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Time-use emissions in Türkiye: An exploration by employment status and gender*

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Abstract

We combine EXIOBASE3, Household Budget Surveys, and Time-Use Surveys to examine time-use emissions in Türkiye. Our main finding is that essential personal time activities—particularly basic eating and drinking—account for a much larger share of emissions in Türkiye than in wealthier economies, even though they occupy a comparable share of daily time, highlighting unique challenges and policy areas for emission reduction in a developing country context. We also identify other key time-use activities driving emissions across employment and gender groups. Policy implications are discussed.

Key words: Environment, climate change, time-use, carbon emissions.

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1. Introduction

Following Türkiye's ratification of the Paris Agreement in 2016, efforts to identify and implement effective environmental policies aimed at reducing greenhouse gas emissions have accelerated, both in policymaking and academic research. In the search for appropriate policy tools, the experiences of other countries offer valuable lessons. Traditional Pigouvian pricing instruments, such as carbon taxes and emissions trading systems, have achieved some international success (Andersson, 2019; Colmer et al., 2020). However, concerns remain regarding their distributional consequences, as these instruments may place a disproportionate burden on vulnerable populations (Dorband et al., 2019; Andersson and Atkinson, 2024). Moreover, it is argued that carbon pricing policies should be complemented by targeted measures addressing specific groups and consumption patterns to improve both effectiveness and equity (European Environment Agency [EEA], 2021).

In assessing the distributional effects of Pigouvian pricing instruments and designing targeted policy responses, several studies take household-level consumption patterns and associated emissions as a starting point (Wang et al., 2016; Ivanova and Wood, 2020; Theine et al., 2022; Sri et al., 2023). However, individual consumption behavior is often closely shaped by time-use patterns. For instance, one person may choose to spend leisure time reading at home or walking in a park, while another may drive to a café or bar. Similarly, one couple may prefer cooking at home, whereas another may dine out regularly. These differing preferences lead to distinct carbon footprints, highlighting the importance of incorporating time-use behavior into analyses of household emissions and policy design.

Unlike studies that focus primarily on expenditure patterns across income levels, time-use analysis shifts the perspective from reducing consumption to reducing carbon footprints through engagement in more sustainable, low-carbon activities. Examining the emissions associated with time-use patterns across different demographic groups—while holding income constant—can offer valuable insights for designing targeted policies that promote environmentally friendly behaviors.

Thus far, analyses of time-use emissions have focused primarily on high-income, advanced economies such as Austria (Smetschka et al., 2019), the UK (Druckman et al., 2012), and Japan (Jiang et al., 2023), as well as China (Yu et al., 2019), which is a large emerging economy. However, time-use emission patterns can differ substantially in countries with lower income levels and distinct consumption structures. Our study is the first to examine time-use emissions in Türkiye, an upper-middle-income country with characteristics that set it apart from both advanced economies and large emerging ones. By contrasting Türkiye's patterns with those observed in wealthier countries, we aim to highlight unique challenges and policy priorities for emission reduction in a developing country context.

To this end, we use EXIOBASE3, an environmentally extended multi-regional input-output database, to calculate the total emissions associated with 200 EXIOBASE product categories in Türkiye. We then construct a concordance to map these emissions to COICOP (Classification of Individual Consumption by Purpose) categories, using the mapping provided by Ivanova and Wood (2020) along with data from TURKSTAT's Household Budget Surveys. In the next step, we apply a second concordance table from Smetschka et al. (2019) to allocate COICOP emissions to time-use activities. Drawing on TURKSTAT's Time-Use Survey, we are ultimately able to estimate both the share of each time-use activity in total emissions and their respective emission intensities.

Our main finding is as follows: in Türkiye, essential personal time activities—such as eating and drinking—account for 46.5% of daily time use and 54.9% of total emissions. In contrast, in Austria, these activities represent a similar share of time use (46%) but only 39% of emissions (Smetschka et al., 2019). We interpret this gap as evidence that emissions in Türkiye are largely driven by fundamental activities, rather than by leisure or luxury consumption, which tend to be more prominent drivers of emissions in more affluent economies.

This distinction presents important challenges for climate policy in Türkiye. While high-income countries may reduce emissions through behavioral changes in discretionary activities, lower-income economies face a more limited set of options, as their most emission-intensive activities are tied to basic needs. Accordingly, policy efforts in Türkiye should prioritize reducing the emission intensity of essential personal time activities rather than relying solely on behavioral shifts.

That said, this does not mean that there is no room for environmental improvements via behavioral change in Türkiye. We explore the key drivers of time-use emissions, apart from personal time activities, by employment status and gender.[1] We find that: (i) Employed individuals, facing long working hours, spend more time on mobility and likely use more emission-intensive transport, (ii) Unemployed men generate high emissions through leisure and related travel, (iii) For unemployed women, unpaid domestic labor is a significant driver of emissions. In Section 6, we discuss possible policies that may promote more sustainable and environmentally friendly behaviors in light of these time-use patterns.

[1] We also explored time-use emissions by age and marital status (though these results are not reported in the manuscript), but the policy implications remain largely unchanged.

The rest of this paper is organized as follows: Section 2 provides a detailed review of the related literature. Section 3 introduces the datasets used in this study and outlines our methodology. Section 4 explains the technique for calculating the emission intensities of time-use activities. Section 5 presents the results, while Section 6 offers a conclusion and discusses the policy implications.

2. Related literature

In the field of environmental economics, recent research has increasingly focused on understanding the heterogeneous impacts of environmental policies across different societal groups by using microeconomic data. This endeavor is undertaken to identify vulnerable groups and contribute to the formulation of environmental policies at the micro-level. Within this literature, two main methodological approaches have emerged to analyze the relationship between consumer behavior and carbon footprint.

The first, and more widely used, approach estimates greenhouse gas (GHG) emissions associated with household consumption expenditures using household budget surveys. Building on this method, studies such as Druckman and Jackson (2009), Ivanova and Wood (2020), Mi et al. (2019), Theine et al. (2022), Wang et al. (2016), and Girod and de Haan (2009) demonstrate that household-level carbon footprints are heavily influenced by income and consumption patterns. These studies reveal significant intra-national disparities and underscore the importance of equitable, targeted climate policies.

The second approach links individuals' consumption behavior with their time-use patterns. A pioneering contribution in this area is Schipper et al. (1989), which connects time use and energy consumption, showing that lifestyle and activity patterns—beyond income and price variables—play a critical role in shaping energy demand. The study finds travel-related activities to be particularly energy-intensive and highlights how changes in societal mobility are essential for projecting future energy use.

Subsequent research on time use and energy consumption has expanded across countries, including Finland (Jalas, 2002; Jalas, 2005; Jalas and Juntunen, 2015), Canada (Brenčič and Young, 2009), Norway (Aall, 2011), and France (De Lauretis et al., 2017). These studies have laid the groundwork for more focused analyses of the relationship between time use and GHG emissions. Four studies in particular provide systematic estimations of emissions based on daily activities: Druckman et al. (2012) for the UK, Smetschka et al. (2019) for Austria, Yu et al. (2019) for China (with cross-country comparisons), and Jiang et al. (2022) for Japan.

Druckman et al. (2012) combined data from the UK Environmental Accounts, an environmentally extended input-output model (EEIO-SELMA), and the 2006 UK

Time Use Survey to estimate GHG emissions per unit of time. The study identifies gender-based differences in emissions, finding that women tend to emit more due to spending less time on low-emission leisure and more on domestic activities.

Smetschka et al. (2019) applied a similar methodology using Austria's 2008–2009 time use data, 2010 household budget data, and a multi-regional input-output model (EORA-MRIO). Their results show that personal time is generally less GHG-intensive and that traditional gender roles significantly shape time-use patterns and related emissions. Factors such as household size, income, and urban infrastructure also influence household carbon footprints.

Yu et al. (2019) utilized Chinese 2008 time use and 2009 household consumption data to estimate activity-based emissions and extended their analysis to six other developed countries: Japan, Austria, Germany, Finland, the UK, and the US. They classified activities by both duration and GHG intensity, revealing cross-country differences in the emissions profiles of specific activities. For instance, travel was found to have higher intensity in the US and lower in Japan, highlighting the importance of country-specific analyses for effective climate policy.

The most recent and comprehensive study in this field is Jiang et al. (2022), which examines household-level carbon footprints in Japan through a time-use lens. Using the 2004 National Survey of Family Income and Expenditure (NSFIE), the 2006 Survey of Time Use and Leisure Activities (STULA), and an environmentally extended input-output table, the authors mapped household expenditures across 85 daily activities. Their findings show substantial variation in both total emissions and GHG intensity per hour, with weekends generating higher emissions due to increased time spent on leisure and travel.

Together, these studies—Druckman et al. (2012) for the UK, Smetschka et al. (2019) for Austria, Yu et al. (2019) for China and other countries, and Jiang et al. (2022) for Japan—demonstrate the analytical power of combining time-use data with household consumption patterns, offering valuable insights into behavioral and policy strategies aimed at reducing emissions.

Despite the absence of studies in Türkiye that directly estimate carbon footprints based on time-use patterns, a growing body of research has utilized Turkish Time Use Surveys (conducted in 2006 and 2014–2015 by TURKSTAT) to examine the distribution of paid and unpaid work, time poverty, and welfare implications.[2] These studies reveal stark gender disparities in time allocation, with women disproportionately burdened by unpaid care and domestic work. For instance, Öneş et al. (2013) and Kongar and Memiş (2017) demonstrate how time poverty coexists with income poverty, particularly among women, and how these

[2] See Erdil et al. (2006) for a time-use study in Türkiye, based on an earlier questionnaire and not on TURKSTAT data.

dual burdens reflect broader structural inequalities in Turkish society. Similarly, Ilkkaracan et al. (2021) use time-use data combined with income data in a macro-micro simulation model to show how public investments in social care—such as early childhood education—can both reduce time poverty and increase female employment.

Other studies have explored determinants of leisure time allocation using TURKSTAT's time-use data. Gemicioğlu and Akkoç (2019), for example, find that unpaid domestic responsibilities significantly limit women's leisure time flexibility, and also wages and education level are the determinants of leisure time demand. Kızılırmak and Köse (2019) show that socio-economic variables like education, income, and childcare responsibilities are key predictors of time spent on different leisure activities. Collectively, these studies provide a robust foundation for extending this research to environmental dimensions such as household-level carbon emissions.

3. Datasets and harmonization

This study aims to calculate the carbon footprints of time-use activities. However, emission intensities for these activities are not directly available. To estimate them, we utilize three datasets: EXIOBASE3, Türkiye's Household Budget Surveys (HBSs), and Türkiye's Time-Use Surveys (TUSs). Brief descriptions of each dataset are provided in Section 3.1.

Our approach for deriving emission intensities involves three steps. First, we use EXIOBASE3 to calculate emissions for 200 EXIOBASE products, based on their emission intensities and total consumption expenditures in basic prices. Next, we map these 200 products to COICOP (Classification of Individual Consumption by Purpose) categories. Finally, we assign emissions from COICOP categories to time-use activities. The details of these conversions are provided in Section 3.2.

3.1. Datasets

EXIOBASE3. EXIOBASE (Stadler et al., 2021) is an Environmentally Extended Multi-Regional Input-Output database (EE-MRIO) that measures environmental impacts, including direct and indirect emissions from 200 products. Emission coefficients represent the $kgCO_2$ equivalent of CO_2, CH_4, N_2O, and SF_6 emitted per million euros of spending, using the Global Warming Potential 100 (GWP100) metric (Solomon et al., 2007). These coefficients vary across countries and years due to differences in transport costs, input-output relationships, and production methods. EXIOBASE3 provides data for 1995-2022, covering 44 countries and five global regions. This study uses total expenditure data and emission coefficients from EXIOBASE v3.8.2.

EXIOBASE3 also includes supply-use tables (SUTs) based on national accounts, detailing annual expenditures at basic prices, trade, transport, and tax margins for 200 products. This information enables the conversion of survey expenditures from purchaser to basic prices and addresses reporting errors.

Table 1 shows total direct and indirect emissions of end consumers (households, government, firms, and non-profit organizations) in Türkiye for 2015, calculated using EXIOBASE.

According to TURKSTAT, Türkiye's total greenhouse gas emissions in 2015 were 475 Mt of CO_2e, based on production data. In contrast, EXIOBASE reports consumption-based emissions, attributing 548 Mt of CO_2e to Türkiye, including emissions from imported goods. Given Türkiye's 2015 foreign trade deficit of USD 6.18 billion (Turkish Statistical Institute [TURKSTAT], 2016), the net export adjustment would bring EXIOBASE's estimate closer to 475 Mt of CO_2e as reported by TURKSTAT.

Table 1

Consumption-Based Emissions According to EXIOBASE

(in million-tons CO_2 equivalent)

	Total Indirect Emissions	Total Direct Emissions	Total Emissions
Final consumption expenditure by households	282.37	39.80	322.17
Final consumption expenditure by non-profit organizations serving households (NPISH)	18.03	1.24	19.27
Final consumption expenditure by government	57.29	5.19	62.48
Gross fixed capital formation	106.36	0.00	106.36
Changes in inventories	38.37	0.00	38.37
Changes in valuables	0.00	0.00	0.00
Total	502.43	46.23	548.65

Note: Authors' own calculations.

Household Budget Surveys (HBSs). The Household Budget Survey (HBS) offers detailed insights into households' socio-economic status, demographic characteristics and consumption patterns (TURKSTAT, 2015). We utilize the 2015 survey to align with the 2014-2015 Time Use Survey. Over the course of 2015, 15,264 sample households were surveyed, with 11,491 valid responses. Consumption expenditures are classified using the five-digit COICOP system, covering 303 products.

Time-use Surveys (TUSs). Türkiye's Time-Use Surveys (TUSs) were conducted in 2006 and 2014-2015; we use the latter for this study (TURKSTAT, 2014-2015). During the 2014-2015 survey, 11,440 sample households were surveyed, with individuals aged 10 and above recording their daily activities in 10-minute intervals on a working day and a weekend day.

The microdata includes respondents' characteristics—such as gender, age, education, employment status, household income, and housing characteristics. Activities are classified into 108 time-use activities using the HETUS Activity Coding List from EUROSTAT. Following Smetschka et al. (2019), we reorganize these 108 activities into 21 time-use categories.[3] In the next step, we once again follow Smetschka et al. (2019) to group these 21 categories into four functional time-use categories plus mobility based on the similarity of their purpose, as shown in Table 2.[4] This grouping not only aids in presenting results more clearly but also captures how individuals allocate time to sustain personal, household, economic, and community systems.

[3] The mapping of 108 time-use activities into 21 categories is not reported, but available upon request from the authors.

[4] We do not impose any assumptions regarding the emission intensities of activities within a functional time-use category; heterogeneous emission intensities within a given category are allowed.

Table 2
Functional Time-use Categories

Functional Time-use Categories	21 Time-use Activities
Personal Time	Sleep and rest Personal Care Eating & Drinking
Committed Time	Repairs & Gardening Food Preparation & Dish Washing Caring for others Cleaning, tidying Shopping, Civic Matters & Services
Contracted Time	Work Study
Free Time	Entertainment & Culture Pet care Sport & Outdoor Activities Spending time with family/friends Reading Recreational courses & study Hobbies & Games Watching TV & Videos/DVDs, Listening to Radio & Music Eating out Volunteering
Mobility Time[5]	Mobility

3.2. The harmonization procedure

As mentioned earlier, our approach for deriving emission intensities consists of three steps. First, we use EXIOBASE3 to calculate emissions for 200 products based on their emission intensities and total consumption expenditures in basic prices. However, the classification used in the EXIOBASE dataset is not well-suited

[5] We aggregate all travel-related time reported in the survey and assign mobility-related emissions to this total. Thus, emission intensity of Mobility Time is an average across all modes of transport.

for linking products directly to specific time-use activities, as it includes highly specialized products such (e.g., anthracite, uranium, and thorium ores etc.) which are not directly relevant to time-use activities. The COICOP classification, as used by Druckman et al. (2012) and Smetschka et al. (2019), categorizes household consumption expenditures in a way that allows for a more intuitive linkage to time-use activities. Therefore, in the second step, we assign the emissions of 200 EXIOBASE products into COICOP categories. In the third step, we use the concordance matrix from Smetschka et al. (2019) to link emissions from COICOP categories to time-use activities. Descriptions of these conversion procedures are explained below.

EXIOBASE-to-COICOP. Ivanova and Wood (2020) aggregate COICOP consumption expenditures into 63 categories and develop a concordance matrix to map these categories to 200 EXIOBASE products (i.e., COICOP (63) x EXIOBASE (200)). The matrix provides the fraction of each of the 63 categories that should be allocated to each of the 200 EXIOBASE products. This matrix serves as our starting point.

There are two issues that prevent us from directly applying the matrix developed by Ivanova and Wood (2020). First, the matrix was created for EU countries, meaning some of its underlying assumptions may not be applicable to Türkiye. Second, the matrix provides proportions for mapping COICOP (63) categories to EXIOBASE (200) products, whereas we need to reverse the process—converting emissions from EXIOBASE products into COICOP categories.

To address the first issue, we carefully examine the concordance matrix from Ivanova and Wood (2020) and adjust its assumptions to better align with Türkiye's context. For instance, households in Türkiye commonly use LPG to fuel personal vehicles, and nuclear energy is not utilized for electricity generation. Based on such refinements, we conclude that aggregating COICOP expenditures into 67 categories, rather than 63, is more appropriate for our analysis on Türkiye. As such, we first create a modified version of matrix by Ivanova and Wood (2020) for Türkiye: COICOP (67) x EXIOBASE (200).

Next, we invert the COICOP (67) x EXIOBASE (200) matrix into EXIOBASE (200) x COICOP (67) format with the help of HBSs. For this inversion, we first distribute household consumption expenditures from 67 COICOP categories—as reported in the Household Budget Surveys (HBS)—into 200 EXIOBASE products using the existing concordance matrix, COICOP (67) x EXIOBASE (200) where COICOP categories are the rows and EXIOBASE products are the columns. This step yields the total expenditure value for each COICOP product (in the rows) that can be allocated to EXIOBASE products. Next, we normalize these allocations by column (EXIOBASE product) such that each column sums to one. Specifically, each cell value in the resulting matrix is divided by its column total, converting absolute expenditures into fractional shares. This normalization yields an EXIOBASE (200) × COICOP (67) matrix where cells indicate the fractional contribution of EXIOBASE products to associated COICOP categories. The resulting EXIOBASE (200) × COICOP (67) matrix is presented in Supplementary Material.

COICOP-to-Time-use. We rely primarily on the concordance matrix from Smetschka et al. (2019) to match 67 COICOP products with 21 time-use activities. However, due to differences in data availability and methodology, their original COICOP classification slightly differs from ours. In the rare cases where the matrix by Smetschka et al. (2019) is not applicable, we use our best judgment to complete the mapping for Türkiye. Consequently, we create a COICOP (67) x Time-use (21) concordance matrix. We provide this matrix in Supplementary Material.

In this 67x21 matrix, where rows represent COICOP products and columns represent time-use activities, cells are binary—taking a value of 1 if a given COICOP category is related to the corresponding time-use activity, and 0 otherwise. The next section details the methodology for using this matrix to allocate COICOP emissions to time-use activities.

4. Calculating emission intensities of time-use activities

Household carbon emissions can be categorized into two distinct types: direct emissions and indirect (or embedded) emissions. Direct emissions are generated during the use-phase of products, such as burning gas for heating and cooking or using petroleum-based fuels for private transportation. Indirect emissions, on the other hand, arise during the production and distribution of goods and services purchased by households.

Indirect emissions are calculated using the EXIOBASE3 database. As mentioned above, EXIOBASE3 provides emission coefficients—measured in kilograms of CO_2 equivalent per million Euros spent on any of the 200 products. To determine the total indirect emissions for each product, we multiply these coefficients by the total expenditure of this product in basic prices which are also reported in EXIOBASE3. Next, we utilize the EXIOBASE (200) x COICOP (67) matrix, construction of which is outlined in the previous section, and recover the carbon footprints of 67 COICOP categories per person in Türkiye in 2015.

Direct emissions data is also sourced from EXIOBASE3. In 2015, the total direct emissions from households amounted to 39.8 million tons (mt). Direct emissions are derived from national accounts and not broken down by specific consumption expenditures. Since direct emissions occur only in the use-phase of products, the convention in the literature is to split the total direct emissions between COICOP categories of Mobility and Electricty, gas and other fuels. Gürer et al.

(2024) calculates the proportion of direct emissions attributable to these two categories in Türkiye in 2019. Based on their findings, we allocate 53% of total direct emissions (21.1 mt) to Mobility and 47% (18.7 mt) to Electricity, gas, and other fuels.

Following the procedure described above, we calculate the per capita per year carbon footprints (including direct and indirect emissions) for 67 COICOP categories in Türkiye for 2015. Next, we use the 67x21 COICOP-Time-use concordance matrix to allocate these emissions to specific time-use activities. For this step, we draw on the approach detailed by Jiang et al. (2022), who provide a formal description using mathematical notation. Here, we offer a more intuitive explanation of the procedure.

Recall that the COICOP-Time-use concordance matrix consists of binary values, where a cell is 1 if a COICOP category is linked to a given time-use activity and 0 otherwise. Consider, for example, the COICOP category Glassware, Tableware, and Household Utensils. Suppose this category is associated with three time-use activities, each with a hypothetical per-person annual time allocation: Eating & Drinking (600 hours), Food Preparation & Dishwashing (300 hours), and Cleaning & Tidying (300 hours). Since Eating and Drinking accounts for 50% of the total time among activities linked to category Glassware, Tableware, and Household Utensils, we assign 50% of this category's total carbon footprint to this Eating and Drinking activity. Similarly, Food Preparation & Dishwashing and Cleaning & Tidying, each comprising 25% of the time, receive 25% of the emissions associated with Glassware, Tableware, and Household Utensils COICOP category.

In other words, we allocate the total emissions from a consumption item across all related time-use activities based on the proportion of time spent on each activity (calculated via TUSs). This process is repeated for all 67 consumption expenditure categories. We then aggregate the emissions assigned to each time-use activity from various expenditure categories to obtain the total annual emissions per person for each activity. Finally, we calculate the emission intensity of each time-use activity by dividing these totals by the annual time spent on each activity per person.

5. Results

This section presents the results in three steps. First, we examine the time-use emissions of a typical individual in Türkiye and compare our findings to the prior research. Second, we analyze emissions by employment status. Third, we incorporate the gender dimension. At each step, we generate descriptive insights that support our main conclusions.

5.1. General results and comparison to the prior research

We begin by calculating the emission intensity of an hour spent by a typical individual in Türkiye. In 2015, total demand-driven direct and indirect emissions amounted to 322.17 million tons of CO_2e. Dividing this by Türkiye's 2015 population yields 4.09 tons CO_2e per person. Further dividing per capita emissions (4.09 tons CO_2e) by total annual hours (24 × 365) results in an average GHG emission intensity of 0.47 kg CO_2e per hour.

According to Smetschka et al. (2019), Druckman et al. (2012), and Jiang et al. (2022), the average GHG emission intensity per hour is 1.3 kg CO_2e/h for Austria in 2009-2010, 1.2 kg CO_2e/h for the UK in 2004, and 0.63 kg CO_2e/h for Japan in 2006. Although these studies employ different input-output models and slightly varying methodologies, the emission intensity per hour estimates are broadly comparable. This is because the figures are obtained by simply dividing total demand-driven emissions by the total number of hours in a year. Differences in overall emission intensities per hour across countries may result from various factors, including income levels, expenditure and time-use patterns, and underlying emission intensities. Although a full decomposition analysis is beyond the scope of this paper, it is reasonable to conclude that income differences are the primary driver.[6]

[6] In 2015, Türkiye's GDP per capita was USD 11,050, compared to USD 48,153.3 for Austria in 2009 (World Bank, n.d.).

Table 3
Time-Use Activities' Total Emissions, Time and Intensity

	Total Emission [1]	Total Emission per Capita [2]	Total Time per Capita [3]	Intensity [4]
Eating & Drinking	77.28	0.98 (24%)	561.43 (6.4%)	1.75
Mobility	43.14	0.55 (13.4%)	386.81 (4.4%)	1.42
Eating out	15.79	0.20 (4.9%)	146.37 (1.7%)	1.37
Repairs & Gardening	3.52	0.04 (1.1%)	39.38 (0.4%)	1.14
Personal Care	25.41	0.32 (7.9%)	298.18 (3.4%)	1.08
Recreational courses & study	4.11	0.05 (1.3%)	103.46 (1.2%)	0.50
Entertainment & Culture	11.06	0.14 (3.4%)	314.84 (3.6%)	0.45
Hobbies & Games	2.74	0.03 (0.9%)	79.86 (0.9%)	0.44
Caring for others	5.85	0.07 (1.8%)	172.54 (2%)	0.43
Cleaning, tidying	8.44	0.11 (2.6%)	255.21 (2.9%)	0.42
Food Preparation & Dishwashing	12.49	0.16 (3.9%)	377.82 (4.3%)	0.42
Pet care	0.69	0.01 (0.2%)	22.54 (0.3%)	0.39
Spending time with family/friends	11.41	0.14 (3.5%)	408.38 (4.7%)	0.35
Watching TV & Videos/DVDs, Listening to Radio & Music	22.20	0.28 (6.9%)	794.40 (9.1%)	0.35
Reading	1.72	0.02 (0.5%)	61.63 (0.7%)	0.35
Sleep and rest	74.07	0.94 (23%)	3213.70 (36.7%)	0.29
Sport & Outdoor Activities	0.58	0.01 (0.2%)	70.14 (0.8%)	0.11
Shopping, Civic Matters & Services	0.42	0.01 (0.1%)	78.60 (0.9%)	0.07
Volunteering	1.22	0.02 (0.4%)	263.52 (3.0%)	0.06
Work (excluded)	0.00	0.00	933.13 (10.7%)	0.00
Study (excluded)	0.00	0.00	178.05 (2%)	0.00

Notes: [1] In million-tons CO_2

[2] Total Emission / 2015 Population (78741053), in ton CO_2, percentages in parentheses

[3] Average annual total time for an activity, in hour, per capita, percentages in parentheses

[4] Total Emission Per Capita / Total Activity Time Per Capita, in kg/ CO_2 per hour.

In the next step, we present total time allocated per capita-year, total emissions per capita-year and emission intensities of 21 time-use activities in Table 3 as calculated in Section 4. Consistent with previous literature, we cannot and do not assign any expenditure or emissions to Contracted Time activities, such as Work and Study. Emissions associated with the workplace are included as indirect emissions in demand-based emissions. Expenditures related to Study are accounted for in other categories (e.g., emissions from clothing are allocated to the Personal Care time-use activity). However, we still include Committed Time activities in our results, as time spent on Contracted Time can influence remaining time-use and expenditure patterns.

The five activities to which an average person allocates the most daily time are as follows. The largest share of daily time is allocated to Sleep and Rest, accounting for approximately 37% of the day. This is followed by Work, which occupies 10.7% of daily time. Leisure activities such as Watching TV, represent the next largest category, with 9.1% of time spent on average. Spending Time with Family and Friends accounts for 4.7%, while Mobility, such as commuting and other forms of travel, constitutes 4.4% of daily time.

The activities with the highest GHG emission intensity per hour include Eating and Drinking, Mobility, Eating Out, Repairs and Gardening, and Personal Care, in that order. In contrast, free-time activities such as pet care, spending time with family and friends, reading, sports and outdoor activities, and volunteering have relatively low GHG emission intensities.

Our methodology for deriving emission intensities of various time-use activities closely follows that of Smetschka et al. (2019), allowing us to compare the activity intensities reported in their study. Notably, the category with the highest GHG emission intensity in Austria, according to Smetschka et al. (2019), is Eating Out, at 9.82 kg CO_2e/h. This is followed by Entertainment and Culture (9.74 kg CO_2e/h), Recreational Courses and Study (3.37 kg CO_2e/h), and, finally, Eating & Drinking (3.30 kg CO_2e/h). Evidently, free-time functional time-use category (as defined in Table 2) include some of the activities with the highest GHG intensity in Austria, as opposed to Türkiye where Eating & Drinking is the activity with the highest GHG intensity.

For clarity and ease of discussion, our results by employment status and gender in the following sections are organized according to the functional time-use categories and mobility defined in Table 2. Figure 1 illustrates the relative importance of these categories in both the total time-use of a typical individual and in total GHG emissions for a typical person in Türkiye.

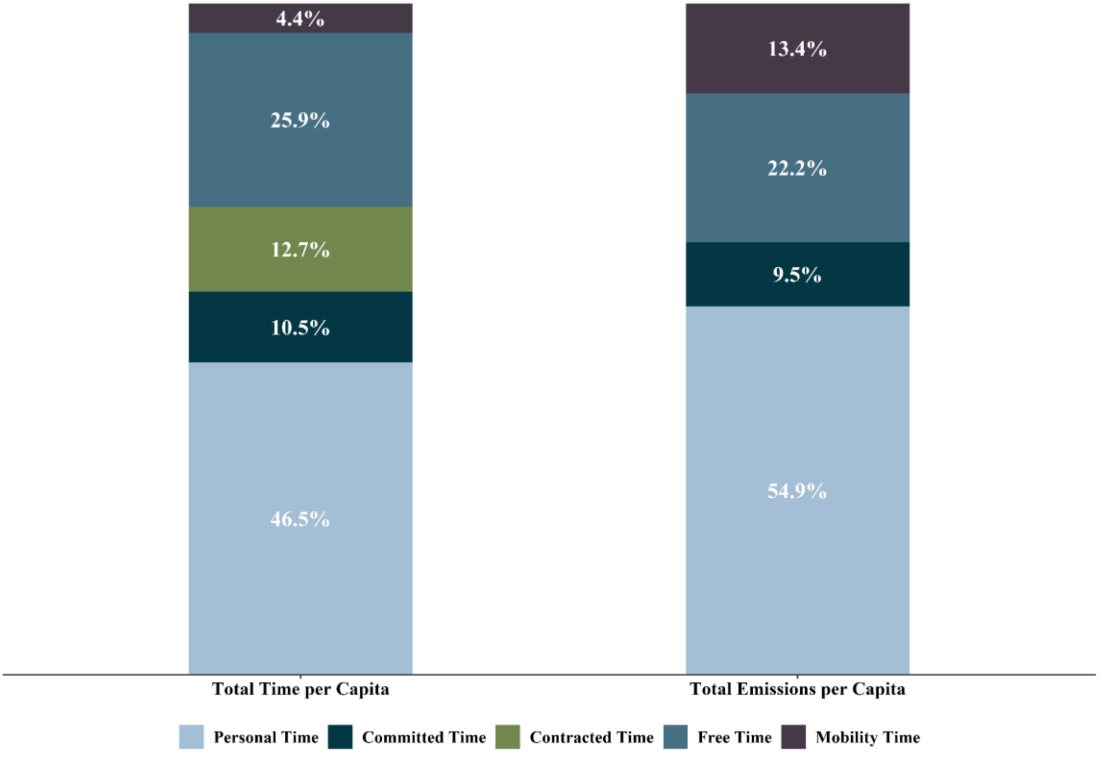
As shown in Figure 1, Personal Time—which includes Eating and Drinking—accounts for the largest share of both total time use (46.5%) and total emissions (54.9%) in Türkiye. This contrasts sharply with the findings of Smetschka et al.

(2019) for Austria. Although Personal Time activities occupy a similar share of daily time in both countries (46%), they account for only 39% of total emissions in Austria, compared to 54.9% in Türkiye.

Turning to other categories, Mobility represents just 4.4% of total time but contributes 13.4% of total emissions. Free Time and Committed Time activities account for 22.2% and 9.5% of total emissions, respectively.

These results underscore a key distinction between the time-use emission patterns of low-income and high-income countries. Individuals in high-income countries as Austria have significantly more disposable income to spend on leisure activities compared to those in low-middle-income countries like Türkiye. For instance, Türkiye lags behind developed nations in per capita consumption of high GHG-intensive animal products, such as meat and milk (Republic of Türkiye Ministry of Agriculture and Forestry Agricultural Economic and Policy Development Institute [TEPGE], 2018). Additionally, per capita wine consumption in Türkiye was 0.8 liters in 2015, compared to 32.1 liters in Austria (International Organisation of Vine and Wine [OIV], n.d.). Thus, it is not that Türkiye excels in green practices, resulting in lower emission intensities for free-time activities (such as Eating Out); rather, it is simply that individuals in Türkiye lack the affluence to engage in more emission-intensive leisure activities. Policy implications of this finding are discussed in Section 6.

Figure 1
Time-Use and Emissions Shares of Functional Time-Use Categories



Note: The definitions of functional time-use categories can be found in Table 2.

5.2. By employment status

In this section, we analyze time-use patterns and their associated emissions by employment status. To do so, we use Time-Use Surveys (TUSs) to calculate the time spent on each activity per person, differentiating between employed and unemployed individuals, and then multiply these durations by the overall GHG emission intensities presented in Table 3. This method is standard in the literature, but it relies on a key assumption that must be understood for proper interpretation. By multiplying the duration of each activity by the emission intensities, we implicitly compare the emissions of employed and unemployed individuals who, by assumption, have the same income (i.e., average income). Although employed and unemployed individuals may have different average income levels, eliminating this income difference is a deliberate aspect of our analysis, allowing us to focus solely on the impact of differing time-use patterns.

We define a person as employed if they work at least four hours per day for five days a week, to account for part-time workers. Therefore, we consider a person employed if their average daily working hours are at least 2.86 (5x4/7). In the analyses by employment status, we focus exclusively on individuals aged 16 and older. The time-use patterns for functional time-use categories and the associated emissions are presented in Table 4.

Table 4

Daily Time-Use Patterns and Emissions, by Employment Status

	Total Time (hour:minute)		Total Emission ($kgCO_2e$)	
	Employed	Unemployed	Employed	Unemployed
Personal Time	09:59	11:37	5.20	6.62
Committed Time	00:54	03:39	0.36	1.56
Contracted Time	07:34	00:39	0.00	0.00
Free Time	04:07	07:09	2.12	2.62
Mobility Time	01:25	00:53	2.01	1.26
Total	24.00	24.00	9.69	12.06

Note: The definitions of functional time-use categories can be found in Table 2.

Assuming similar income levels, unemployed individuals emit 2.37 $kgCO_2e$ more emissions per day than employed individuals. This difference arises because not working—an activity with zero emission intensity—frees up considerable time for other activities that generate emissions. A detailed analysis of time-use and emission patterns for unemployed individuals is deferred to the next section, as these patterns vary significantly by gender.

Employed individuals contribute most to emissions through Personal Time activities, particularly Sleep & Rest, Personal Care, and Eating & Drinking (a detailed activity breakdown is not provided here). As emphasized in the previous section, the high levels of emissions associated with these fundamental activities underscore the challenges of achieving significant reductions through behavioral change. Nevertheless, some opportunities for reduction remain.

As mentioned in Section 5.1, we do not attribute any emissions to Committed Time. However, it is worth noting that employed individuals spend an average of 7 hours and 34 minutes per day, including weekends, on Contracted Time (i.e., working). This implies that someone working five days a week reports spending around 10 hours and 35 minutes at the workplace per workday, while those working six days a week report an average of 8 hours and 49 minutes at the workplace per workday. On average, people spend about 4.4% of their daily time on Mobility as shown in Table 3, but this figure rises to approximately 6% for employed individuals.[7] Time-use surveys provide insights into the purpose of this mobility. We estimate that, beyond their long working hours, employed individuals spend roughly one hour per day—or more than one hour on workdays—commuting for work, accounting for 4.2% of their daily time. On average, they have just over four hours of free time per day, likely significantly less on workdays.

Our analysis highlights two key aspects of the time-use patterns of employed individuals. The first aspect is the significant amount of time spent on mobility for work purposes. It is well-established that individuals, especially in large cities as Istanbul, spend a substantial portion of their day commuting. According to Gürsoy et al. (2016), approximately 52% of a driver's travel time in Istanbul during the morning peak is spent in traffic congestion, with this figure rising to 58% in the evening. Despite this, many individuals prefer driving to using public transportation options such as trains, subways, and the bus rapid transit system (metrobüs), likely due to insufficient and inefficient public transportation infrastructure.

The second aspect concerns the high emission intensity of mobility, which ranks second only to eating and drinking. As illustrated in Figure 1, mobility accounts for a disproportionately large share of total emissions relative to the time spent. Beyond inadequate public transportation, the "time-squeeze" problem—stemming from long working hours—limits leisure and household time, leading individuals to choose relatively quicker, more comfortable but less environmentally friendly transportation options like personal vehicles and taxis instead of e.g., employee shuttles. This choice is made in an effort to save time, further contributing to the high emission intensity of mobility. Policy recommendations, which will be discussed in Section 6, should focus on facilitating the transition to more sustainable modes of transportation for employed individuals.

[7] Employed individuals in large cities likely spend a greater share of their time commuting; however, time-use surveys unfortunately do not include information on place of residence.

5.3. By employment status and gender

In this section, we examine the time-use emissions patterns of employed and unemployed individuals by gender, resulting in four groups: employed women, employed man, unemployed women, and unemployed man. We then multiply the time spent on each activity by the overall emission intensities, as done in the previous section, and compare the results. It is important to note that by multiplying with overall intensities, we eliminate any income differences across groups, allowing us to focus exclusively on variations in time-use patterns. Results are presented in Table 5.

Table 5
Daily Time-Use Patterns and Emissions, by Employment Status and Gender

		Men		Women	
		Employed	Unemployed	Employed	Unemployed
Total Time (hour:min)	*Personal Time*	09:57	11:55	10:03	11:27
	Committed Time	00:31	01:10	02:09	04:59
	Contracted Time	07:45	01:01	06:57	00:28
	Free Time	04:18	08:36	03:32	06:23
	Mobility Time	01:27	01:16	01:16	00:41
Total Emissions ($kgCO_2e$)	*Personal Time*	5.20	6.67	5.21	6.59
	Committed Time	0.21	0.56	0.87	2.09
	Free Time	2.20	3.25	1.83	2.28
	Mobility Time	2.07	1.81	1.80	0.97
	Total	9.68	12.29	9.71	11.93

Note: The definitions of functional time-use categories can be found in Table 2.

As shown in Table 5, unemployed men exhibit time-use patterns resulting in the highest emissions, producing 12.29 $kgCO_2e$ per day, compared to unemployed women, who emit 11.93 $kgCO_2e$ per day. Both groups allocate similar amounts of time to the Personal Time functional category, leading to comparable emissions from these activities.

However, unemployed men spend most of their remaining time on Free Time activities (8 hours and 36 minutes) and Mobility for Free Time Activities (calculated from TUS data as 35 minutes). In contrast, unemployed women dedicate a significantly larger portion of their time outside Personal Time to Committed Time activities, such as Caring for Others, Food Preparation & Dishwashing, and Cleaning & Tidying. Since Committed Time activities are less carbon-intensive than Mobility (see, e.g., Figure 1), unemployed women ultimately cause fewer emissions per day.

As shown in Figure 1, Free Time activities account for 22.2% of total emissions, while Committed Time activities contribute 9.5%. Our findings indicate that, beyond fundamental Personal Time activities, unemployed men primarily generate emissions through Free Time activities and Mobility associated with these activities. In contrast, unemployed women contribute to emissions not only through Free Time activities but also significantly through unpaid domestic labor (Committed Time).

Therefore, policy proposals aimed at reducing emissions from Free Time activities should primarily target unemployed men, though unemployed women should also be considered. On the other hand, proposals for reducing emissions from Committed Time activities should dominantly target unemployed women. A further discussion on policy can be found in the next section.

Although the article does not provide a detailed gender breakdown, it is noteworthy that women, on average, emit more CO_2e per day than men—a difference largely attributed to their greater involvement in unpaid domestic labor. In contrast, men's emissions, aside from Personal Time activities, are primarily linked to commuting and participation in other carbon-intensive activities such as Eating Out. This disparity underscores the "double shift" faced by employed women, who spend a substantial portion of their day—2 hours and 9 minutes—on Committed Time activities, balancing both paid employment and domestic responsibilities. Addressing this dual burden through policies that reduce the time and emissions associated with Committed Time could contribute to both gender equality and environmental sustainability.

6. Conclusion and policy discussion

Markets tend to supply goods that are in demand. Therefore, the fight against climate change requires changes not only in production methods but also in consumption habits. How individuals use their time partly shapes their consumption expenditure patterns. As a result, transforming time-use patterns into a more environmentally friendly structure has the potential to contribute to the fight against climate change. To this end, this study examines time-use patterns and their associated emission intensities in the context of a developing economy: Türkiye.

We begin by using the environmentally extended multi-regional input-output dataset, EXIOBASE3, to calculate the emissions of 200 EXIOBASE products. By carefully examining and adapting existing concordance tables from the literature—partly with the assistance of Household Budget Surveys—to suit the specific context of Türkiye, we first map the emissions of EXIOBASE products to COICOP expenditure categories. We then use the Time-Use Surveys to allocate the emissions of these COICOP categories to specific time-use activities. Subsequently, we leverage the Time-Use Surveys once more to calculate the emission intensities of each activity and analyze the time-use emission patterns of different demographic groups.

The following are the four main conclusions drawn from our exploratory analyses and the corresponding policy discussions.

Conclusion 1. In Türkiye, the Personal Time functional time-use category—including Eating and Drinking—makes up 46.5% of daily time use and 54.9% of total emissions, whereas in Austria, it accounts for a similar 46% of time use but only 39% of emissions. This difference stems from the fact that individuals in Türkiye primarily generate emissions through essential activities, while in more affluent economies like Austria, leisure-related activities are among key drivers of emissions. This highlights important challenges for policy design in Türkiye. High-income countries are more likely to achieve emission reductions through behavioral changes, especially in leisure activities. In contrast, lower-income economies have fewer such opportunities, as the most emission-intensive category—Eating and Drinking—is a basic necessity. Therefore, policy efforts in Türkiye should primarily focus on reducing the emission intensity of essential Personal Time activities.

As such, efforts should prioritize reducing the greenhouse gas intensity of food and beverages by increasing the use of renewable energy sources and promoting sustainable practices in agriculture. For example, the primary source of greenhouse gas emissions in agriculture is methane produced by cattle (Murphy et al., 2013). Various strategies exist to reduce methane emissions, but it is essential to implement solutions that avoid any welfare loss. For instance, feed supplements and improvements in herd health can enhance animal welfare while effectively reducing greenhouse gas emissions (Beauchemin et al., 2011; Llonch et al., 2017).

Conclusion 2. Mobility accounts for 13.4% of total emissions, despite constituting only 4.4% of daily time-use, indicating its high emission intensity. Employed individuals spend larger share of their daily time (6%) on Mobility and possibly contribute to high emission intensity of this category via their choice of transportation mode.

Two key policy areas could address this issue for employed individuals: improving public transportation infrastructure and reducing working hours. First, enhancing public transportation infrastructure is critical. The current limitations of public transit options, coupled with long working hours, push individuals toward private cars and taxis, which are more GHG-intensive. By expanding and improving the efficiency of public transportation systems, such as trains, subways, and bus rapid transit (metrobüs), individuals may find it more convenient to use these options, thus reducing their carbon footprint. Second, addressing the "time-squeeze" problem by reducing working hours and promoting remote work can help alleviate the pressure on employed individuals, giving them more time and potentially encouraging cheaper and more environmentally friendly transport options such as employee shuttles and public transportation.

Conclusion 3. Free Time activities account for 22.2% of total emissions. The target group is mainly unemployed men (though unemployed women's Free Time emissions are also not negligible), who have more free time and less domestic work, tend to generate higher emissions through leisure activities and related travel.

To address this, policies should encourage low-emission leisure options and reduce travel for such activities. This could involve identifying socio-culturally underserved districts, where cultural and recreational activities are limited and green spaces are scarce, and expanding these facilities. Government subsidies for such activities could also help. Increasing urban green spaces, along with more theatres, libraries, and free public education courses, would provide accessible, low-emission leisure options. These changes would not only benefit unemployed men but also guide employed individuals toward less carbon-intensive activities in their free time. Local governments have an essential role in identifying disadvantaged areas and implementing these measures.

Conclusion 4. Committed Time activities, including cleaning, dishwashing, cooking, and caregiving for children and the elderly, account for 9.5% of total emissions. Unemployed women, who spend nearly as much time on these tasks as a full-time job, are the primary target group.

Local governments play a vital role in addressing the emissions via Committed Time activities. Providing child and elderly care services, as well as meals for primary school children—especially in low socio-economic areas—can reduce the burden on women, freeing up time for lower-emission leisure activities. These services also promote economies of scale, reducing overall emissions. Additionally, women who are unable to work due to childcare responsibilities may be reintegrated into the workforce, offering both economic and environmental benefits.

We hope that our methodology for deriving time-use emissions in Türkiye, along with our findings, will spark further scientific and policy discussions on reducing the emission intensities of fundamental time-use activities and transforming existing habits into a more environmentally friendly structure.

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Özet

Türkiye'de zaman kullanımı kaynaklı emisyonlar: İstihdam durumu ve cinsiyete göre bir inceleme

Bu çalışmada, EXIOBASE3, Hanehalkı Bütçe Anketleri ve Zaman Kullanım Anketleri birleştirilerek Türkiye'de zaman kullanımı kaynaklı emisyonlar incelenmektedir. Temel bulgumuz, zorunlu kişisel zaman kullanım faaliyetlerinin—özellikle temel yeme ve içme faaliyetlerinin—günlük zamanın benzer bir kısmını kaplamasına rağmen, Türkiye'de daha zengin ülkelere kıyasla emisyonların çok daha büyük bir bölümünü oluşturduğudur. Bu durum, Türkiye gibi gelişmekte olan ülkelerde karbon emisyonlarının azaltılmasına yönelik politikalarda karşılaşılabilecek özgün zorluklara ve müdahale alanlarına dair önemli ipuçları sunmaktadır. Ayrıca, istihdam durumu ve cinsiyet gruplarına göre emisyonları artıran diğer temel zaman kullanım faaliyetleri de belirlenmiştir. Çalışmada ilgili politika önerileri tartışılmaktadır.

Anahtar kelimeler: Çevre, iklim değişikliği, zaman kullanımı, karbon emisyonları.

JEL kodları: Q54, Q56, Q58, J10.