenance, was modelled as an intermediate input to market production.

The model accounts for all approximately 500 bn. hours spent by Brits aged 8 and above, and not only the around 11% of the day that is spent in paid work. The average person aged 8 or above spent 3% less time in household production in 2015 than in 2005 while the time in final consumption was close to unchanged (see Appendix F for detailed time use figures). An estimated 11.4 and 10.5 bn. hours were imported, and 7.0 and 6.5 bn. hours were exported in 2005 and 2015, respectively. The estimated imported time is included in the time row of Table 3.

While the total economic value of household production increased slightly between 2005 and 2015, the output of household production per person was practically unchanged. Further disaggregation by activity category offers additional insight into household production, but such detail falls outside the scope of this analysis. Across final consumption activity categories, the direct use of market products is slightly more equally distributed in 2015 than in 2005. Figure E1 and E2 in Appendix E show the direct use of time, market expenditures and household production for each household composition and final consumption category across income groups. The distributions across income groups of the direct use of household-produced products do not seem to have changed notably for any of the final consumption categories. The direct use patterns visible from the input-output

Table 4 Value-added and hourly wage in household production activities

		Preparing food and table	Cleaning and laundry	Maintain home and vehicle	Manage household, shopping	Child and adult care	Pet care	Voluntary work	Gardening	Travel
Value-added, bn. 2015-GBP	2005	375.2	162.2	30.7	131.4	42.5	4.9	41.6	33.4	435.2
	2015	273.1	190	30.5	137.9	50.0	8.8	42.3	33.7	479.3
Hourly wage	2005	23.0	12.4	9.6	11.1	3.8	0.9	11.6	12.1	14.4
	2015	15.1	12.5	11.4	11.7	4.7	1.5	11.7	11.2	15.1

tables show many interesting stories not analysed further here. E.g., the use of time and direct inputs of market and household-produced products to playing computer games and surfing the internet/e-mailing increased notably in the 10 years, with a 23% and 14% increase in time use, 92% and 176% increase in direct market expenditures, and 63% and 56% increase in the direct use of household-produced products.

4.2 Inequalities in activity patterns across income groups and household compositions

This section primarily focuses on the 2015 analysis and first provides a detailed presentation of the total (upstream and direct) consumption during time spent in the four categories of household final consumption activities. It proceeds with the inequality in upstream time use. Lastly, it compares a traditional market expenditure measure of inequality with one including household production.

When including the upstream production as input to the household's final consumption activities, we obtain a full picture of the value of final consumption. The areas of each bar in Fig. 2 represent the total input value to household consumption in an activity for an average person-day of different household types, in 2015. For each final consumption category, the daily duration averaged over individuals aged above 8 in the household type is shown in minutes on the x-axis and the total value in 2015-GBP of expenditure per minute is shown on the y-axis, distributed on household production and the different market inputs (materials, services, and capital goods). Appendix G shows the figures for all household types in both years.

We find, as the comparisons of the lowest-income and highest-income household compositions in Fig. 2 illustrate, a positive association between income and both the total expenditure per minute and the total use of household-produced products in the final consumption activity categories. For instance, the detailed results (Appendix C and D) show that households with higher incomes have higher values of transport as inputs to their final consumption activities because they travel more. However, the ratio between the total use of household-produced products and market products is negatively associated with income, making household-produced products constitute a larger share of total final consumption for lower-income households. Across community time, home leisure, and basic consumption, retired households are the household composition using the highest value of household-produced product per person-day. In 2015, for the average person across household types, the total (direct and upstream) value of household-produced products was between 0.5 and 1.8 times

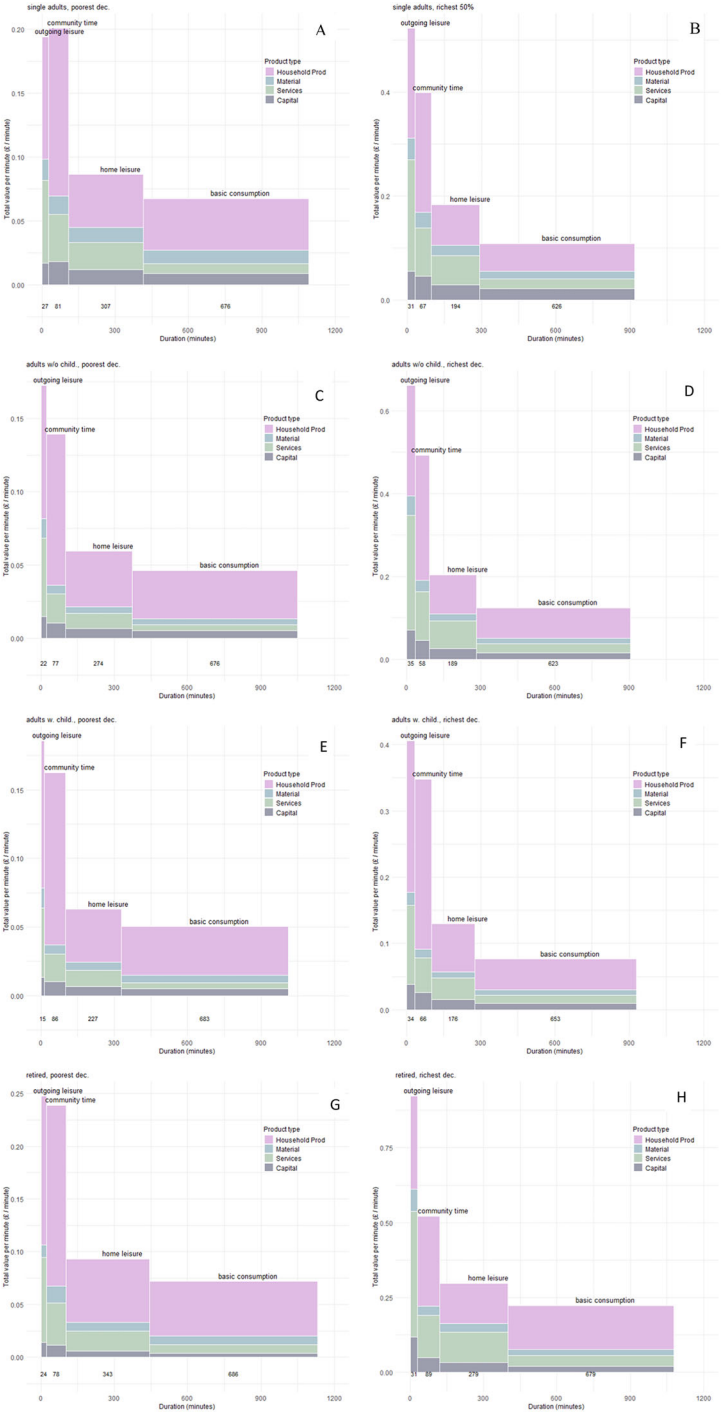

Fig. 2 Total value of household consumption (household-produced, material, services, and capital) in 2015 for an average person-day for eight household types. Each of panels **A**–**H** presents one household type

the total value of market products in outgoing leisure. The ratio was between 1.4 and 3.8 in community activity, making it the group of final consumption activities with the highest household-produced-to-market product ratio, though the per-minute input of market products was higher than in home leisure and basic consumption (Fig. 2). The household-produced-to-market product ratio was between 0.8 and 2.3 in home leisure, with the highest-income households using a higher value of market products than household-produced products, and between 1.0 and 3.3 (2.7 for the household type with the second highest ratio) in basic consumption. In the following sections, we go through the final consumption activity groups one by one.

Zooming in on *outgoing leisure* shows, as expected, that the average person in multiple-adult households with children spends less time and less value of household-produced products in this than other household compositions. Also following what was hypothesised, among the final consumption activity categories, the total input value in outgoing leisure activities exhibits the largest difference between the household types. In 2015, the average person in the household type with the highest value (the highest income retired household type, Fig. 2H) consumed 10.2 times more than the average member of the household type with the lowest value (the lowest income households with more adults and children, Fig. 2E). The expenditure per minute in outgoing leisure was higher in 2005 than in 2015 across household types. This is due to higher market input values and slightly less time spent in outgoing leisure in 2005.

As expected, *community activity* exhibits the lowest difference in the total input value per person across household types. In 2015, an average person from the household type with the highest consumption (the highest-income retired households, Fig. 2H) consumed 4.3 times as much as the group with the lowest consumption (the lowest-income household type with multiple adults and no children, Fig. 2C). The total consumption pattern for community activity did not change notably from 2005.

In *home leisure*, an average member of the household type with the highest total input value to the activity (the highest-income retired households, Fig. 2H) used 6.0 times as much as the type with the lowest (the third lowest-income households with more adults and children). The total consumption of market and household-produced products in home leisure was notably lower for an average person in multiple adult households with children than other household types. Across household types, the consumption in home leisure increased slightly from 2005 from small increases in both the per-minute consumption of market and household-produced inputs.

In *basic consumption*, like in home leisure, multiple adult households with children had slightly lower input values of household-produced products per person than other household types. It is the activity category with the least variation in time use and market inputs across household types. In 2015, an average member of the household type with the highest total consumption in the activity (the highest-income retired households, Fig. 2H) consumed 4.8 times as much as an average member from the type with the lowest consumption per person (the lowest-income multiple adult households without children, Fig. 2C). The second highest per-person consumption is found for the third highest income group of retired households where the average member consumed only 3.0 times as much as the lowest consumption households. Thus, the total consumption in basic consumption varies less between

households than in home leisure and outgoing leisure. No major changes from 2005 to 2015 are observed.

Compared to other low-income households, the average person of the lowest-income single adult household consumed a high value of market inputs in all final consumption activity categories in both years, giving them a low household-produced-to-market products ratio. In 2015, in home leisure, the lowest income decile of single adult households used a value of household-produced products that was 0.9 times the value of market products, while the other lowest income deciles used between 1.6 and 1.8 times as much household-produced product as market product in basic consumption (Fig. 2A, C, E, G). This indicates that more adult households benefitted from economies of scale.

The increase in total market input values from a higher income mainly occurs in services (Fig. 2). On average, in basic consumption, the share of material, capital, and services is almost equally distributed (Fig. 2). Across household types, in home leisure and community time, the service shares on average constitute a little more than half of the total market value, with material and capital almost equally distributed. In outgoing leisure, services contribute with two-thirds while capital contributes with close to one-fifth. In general, there has been an increase in the service share of market inputs from 2005 to 2015. Retired households use a larger proportion of services (Fig. 2). The lower share of capital used by retired households compared to other households in basic consumption and home leisure might indicate that they bought their capital at an earlier stage in life.

The sum of production time used upstream to the consumption activities across household types matches the total production time spent in the UK. Figure 3A, C, E, G show the total use of production time (including a small contribution from imported time) upstream to final consumption activities per minute directly spent in the consumption activities in 2015. While household production time is always used to produce products for the household's own consumption (except for voluntary work), the market production time used upstream to a household type's consumption time draws on all other household types' time. In Fig. 3, the deviations from the trend in each line are most likely due to small sample sizes. It comes as no surprise that higher-income households have a larger total production-to-consumption time ratio across all household types and final consumption activity categories (Fig. 3), given that they do more household production and that they consume more market products containing upstream paid labour time. Figure 3B, D, F, H include only each household type's own production time in the numerator. For retired households, this household production-to-final consumption time ratio is close to unrelated to income, except for in home leisure (Fig. 3B, D, F, H). As expected, basic consumption is the activity category closest to being unaffected by income, both when and when not including other households' production time in the ratio. This also applies to 2005 (see Appendix H). Removing the upstream use of other households' production time from the numerator affects the production-to-consumption time ratio in basic consumption of high-income households the most, showing that high-income households draw more on time from market production. In the other final consumption categories, the ratio also becomes slightly more similar across income groups.

Except for higher-income households' use of time in outgoing leisure, less time is spent upstream of the final consumption activity than in the final consumption activity itself in 2015 (Fig. 3A, C, E, G) and 2005 (Appendix H). In both years, households put

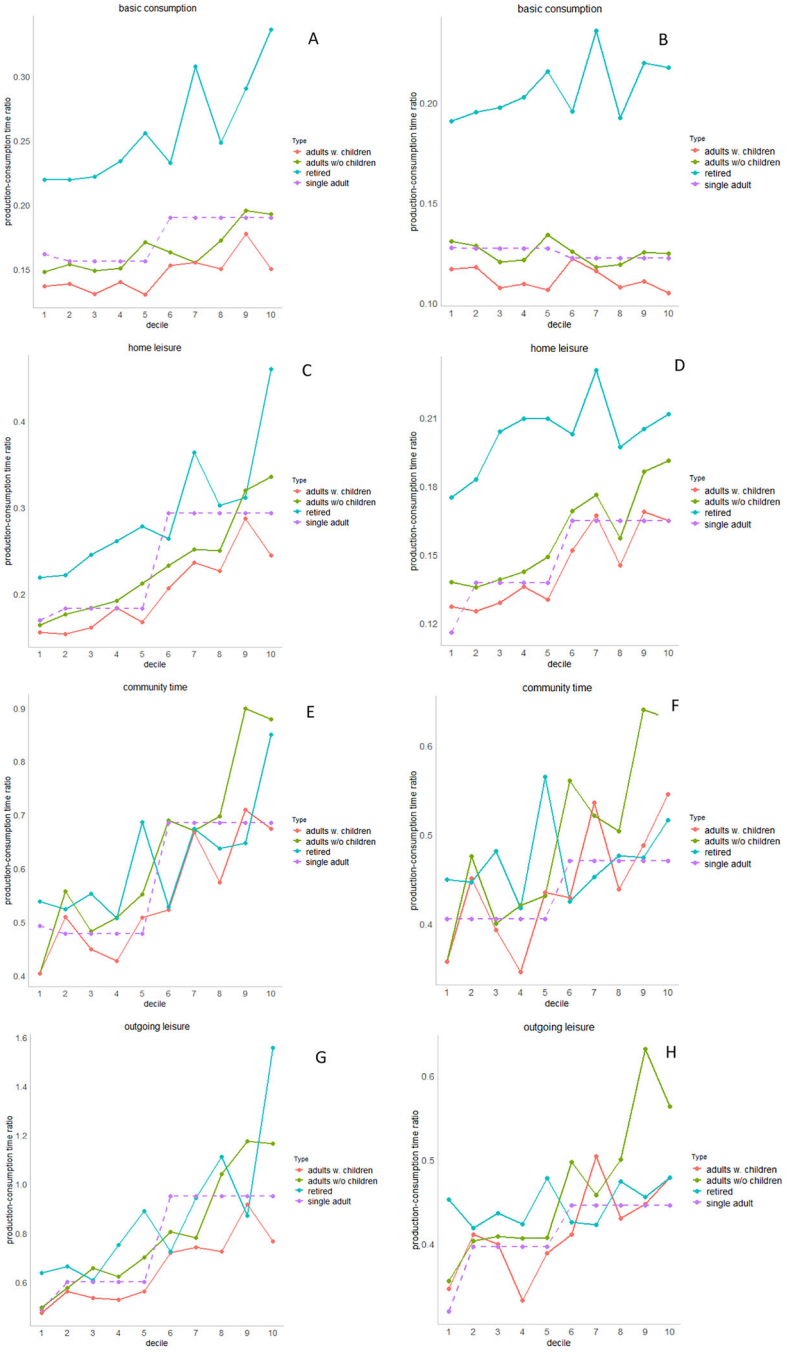

Fig. 3 Total production-to-consumption time ratio per consumption activity category, 2015. Numerators are total production time by all household types (panels **A**, **C**, **E**, **G**) and total production time by own household type (panels **B**, **D**, **F**, **H**)

more production time into community time and outgoing leisure activities compared to other activities. The total production time used upstream to outgoing leisure consumption is highly income dependent with the production-to-consumption time ratio doubling from the lowest to the highest income group for more of the household types (Fig. 3A, C, E, G). When considering only household type's own production time in the numerator, the relatively high ratio for outgoing leisure is surprising, since what characterises consumption during the activity is that you purchase the final experience. The high ratio is driven by transport which constitutes between half and four-fifths of the direct household production input. In contrast to outgoing leisure, the activity categories with the lowest household production-to-consumption time ratio, namely home leisure and basic consumption, are usually undertaken in or near the home, thereby not requiring much direct transport time.

Across final consumption activity categories and income groups, in both 2015 and 2005, the ratio between the production time by each household group and the consumption time is higher for multiple adult households without children than for multiple adult households with children (Fig. 3B, D, F, H). This is driven by the lower production-to-consumption ratio of the included children (above 8 years of age). The lower production-to-consumption ratio is maintained for multiple-adult households with children when market production is included (Fig. 3A, C, E, G). This indicates that they benefit from economies of scale. Additionally, in both years, retired households have a substantially higher production-to-consumption ratio, both when and when not including the upstream market production time, in the activities undertaken in or near home: basic consumption and home leisure (Fig. 3).

Despite income and household production being negatively associated, household production has an overall positive effect on equality in all activity categories except outgoing leisure. The direct market expenditure distribution is approximately the same as the income distribution for all household compositions (Fig. 4). In (Fig. 5 A, B, C, D), the original equivalised disposable income line (in grey) is maintained to enable its comparison with consumption including the upstream consumption expenditures of market and household-produced products. For the same reason, the values on the x-axis show the original equivalised disposable income distribution. With the inclusion of household production inputs to final consumption expenditures, multiple-adult households with children have the most equal basic consumption across income groups while retired households have the least equal basic consumption (Fig. 5A). Other consumption activities do not exhibit notable differences between household types (Fig. 5B–D). For all household compositions, outgoing leisure is the most unequal (Fig. 5D) and community activity (Fig. 5C) is generally the most equal final consumption activity, in accordance with the hypotheses. The same figure was found for 2005.

5 Discussion

5.1 Contribution to existing knowledge

This study expands the input-output tables for the UK, 2005 and 2015 by detailing the households' complete use of time and money, covering all days of the year and all hours

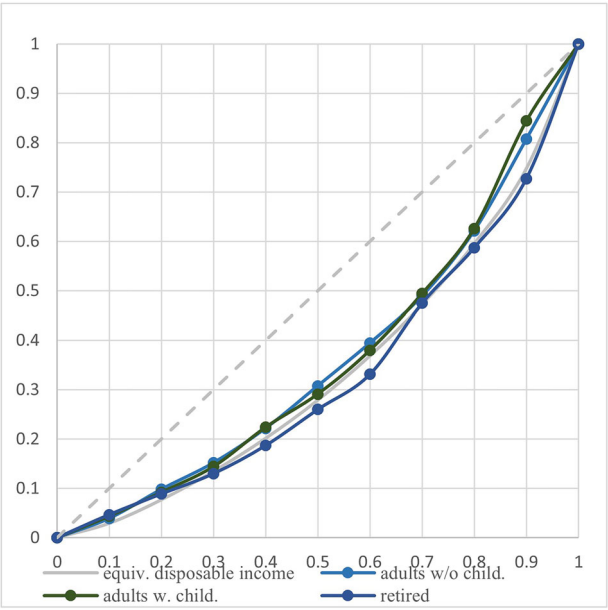

Fig. 4 Distribution of traditional consumption expenditures for market goods, for three household compositions; cumulative household share ranked by disposable income (x-axis), and cumulative disposable income and direct market expenditure share (y-axis), 2015

of the day. By distinguishing household production time from consumption time, the detailed tables enable a detailed analysis of consumption patterns across different household types. This approach reveals how the upstream use of market and household-produced products varies across household types and consumption activities. Modelling the household activities and their time use makes the input-output tables useful for understanding economic decisions in a wider social context (Minx & Baiocchi, 2009). From a household well-being perspective, the specific activities in which additional household production is consumed are of particular importance.

To the authors' knowledge, no existing input–output analysis has achieved such a high level of detail regarding the combination of household activities and household types; including studies that aim to calculate the environmental footprints of household activities (e.g. Jalas, 2002; Jiang et al., 2022; Smetschka et al., 2019; Yu et al., 2019). The inequality literature typically focuses on income, wealth, or an aggregate measure of (direct) consumption (Fisher et al., 2020). Consumption expenditures better capture households' use of resources and are a better measure of their living standards than income (Brewer & O'Dea, 2012). A branch of literature has investigated the impact of household production on income inequality (Frick et al., 2012), but has not examined household activities at a more detailed level. With the included time and expenditure dimensions and the focus on the total (direct and upstream) use in (final) consumption, our analysis provides a novel understanding of inequality in time and expenditures on market and household-produced products consumed in different final consumption activities. The modelling of consumption activities enabled a detailed analysis of the inequalities in *how* Brits consume.

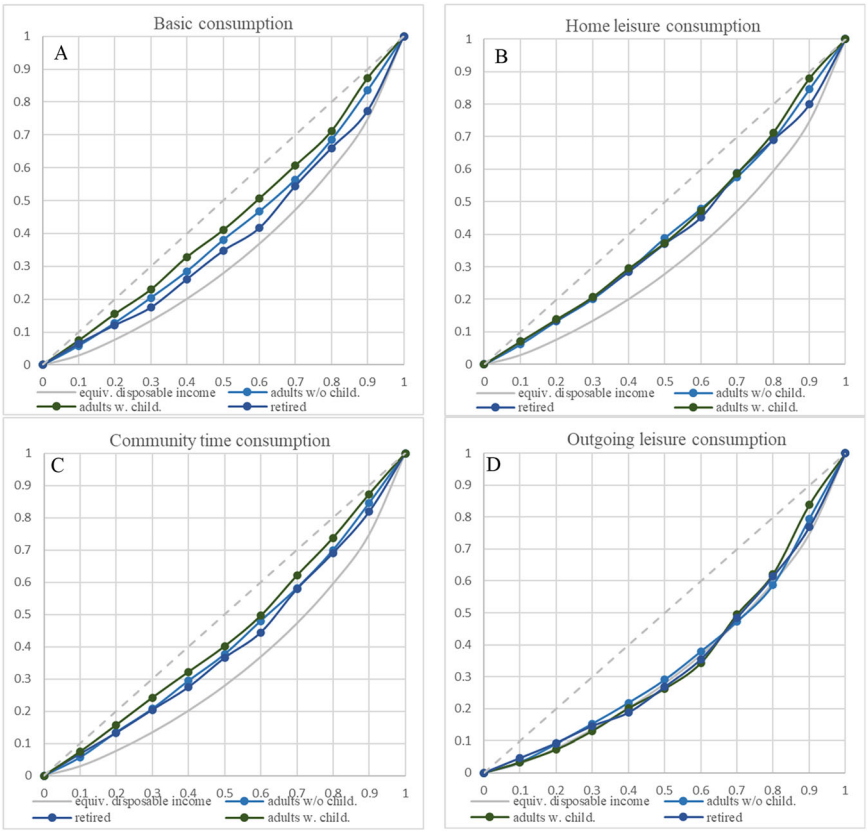

Fig. 5 Distribution of total final consumption expenditures including household production per activity group (panels **A**–**D**) for three household compositions; cumulative household share ranked by disposable income (x-axis), and cumulative disposable income and total consumption expenditure share (y-axis), 2015

Naturally, household income and market expenditures are positively related. We also find household income and household production value to be positively related, confirming the findings of studies using input-based valuation of household production time (Frick et al., 2012) while our study values most household-produced products by the same output-based value across household types. Also supporting previous studies' results (Gautham & Folbre, 2024; Frazis & Stewart, 2011; Frick et al., 2012; Ragnarsdóttir et al., 2023), the consumption of household-produced products was found to be less unequally distributed than market expenditures, except for in outgoing leisure. That the total consumption of outgoing leisure is as unequal as market expenditures is consistent with expectations since outgoing leisure would be considered the most luxurious and least substitutable by household-produced products. In Appendix K, we valued household production time using the national average wage of 15 £/hour for 2015, aligning with the valuation methods in other studies. For each final consumption activity category, we compared the distribution of wages upstream to the activity using the wage valuation method described here and our original method. Using both methods, the upstream household production

wage distribution is very equal across households, excluding in outgoing leisure. The distribution shows some dependence on the valuation method in outgoing leisure, with our preferred method resulting in more equal distributions for household types without children compared to the market wage method. The distributions in other final consumption activities are only to a limited extent dependent on the valuation method.

Viewing the input-output tables purely as an accounting tool shows impacts of including household production within the range found in other studies preferentially using an output-based method. In Bulgaria, Finland, and Germany outputs from household production constituted around 60% of total final consumption (Goldschmidt-Clermont & Pagnossin-Aligisakis, 1999). Our current estimates of 69% in 2005 and 68% in 2015 are slightly higher. The UK household satellite accounts show the intermediate consumption in eight different household production activities and value the activities economically (ONS, 2018). While the ONS (2018) found the value added from household production to be equivalent to 64% of the original GDP in 2015, the current study only found it equivalent to 51% of the original GDP in 2015. This difference occurs because the ONS (2018) only allocated 17% of market expenditures as inputs to household production while the current allocated 41%, thus subtracting more input value from the output value of each household-produced product.

5.2 Implications for policy and practice

The substantial disparities in the total (direct and upstream) use in final consumption activities between households with different income levels reflect large disparities in the draw on material and human resources. That the inputs required for one minute of activity can differ so markedly suggests underlying inequalities in how resources are distributed and utilised across society. From an environmental and social perspective, the consumption patterns observed among higher-income households may be associated with disproportionately high use of both material resources and other people's time. Conversely, the consumption patterns of lower-income households may reflect limited access to products, including the time-intensive services usually constituting outgoing leisure activities. The substantial disparities highlight the need for further research into the drivers and consequences of these patterns in relation to sustainability and social equity. Such insights can support the development of measures that encourage less resource-intensive consumption among higher-income households and improve consumption opportunities for lower-income groups.

The results indicate that examining the specific activities in which people consume may offer a more nuanced basis for welfare analysis than relying solely on traditional income-based measures. Among the final consumption activity categories, community activity is the one where the outputs of household production make up the largest share of total inputs. These outputs contribute to the more equal distribution of consumption in this activity. Given the well-documented positive affect associated with social and worship activities, as well as spending time with friends (Kahneman et al., 2004; Krueger et al., 2009), this form of consumption may be beneficial to promote. However, each minute spent in community time requires a considerable amount of production time, even for lower-income households, with transportation

comprising a substantial share. This underscores the importance of ensuring equitable access to nearby public spaces that facilitate social interaction. Among the consumption activities, outgoing leisure is the most unequally distributed across income groups. Given the documented health benefits associated with cultural participation, promoting more equitable access to such activities could support social mobility (Mak et al., 2020). Since household production is also dependent on market production, households cannot always compensate for a loss in income by increasing household production activity (Goldschmidt-Clermont & Pagnossin-Aligisakis, 1999). It is intuitive that inputs to the consumption of outgoing leisure (such as a theatre or stadium) are more difficult to compensate for. In practice, home leisure activity might be the alternative as indicated by more time spent in this by lower-income households. However, the enjoyment of home leisure activities decreases faster and at a higher rate with the duration of the activity compared to leisure activities outside the home (Gershuny, 2011).

Distinguishing households in the same income group by their composition also allows the identification of distinct consumption patterns. E.g., retired households consume a notably higher value of household-produced products in all their final consumption activities. This implies that retired households may be better off than traditional income measures suggest.

Lower-income households are less deficient in time, and their final consumption activities require less upstream production time than those of high-income households. Thus, lower-income households draw less on the pool of human resources, including their own. The time distribution suggests that policies that support and enable lower-income households to engage more in household production – such as self-help initiatives and improved infrastructure – could help narrow consumption gaps while only reducing these households' own time for final consumption activities. Household production activities are, however, generally associated with fewer positive feelings than most consumption activities (Kahneman et al., 2004; Krueger et al., 2009). Further, a key question is whether household production can remedy the lower consumption of lower-income households beyond what it already does (is more cleaning or maintenance useful?). Maintaining the larger amount of capital owned by higher-income households will necessarily require more (own or market) work time. Consequently, these households need to do more household production or purchase more services to keep the same level of cleanliness and maintenance. Nevertheless, household production can improve conditions that are associated with poverty. Quality of housing, measured by clutter, cleanliness, indoor climate, maintenance level, hazard risk, and structural quality, is positively associated with psychological health (Evans, 2003), specifically among children (Rollings et al., 2017). Bad air quality from high indoor CO_2 concentrations, as can emerge from improper ventilation of the house, reduces decision-making performance and in the long run disadvantages people exposed to it (Satish et al., 2012). Clutter, cleanliness, indoor climate, and maintenance level seem to be elements that can be improved without high money expenses. These processes can, however, be restricted by frequent relocations, which occur more often for people in poor-quality housing (Evans, 2003). Though results are mixed, research further indicates that spending more time with children improves their skills and behaviour. Fathers' time spent with children aged 4 to 8, especially in educational activities increased the children's cognitive

skills (Cano et al., 2019). Engaged mother time was negatively associated with adolescents' delinquent behaviour (Milkie et al., 2015) and positively and persistently associated with verbal and psychological adjustment outcomes for children aged 3 to 7 (Bono et al., 2016). This suggests a positive return to time spent in several household production activities that might be possible to exploit, potentially improving future consumption levels.

5.3 Limitations

A main challenge to the design of the input-output tables is that household expenditure and time use data are separately collected. However, it is still meaningful to match households on a group level based on their characteristics. A (rarely used) solution to this data issue is collecting time use and expenditure data from the same households (Antal et al., 2020), preferably as cohort studies. Unless respondents are asked which equipment they use during an activity, combined surveys do not create the link between activities and market expenditures. Gathering empirical evidence of this is very challenging. A diary collecting consumption during activities would be very demanding for respondents, who in the UK 2015 survey already recorded the use of ICT, the presence of other persons, and the mode of transport in each activity. Wearable cameras, which are objective instruments (Gershuny et al., 2020; Kelly et al., 2015), could observe consumption during an activity and provide empirical evidence linking activities and market expenditures. This method will still only capture used products and not products that are purchased but rarely used. However, one study found limited sensitivity of the total use and associated footprints in different household activities based on the matching of time use and expenditures by three different authors (Jiang et al., 2022).

Another challenge is assigning an economic value to household-produced products when the output is not very clear. When people engage in meal preparation the output is one or more meals. Even in this case, the specific quality of meal is unknown. In Appendix I and J, we value meals using the national average restaurant meal price rather than a household-type-specific price. This makes the total input value to basic consumption marginally more equal. The outputs of other household production activities, such as maintenance, are even less uniform; it could be clean windows or a sanded worktop. In such cases, the current best option was to assign the value based on the duration of the activity and an artisan price. For the very broad maintenance activity, collecting the purpose of the maintenance activity would make the estimation of an output-based value independent of time possible (Ironmonger, 1997). Further, between 2005 and 2015, an increasing integration of ICT into daily life has occurred. Presumably, this is the most important area in which production has moved from the market to the household sphere. The current 2015 TUS collects the use of ICT in activities and includes some ICT-dependent activities. The current level of detail is not enough to distinguish production (like replying to emails from an artisan) and consumption activities (like replying to emails from a friend).

The UK time use data do not include observations of children younger than 8. Thus, since the expenditure data covers expenditures of the entire household, a discrepancy arises when the two data sources are used together. This does not influence the analysis of retired households and more adult households without

children. Since young children do not engage in household production, we also do not expect it to influence the output of household production. Thereby, it would not affect the areal of each bar in Fig. 2, i.e. the total input value to each consumption activity. It would also not influence the relative contributions of market vs. household-produced products. Since young children spend time in consumption activities, showing the average expenditures per person rather than per person aged 8 and above would widen the bars in Fig. 2 and make them lower for households with children. This would reflect a lower total value per minute. Since we do not know young children's distribution of consumption time, the effect on the total input value per minute differ across the consumption activities in unknown ways. Since, in the UK, couples with young children are less likely to be on an increasing income trajectory than couples with older children (Rigg & Sefton, 2006), the lower total input per minute values are mainly expected to apply to lower-income households with children. Thus, including the consumption time by young children might make the inequality in the total value of inputs to final consumption per minute larger for households with children than currently reflected in Fig. 2 but would have no influence on the inequality measure reflecting the total value of inputs to consumption.

Our study distributes the household final demand vector based on the reported time and expenditure values in the TUS and LCF, weighted and scaled to be representative of the UK population of households. This is a *report as it is* approach with no steps taken to smoothen out values, e.g., by fitting a regression model on the raw data and using predicted values. Instead, adequate sample sizes of household types were ensured by merging too small groups, although not avoiding smaller discontinuities in the presentation of the results. Further, the household-level approach implies that the average person in each household type is a certain combination of ages and sex that is representative of its type at the UK national level. Characteristics like age and sex differences between the household types might explain some of the differences in activity patterns but have not been investigated separately.

5.4 Directions for future research

With detailed modelling of household activities, our input-output tables support a wide range of research questions. These include changes in product provision over time, environmental footprints of consumption patterns, and the role of household-produced goods as substitutes for market products across household types. In particular, our detailed modelling of care activities, including care produced in a secondary activity, offers a strong foundation for analysing the provision and consumption of care. We did not explore care provision further in our current analyses due to our focus on consumption disparities. We treated care as the only feasible secondary production activity, assuming it is the only type of production that can realistically occur concurrent with another production activity (e.g. comforting a child while stirring a pot). For example, if someone reports cleaning and maintenance in the same time slot, we interpret this as alternating between tasks rather than producing complete outputs from both simultaneously. Moreover, our work provides a foundation for further research into how more equitable patterns of product and

time uses can be promoted; an essential step towards fostering inclusive well-being and ensuring that all households have the means to participate in beneficial consumption activities.

In our current work, we have referred to the value added from household production as wages. However, part of this value added may also be attributed to capital inputs. We defined household production activities from a human-centred perspective. However, consumer capital, such as TVs, also generates outputs (services) for household members (Gershuny, 2025). Capital, such as TVs, was valued based on its purchase price rather than the value of its service flows. To some extent, watching TV might substitute cinema visits (Gershuny, 2025). Consumption as indicated by time diary records reveal activities that are invisible to any part of the conventional economic-statistical apparatus: notably passive entertainment – such as the *use of* radio, television, music-playing machinery as well as internet IT devices. Thus, passive entertainment draws on service flows from capital, in addition to the household production of a clean and well-maintained home. In future work, creating a new and consistent understanding of the value flows of consumer capital would be relevant from methodological and policy perspectives, particularly in how we account for the evolving roles of technology and household assets in shaping consumption patterns.

Extending our developed input-output structure with environmental account would capture economic, social, and environmental phenomena, enabling analysis of trade-offs (Stahmer, 2010; Minx & Baiocchi, 2009). In accordance with the interest in consumption-based environmental footprint accounting, input-output tables are increasingly used to estimate environmental footprints of household activities (Madsen & Weidema, 2023). Because the input-output structure enables tracking all upstream time and expenditures required by a market or household-produced product, the emissions associated with each part of the upstream production activities can be summed up to a footprint of the final product consumed. The environmental impact per time and money unit can guide consumers and decision-makers to select activities and products with lower environmental impact. Adding an emission extension to our current work would make the developed input-output tables able to estimate footprints at an unprecedented level of detail of household types. Most existing studies have allocated emissions from existing input-output tables to household activities without capturing the flows between household activities (Madsen & Weidema, 2023). While this is an important step to compare the environmental impact of household production to market production, it neglects that the household-produced product is indeed produced to be consumed in a final consumption activity. Oswald et al. (2020) investigated energy footprints across 86 countries and income groups, finding large product-dependent inequalities. The current approach would also incorporate time use, revealing effects such as the substitution of cinema time (outgoing leisure) for TV time (home leisure) when examining environmental footprints and consumption inequality.

6 Conclusion

In this study, we investigated how including the upstream use of time and (market and household-produced) products in detailed consumption activities can nuance and

improve the general understanding of inequality between households. The study presents a novel assessment of inequality, offering a more nuanced and comprehensive understanding as a complement to inequality measures used in existing literature. It shows that including the upstream value of the outputs of household production and market products has an equalising effect on expenditure-inequality in final consumption activities. The direct and upstream product and time consumption during final consumption activities vary remarkably across activities, indicating that policies targeting unequal consumption possibilities should be activity specific. To perform this analysis, we extended two input-output tables (for the UK in 2005 and 2015) with unprecedented level of detail of household production and consumption activity categories, distinguishing households by their income level and composition. This gives a detailed overview of all the consumption and production occurring in the UK economy and the associated time use. It shows the interactions between the household and market sides of the economy by combining the market production from traditional input-output tables with the expenditures from the Living Cost and Food Survey. Beyond the current application in analysing disparities in total consumption patterns across household types and activities, the developed input-output structure and valuations of household-produced products are intended to serve as a foundation for further work on total (direct and upstream) inputs to consumption and the integration of household production in economic accounts.

Large disparities in the market and household-produced inputs to consumption activities reflect unequal use of human and material resources, with potential implications for both social equity and environmental sustainability. Households put more production time and product inputs into a minute spent in community and outgoing leisure consumption activities compared to other consumption activity categories. Timewise, these activities are more luxurious. However, in terms of the degree to which the two activity categories are inclusive, they differ notably. The total input value to community activity is the most equally distributed across household types while the input value to outgoing leisure consumption is the most unequally distributed. These findings underline the need to support and expand facilities that enable community engagement, as such activities are already widely valued. At the same time, policies should aim to reduce barriers to outgoing leisure participation for households currently underrepresented in such activities, given their potential benefits for health and social mobility. Home leisure and outgoing leisure both require relatively high shares of market products relative to household-produced products. However, unlike outgoing leisure, the time spent in home leisure is larger for lower-income households. Given its relatively high demand for market inputs and diminishing enjoyment after a shorter period in the activities, support for reallocating time away from home leisure may be beneficial for lower-income households. Meanwhile, basic consumption activities exhibit the lowest production-to-consumption time ratio, the least dependence of this ratio on income, and a relatively equal use of time across household types, suggesting that this category of activities is more available to, or most needed by, all.

Household-produced products are important contributors to daily life and their total input values to consumption activities exceed the value of market inputs across most categories of final consumption activities. Although the total value of household production is higher for higher-income households, in relative terms, it contributes

less to their final consumption activities than in lower-income households. Recognising the economic value of household production in national accounts and social policy may lead to more inclusive assessments of well-being and better-targeted support for vulnerable populations. Such recognition should be accompanied by an understanding that household production cannot fully compensate for inadequate access to market or public goods and services.

Data Availability Data will be made available on request.

Supplementary information The online version contains supplementary material available at https://doi.org/10.1007/s11150-025-09792-3.

Author contributions All authors contributed to the study's conception and design. S.T.M. created the model and performed the analysis. The first draft of the manuscript was written by S.T.M. All authors commented on previous versions of the manuscript and approved the final.

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Compliance with ethical standards

Conflict of interest The authors declare no competing interests.

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