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Work Hours and CO_2 Emissions: Evidence from U.S. Households

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ABSTRACT

The degrowth movement proposes worktime reduction policies to help high-income countries meet their climate goals while supporting full employment. However, the work hours elasticity of carbon emissions remains uncertain despite a growing number of empirical analyses. This paper estimates the impact of work hours on emissions using household data from the United States. We calculate the carbon intensity of goods using input-output tables from the Bureau of Economic Analysis, which we combine with spending data from the Bureau of Labor Statistics to estimate carbon footprints for a representative sample of U.S. households. There is strong evidence that households with longer work hours emit more CO_2, but our household-level estimate of the work hours elasticity of carbon emissions is lower than most country-level estimates. Our results suggest that differences in work hours account for a small fraction of differences in per capita carbon footprints across high-income countries.

Highlights

- Households with longer work hours have significantly larger carbon footprints.
- Our estimated household-level work hours elasticity is smaller than most country-level estimates.
- Work hour reduction policies likely generate modest reductions in carbon emissions.

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1. Introduction

Addressing climate change is a daunting task that will require people in high-income countries to fundamentally change their way of life. Many of these changes in where we live, how we get around, and what we consume may be difficult, at least in the short run. However, work time reductions have the potential to both curb carbon emissions *and* improve the quality of life. The degrowth movement proposes shorter work hours in high-income countries to reduce the scale of the economy and ensure full unemployment (Victor 2008). While no one argues that work time reduction policies are a panacea for climate change, shorter work hours could complement other policies to reduce emissions, such as carbon taxes, fuel-efficiency standards, and investments in

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renewable energy. This paper analyzes the potential of work time reduction policies to mitigate carbon emissions.

John Maynard Keynes (1930) famously suggested that technological advancement would make 'fifteen-hour work weeks' possible by the early twenty-first century. History has unfolded very differently. Americans continue to work particularly long hours despite an expressed desire for more reasonable schedules (Schor 1992; Boushey 2016). Long work hours are often set by managers (Wheatley, Hardill, and Philp 2011) or as a requirement for health and retirement benefits (Schor 1992), but workers may also choose long hours in attempt to 'keep up with the Joneses' (Alesina, Glaeser, and Sacerdote 2005; Bowles and Park 2005; Frank 2005). Economic theory suggests that individuals work longer hours if consumption is a more positional good than leisure (Arrow et al. 2004), as empirical research suggests (Solnick and Hemenway 2005). This may explain why there is little or no relationship between aggregate happiness and aggregate incomes in high-income countries (Easterlin 1974, 1995; Clark, Frijters, and Shields 2008), and why shorter work hours are correlated with higher levels of subjective wellbeing (Alesina, Glaeser, and Sacerdote 2005; Pullinger 2014).

Environmental economists note that if consumption is a positional good then policies that reduce work hours and incomes can improve welfare as well as the environment. The greater the competition for status, the lower the cost of environmental protection (Brekke and Howarth 2002; Wendner and Goulder 2008). Ecological economists have stressed the win-win nature of policies that reduce work, incomes, and consumption emphasizing the advantages of reducing the scale of the economy by devoting productivity gains towards greater leisure rather than more consumption (Schor 2005, 2010). Work hour reduction policies are a central plank of the degrowth platform for a sustainable economy (Sanne 2002; Victor 2008; Jackson 2009; Kallis 2011).

The theoretical relationship between work hours and carbon emissions is ambiguous, since some forms of leisure are quite carbon-intensive; but a growing body of empirical research suggests that work time reduction policies decrease carbon emissions. Most high-income countries have substantially shorter work hours and significantly smaller carbon footprints than the U.S. For example, the average German worker toils 23 per cent fewer hours than their American counterpart, and the average German emits 46 per cent less carbon (IEA 2018; OECD 2018). This cross-country correlation suggests that policies to reduce work time may help countries mitigate greenhouse gas emissions and meet their international climate obligations. Work time reduction policies may represent a win-win policy for Americans to achieve a better work-life-environment balance (Buhl and Acosta 2016).

The effectiveness of work time reductions as a tool for addressing climate change depends crucially on the work-hours elasticity of carbon emissions, or the percentage change in emissions resulting from a one percent change in work hours. Rosnick (2013) demonstrates the stakes of this question by simulating the climate impact of reducing worldwide work hours by 0.5 per cent a year over the twenty-first century. If the work-hours elasticity of carbon emissions is 1.0, then these work time reductions would reduce emissions by enough to prevent 25–51 per cent of future warming that is not already locked-in; if the elasticity is 0.5, then they would prevent 13–27 per cent of this warming. Elasticities in this range suggest that work time reductions can make a sizable contribution to climate change mitigation. However, there remains considerable uncertainty about the magnitude of the elasticity between work hours and carbon emissions. Improving our understanding of the relationship between work hours and emissions can clarify the extent to which work time reductions provide a useful policy lever to mitigate carbon emissions.

This paper sheds new light on the relationship between work hours and carbon emissions. Most empirical research has identified this elasticity using cross-country data. These studies have resulted in a wide range of results, which are sensitive to the studies' samples and methodologies. To date, only Nässén and Larsson (2015) have estimated the work-hours elasticity of carbon emissions at the household-level, using data from Sweden. We contribute to this literature by estimating this elasticity using data on household work hours and consumption patterns in the U.S. We use the Bureau of Economic Analysis' input-output tables to calculate the carbon intensity of goods, which we combine with expenditure data from the Bureau of Labor Statistics to estimate carbon footprints for a large representative sample of U.S. households.

Our model identifies the likely impact of work hours on carbon emissions using differences in work hours and carbon footprints across households. This identification strategy is imperfect, since differences in work hours across households are not primarily driven by exogenous differences in worktime policies. That said, our results provide a useful complement to country-level studies that implicitly assume that countries' worktime policies are uncorrelated with their climate policies. Our analysis attributes all carbon emissions to consumers, so our household-level estimates are directly comparable to country-level and state-level estimates. We show that households with shorter work hours have lower expenditures, which suggests that worktime reduction policies would reduce total output. Our results also indicate that Americans with longer work hours emit more CO_2, which suggests that worktime reduction policies would reduce total carbon emissions. We present robust evidence that the elasticity of carbon emissions with respect to work hours is approximately 0.3. This estimate is substantially lower than most cross-country estimates. The discrepancy between our household-level estimate and most country-level estimates may reflect the fact that other countries have adopted *separate* policies to address environmental externalities and positional externalities, or that there is a social multiplier in abating carbon emissions through shorter work hours.

2. Literature Review

The literature suggests that long work hours may increase CO_2 emissions through both a *scale* effect and a *compositional* effect (Knight, Rosa, and Schor 2013). Holding hourly wages constant, lengthening work hours expands the scale of the economy by increasing incomes, expenditures, and ultimately emissions. Longer work hours may also increase emissions by shifting the composition of expenditures towards more carbon-intensive goods and services—what we refer to as the 'composition' effect. For example, people with little free time may drive to work rather than take mass transit, and they may take shorter, but more carbon-intensive, vacations.

Empirical studies have primarily analyzed the relationship between work hours and emissions, energy use, or ecological footprints using country-level data, with just one existing study using U.S. state-level data (Fitzgerald, Schor, and Jorgenson 2018) and one study using household-level data (Nässén and Larsson 2015). Most cross-country studies find that countries with shorter work hours (hours/worker) also have smaller carbon footprints

(CO_2/population), when controlling for rates of labor force participation (workers/population) and productivity (GDP/hour). Rosnick and Weisbrot (2007) estimate the elasticity of energy use with respect to average work hours across countries using 2003 data. Their point estimates suggest a 1 per cent increase in hours worked increases energy use between 1.3 per cent and 2.8 per cent, depending on their sample. Hayden and Shandra (2009) analyze the ecological footprints of 45 countries in the year 2000 and estimate a work-hours elasticity of approximately 1.2.

More recent studies use panel data to estimate work hour elasticities using variation in work hours within countries over time. Knight, Rosa, and Schor (2013) conduct a difference-in-difference analysis of carbon emissions and work hours in nearly 30 developed countries from 1970 to 2007. They estimate that a 1 per cent increase in work hours is associated with a 1.3 per cent increase in consumption-based CO_2 footprints and a 0.5 per cent increase in production-based CO_2 footprints. Fitzgerald, Jorgenson, and Clark (2015) estimate a model with country and year fixed effects that finds that a 1 per cent increase in work hours increases non-renewable energy use by 0.3 per cent in 52 countries and 0.4 per cent in 23 high-income countries. Shao and Rodríguez-Labajos (2016) analyze the work-hours elasticity of carbon emissions for 37 developed countries using a Generalized Method of Moments estimator with lagged levels and lagged differences. This method produces much smaller elasticities of about zero in the late twentieth century and about −0.1 in the early twenty-first century. Shao and Shen (2017) allow their elasticity estimate to vary across groups of EU-15 countries, and they report the work hours elasticity of carbon emissions is approximately zero for countries with short working hours, 3.5 for countries with medium working hours, and zero for countries with long work hours. Taken together, these cross-country studies suggest that long work hours are correlated with larger carbon footprints, but the degree of correlation is a matter of dispute.

Fitzgerald, Schor, and Jorgenson (2018) build on these cross-country studies to analyze the relationship between work hours and emissions across U.S. states from 2007 to 2013. Their analysis includes fixed-effect regressions that estimate the elasticity using variation in hours and emissions within states over time. These results suggest that the work hours elasticity of carbon emissions is approximately 0.7.

Finally, Nässén and Larsson (2015) analyze Swedish household data to study the relationship between work hours and greenhouse gas emissions. Like our paper, they estimate households' carbon footprints based on their consumption patterns using carbon intensities calculated from national input-output tables. However, their expenditure data does not include information about work hours, so Nässén and Larsson (2015) separately estimate the 'income effect' and the 'time effect' of work hour reductions. Their results suggest that the income effect swamps the time-use effect, and that a 1 per cent decrease in work hours *decreases* carbon emissions by 0.82 per cent through the income channel and *increases* emissions by 0.02 per cent through the time channel, for a total elasticity of about 0.8.

This paper contributes to the literature by providing new estimates of the work-hours elasticity of carbon emissions using a large nationally representative sample of U.S. households. We observe both the expenditures and work hours of all household members for an entire year, which allows us to estimate the impact of work hours on carbon footprints in a single empirical model. While other researchers have analyzed time-use data to predict how workers would spend an extra hour of leisure (Druckman et al. 2012; Nässén and Larsson 2015), we simply analyze the consumption baskets, and hence emissions, of households with a range of work hours. Our results clarify the extent to which shorter working hours can help the U.S. achieve the sharp reductions in carbon emissions that are necessary to mitigate the cost of climate change.

3. Data and Methods

We analyze the relationship between work hours and carbon emissions using a sample of U.S. households in the Consumer Expenditure Survey (CEX) Public Use Microdata. We use data from the Interview Survey, which collects detailed consumption data from households over the course of a year. After a preliminary interview, each household is interviewed about their quarterly expenditures for a maximum of four consecutive quarters at three month intervals. This cross-sectional data covers 85–95 per cent of household expenditures. While this survey fails to capture household expenditures on some housekeeping supplies, personal care products, and nonprescription medication, these goods are responsible for a negligible share of CO_2 emissions. We use the CEX data on household consumption to estimate households' emissions using carbon intensities calculated from the BEA's input-output tables. Our method allows us to estimate the following equation:

$$\begin{aligned}\ln(\text{hh. CO}_{2i}) =& \beta_1 \ln(\text{hh. work hours}_i) + \\ & \beta_2 \ln(\text{hourly wage}_i) + \beta_3 X_i + \varepsilon_i\end{aligned} \quad (1)$$

where household i's annual CO_2 emissions are a function of its members' total work hours, its members' average wage, and a battery of control variables (X). Our control variables vary by specification in Table 3 to account for well-established determinants of household emissions and pro-environmental behaviors, including household size and type, urban density, age, gender, race, and educational attainment (Rosa and Dietz 2012; Franzen and Vogl 2013; Fremstad, Underwood, and Zahran 2018; Melo et al. 2018).

Our econometric analysis identifies the impact of work hours using variation across households, and our log–log specification allows us to directly compare our estimate of the work-hours elasticity of emissions, β_1, to other analyses using variation across countries or U.S. states. We expect households with longer work hours to have larger carbon footprints because, everything else equal, they will earn higher incomes and have greater expenditures. If work hours *only* increase CO_2 emissions through the scale effect, then the work-hours elasticity of emissions will be equal to the wage elasticity of emissions, β_2. In this case, an increase in income has the same effect on a households' CO_2 emissions regardless of whether it is the result of longer work hours or higher wages. On the other hand, if work hours also increase emissions through a compositional effect, then our estimate of β_1 will be greater than our estimate of β_2, suggesting that households with longer work hours consume more carbon-intensive goods.

Households' carbon emissions are based on the consumption baskets reported in the CEX's Interview Surveys. We then estimate the carbon footprint of each household (in $kgCO_2$) by multiplying each household's annual expenditures on 27 categories of goods (in U.S. dollars), by the carbon intensity of those goods (in $kgCO_2/\$$). Our carbon intensities are calculated in Fremstad and Paul (2017) using input-output tables from the

Bureau of Economic Analysis' and CO_2 emissions data from the Energy Information Agency to compute the kilograms of CO_2 directly and indirectly embodied in $1 of output of 64 industries in the U.S. economy.[1]

Approximately 25 per cent of U.S. emissions are embodied in imports produced using more carbon-intensive production technology (Weber and Matthews 2008), and multi-regional input-output (MRIO) models allow researchers to separately estimate carbon intensity of imported and domestically produced goods (Hertwich 2011). This paper nevertheless assumes that the carbon intensity of imported goods is equal to that of domestically produced goods, because we do not observe whether households' purchase imported or domestically produced goods. We do not believe these data constraints pose a serious problem for our analysis. Even if the carbon intensity of domestically produced goods differs from that of imported goods differs, our estimates are unbiased as long as households' decisions to purchase domestic or imported goods is not systematically correlated with work hours. However, future research may improve upon our study by merging MRIO estimates of carbon intensities with household-level data that distinguishes between domestic and foreign goods.

Unlike most existing analyses, we impute utility expenditures for renters who have electricity, gas, or heat included in their rent (consisting of about 30 per cent of renters in the U.S.) to avoid underestimating the carbon footprints of these households. Our methodology attributes 82 per cent of U.S. CO_2 emissions to final users, as described in detail in Fremstad and Paul (2017).

Work hours and wage data are also observable in the CEX. The CEX asks households about each member's work hours over the previous 12 months in the final (fifth) interview, which covers the same period as the four quarters of expenditures data and our calculated carbon footprints. For each member, we observe how many weeks they worked in that year as well as their usual work hours per week. We combine these variables to calculate the annual work hours of each household member. The CEX also provides earnings data, which we use to calculate each member's hourly wage.[2] Since we conduct our analysis at the household level, we also calculate the number of workers in each household, the total annual work hours of household workers, the average work hours of household workers, and the average wage of household workers (weighted by the members' annual hours worked).

The CEX provides data on 76,448 household-quarters from 2012 to 2014. We drop 680 observations with missing geocodes, incomplete renter information, and negative wages, incomes, or total expenditures. We further restrict our analysis to households that report expenditures over four consecutive quarters, which reduces our sample size to 38,464 household-quarters, or 9616 household-years. Although this cuts our sample size by about half, it ensures that we compare work hours and carbon emissions over the same period. Since this paper is focused on the effect of work hours on carbon emissions, we further restrict our analysis to households that are likely to be affected by policies to reduce work time. In our central analysis, we limit our sample to 5926 households in which members collectively work at least 1000 hours a year, equivalent to approximately

[1]These emissions estimates include only carbon dioxide emissions, which account for approximately 80 per cent of greenhouse gas emissions.

[2]About half of members provide no earnings data or incomplete earnings data, so we use the CEX's mean imputed wage and salary for each member.

Table 1. Summary statistics.

	Mean	Std. Dev.	Min	Max
Hh. CO_2 emissions (in kg)	27,888	15,556	1717	170,274
Per capita CO_2 emissions	11,538	7318	601	86,142
Hh. size	2.9	1.6	1	29
Hh. workers	1.7	0.8	1	16
Avg. hours per week	40.6	8.9	10	96
Avg. weeks per year	48.1	7.2	7	52
Hh. annual work hours	3252	1579	1000	32,980
Avg. annual work hours	1976	538	480	4992
Avg. hourly wage	23.56	17.59	0.00	199.47
Age of reference person	47.0	13.7	16.0	87.0

Note: This table provides unweighted means of key variables for the 5926 observations in our primary sample.

one half-time job. However, we also estimate the elasticity for four other samples, including a sample with all households with at least one paid worker, and a sample that excludes all households with a retired or unemployed member (following Nässén and Larsson 2015).

Table 1 presents the sample means for our key variables. The consumption basket of the mean U.S. household generates 27.9 metric tons of CO_2 each year, including both direct and indirect (or embodied) emissions. Equivalently, the average person in our analysis emits 11.5 metric tons of CO_2, when we exclude emissions attributed to local, state, and federal government. The mean household has 2.9 members, 1.7 of whom worked for pay at some point in the previous 12 months. The average worker in our sample works 1976 hours a year, or about 40.6 hours a week for 48 weeks a year.[3] Together, workers in the mean household devote 3252 hours a year to paid work. The mean households' members are paid the equivalent of approximately \$24 an hour.[4] The mean reference person is 47 years old.

Table 2 reports our sample means when we stratify the sample by households' annual work hours. The third column shows that households that work 5000 hours annually generate nearly twice the emissions of households that work 1000–2000 hours annually; however, this largely reflects the fact that households with longer hours have more members and more workers. Per capita CO_2 emissions vary little by household work hours, because households with long work hours tend to be larger households. Households with members that collectively work less than 1000 hours a year tend to earn *much* higher (hourly) wages than other households in our sample. These households may include self-employed professionals, who are unlikely to be impacted by work time reduction policies, and we exclude this 7 per cent of observations from our central analysis.

4. Results

Estimates of the parameters of Equation (1) are presented in Table 3, which also shows how we build our battery of control variables. Column (1) shows that, without any control variables, the elasticity of household CO_2 emissions with respect to its

[3]Note that a 2000 hours work year is equivalent to a 40 hours workweek for 50 weeks a year (2 weeks of vacation is standard in the U.S.). Our estimates of weekly hours worked are consistent with the U.S. Current Population Survey (CPS). According to the CPS, in 2013 weekly hours worked in the United States were 38.6 hours, or 42.6 hours when restricted to persons who usually work at least 35 hours or more per week (CPS 2013).

[4]Some employees are paid salaries rather than an hourly wage.

Table 2. Variable means by households' annual work hours.

Hh annual work hours	Hh. CO_2 emissions (in kg)	P.c. CO_2 emissions	Hh. size	Hh. workers	Hh. annual work hrs.	Avg. annual work hrs.	Avg. hourly wage	Age of reference person
1000–2000	20,850	11,453	2.2	1.1	1528	1418	19.3	49.6
2000–3000	23,710	11,829	2.5	1.2	2292	2012	25.1	46.9
3000–4000	30,981	11,480	3.1	1.9	3468	1980	24.1	45.9
4000–5000	32,077	11,423	3.1	2.1	4362	2122	22.7	44.8
5000 or more	38,262	11,174	4.0	3.0	6379	2229	20.2	47.4

Note: This table provides weighted means using the CEX's survey weights, so the mean for 1000 or more annual work hours differ slightly from Table 1. Note our baseline analysis excludes the 7 per cent of households with members who collectively work fewer than 1000 total work hours.

Table 3. Determinants of household CO_2 emissions.

	(1)	(2)	(3)	(4)	(5)
ln(Hh. hours)	0.484***	0.321***	0.253***	0.266***	0.269***
	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)
ln(Hourly wage)	0.251***	0.213***	0.209***	0.205***	0.206***
	(0.012)	(0.012)	(0.011)	(0.011)	(0.011)
Hh. Controls		Hh. size	Hh. type	Hh. type	Hh. type
Age controls				Age(^2)	Cohort FE
Urban density FE		Y	Y	Y	Y
Gender FE		Y	Y	Y	Y
Race FE		Y	Y	Y	Y
Education FE		Y	Y	Y	Y
Observations	5926	5926	5926	5926	5926
R-squared	0.286	0.417	0.448	0.455	0.455

Note: Results from weighted OLS regressions using the CEX's survey weights.
Standard errors in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

members' total work hours is 0.48, so that a 1 per cent increase in work hours is associated with about a 0.5 per cent increase in emissions. Like other empirical studies, we find that longer work hours are correlated with larger carbon footprints, which suggests worktime reduction policies would reduce emissions. Our estimate of the elasticity falls to 0.32 in column (2), where we control for household size and include dummy variables for urban density and the reference person's gender, race and ethnicity, and education. Although we do not report the estimates for all control variables, we do find that households' carbon footprints are significantly higher for households with more members, households that live in rural and suburban areas, and households whose reference person has completed a higher level of education. In column (3) we replace our linear measure of household size with six household-type dummy variables for different combinations of adults and children, which decreases our estimate of the work-hours elasticity of carbon emissions to about 0.25. Column (4) controls for the reference person's age and age-squared, which has little effect on our results. Finally, column (5) replaces the quadratic age terms with cohort fixed-effects, which allow for households' emissions to vary with the reference persons age (i.e., they are in their 20s, 30s, 40s, etc.), and this specification represents our fully specified model. The final two columns suggest that emissions increase significantly with age, everything else equal. However, expanding the battery of controls does not have much impact on our estimate of the elasticity between CO_2 emissions and work hours, which is consistently about 0.3.

Our estimate of the work hours elasticity of emissions across U.S. households is much smaller than most cross-country estimates, as well as Fitzgerald, Schor, and Jorgenson's (2018) state-level estimate and Nässén and Larsson's (2015) household-level estimate. However, our estimate is consistent with the established finding that poor households' consumption baskets are more carbon intensive than those of rich households (Kerkhof, Nonhebal, and Moll 2009; Shammin and Bullard 2009).[5] For the carbon intensity of consumption to fall with expenditures, the expenditure elasticity of emissions must be less than one, and the income elasticity of emissions will be even lower if households smooth consumption over time. Our data confirms this. When we regress log household CO_2 emissions on log household expenditures with our full battery of controls (but without wages and work hours) we arrive at an expenditure elasticity of 0.82. When we similarly regress log household CO_2 emissions on log household after-tax income we estimate an income elasticity of 0.31, about the same as our elasticity with respect to work hours.

Our analysis provides strong evidence that longer work hours is associated with larger carbon footprints. While our estimate of the work-hours elasticity of emissions is smaller than most prior research, it is quite precise. Our results imply that carbon emissions increase less than proportionately with annual work hours, presumably because household necessities such as transportation and home heating and cooling are particularly carbon intensive. Our estimates provide some evidence that lengthening work hours changes the *composition* as well as the *scale* of consumption baskets. If work hours only influenced emissions by increasing expenditures and expanding the size of the economy, then the work-hours elasticity and the wage elasticity of emissions would be equal. Our estimates in column (5) reveal a work-hours elasticity of 0.27 and a wage elasticity of 0.21, and these estimates are statistically distinguishable. In other words, increasing work hours by 1 per cent appears to have a greater impact on household emissions than increasing wages by 1 per cent, even though both changes raise household income by the same amount. Since our work-hours elasticity is significantly larger than the wage elasticity, it seems that longer work hours not only augment expenditures but also shift expenditures towards more carbon-intensive goods. Thus, we find some evidence that work hours increase emissions through both the scale effect and the compositional effect.

Recall that our preferred specification estimates the work-hours elasticity of carbon emissions for a sample of households in which members collectively work at least 1000 hours a year. It is sensible to focus our analysis on households that are likely to be impacted by work time reduction policies, but the 1000 household work hours cutoff is arbitrary. Table 4 presents our elasticity estimates using 4 other samples with at least one paid worker, positive wages, and information for all our variables. Column (1) includes all households in our data, column (2) excludes households with a retired or unemployed member, column (3) excludes households whose members collectively work less than 500 hours annually, and column (4) excludes households whose members collectively work less than 2000 hours annually. In all cases we find clear evidence that carbon footprints increase with both work hours and wages. The sample in column 4 is probably most representative of households that would be impacted by

[5]The consumption baskets of low-income households tend to be more carbon intensive than those of high-income households, but low-income households still have substantially smaller carbon footprints than high-income households because they have much lower expenditures. This is why, at least in the U.S., a (non-rebated) carbon tax is regressive while a tax-and-dividend scheme that rebates carbon revenues in equal lump-sum payments is progressive.

Table 4. Determinants of household CO_2 emissions in other samples.

Sample	(1) All	(2) No retired or unemployed	(3) Hh. with total hours > 500	(4) Hh. with total hours > 2000
ln(Hh. hours)	0.154***	0.174***	0.232***	0.335***
	(0.010)	(0.013)	(0.014)	(0.019)
ln(Hourly wage)	0.180***	0.191***	0.201***	0.226***
	(0.011)	(0.013)	(0.011)	(0.013)
Hh. controls	Hh. type	Hh. type	Hh. type	Hh. type
Age controls	Cohort FE	Cohort FE	Cohort FE	Cohort FE
Urban density FE	Y	Y	Y	Y
Gender FE	Y	Y	Y	Y
Race FE	Y	Y	Y	Y
Education FE	Y	Y	Y	Y
Observations	6406	5510	6147	5154
R-squared	0.453	0.473	0.461	0.436

Note: Results from weighted OLS regressions using the CEX's survey weights.
Standard errors in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

work time reduction policies. Our results show that for households that work at least 2000 hours annually, the work-hours elasticity of emissions is about 0.34, which is higher than our baseline estimate, 0.27. We also find stronger evidence that work hours increase carbon emissions through both a scale and a compositional effect among households that have at least 2000 annual work hours.

Returning to our original sample, comprised of households in which members collectively work at least 1000 hours a year, we test whether the work-hours elasticity of carbon emissions varies with households' work hours. We do this by estimating Equation (2), which interacts both households' work hours and households' average wage with households' total hours in order to determine if these elasticities vary substantially with total work hours.

$$\begin{aligned}\ln(\text{hh. CO}_{2i}) =& \beta_1 \ln(\text{hh. work hours}_i) \\ &+ \beta_2 \ln(\text{hourly wage}_i) + \beta_3 \ln(\text{hh. work hours}_i) * \ln(\text{hh. work hours}_i) \quad (2) \\ &+ \beta_4 \ln(\text{hourly wage}_i) * \ln(\text{hh. work hours}_i) + \beta_5 X_i + \varepsilon_i\end{aligned}$$

where all terms carry from Equation (1). Figure 1 presents the average elasticity estimates and their 95 per cent confidence intervals for households with log work hours that vary from 7 to 9 (or work hours that vary from approximately 1000–8000 a year). As in Table 4, we find that the work-hours elasticity of carbon emissions is lower for households with short work hours than it is for households with long work hours. Moreover, the gap between the work-hours elasticity and the wage elasticity also increases with work hours. Consistent with Table 4, Figure 1 suggests that the compositional effect of work hours on emissions is larger for households working the longest hours.

5. Robustness

Our results show that U.S. households' carbon footprints increase steadily with work hours. We estimate a work-hours elasticity of carbon emissions of about 0.3 across a variety of specifications. Our paper also suggests that work hours may increase carbon emissions through both a scale effect and a compositional effect, and that the compositional effect is largest for households with long work hours. In this section, we

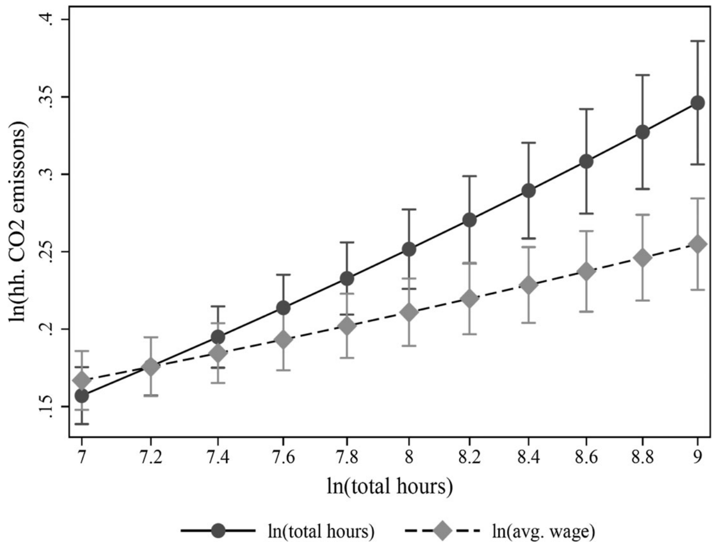

Figure 1. Work hours elasticity and wage elasticity of carbon emissions.

examine the robustness of these results by allowing our elasticities to vary across household types and by decomposing household work hours by the number of workers and workers' average work hours.

5.1. Elasticity by Household Type

One challenge in estimating the elasticity between carbon emissions and work hours using household-level data is that we do not observe how households share the burdens and rewards of paid and unpaid work. Our specification in Equation (1) uses the household as the unit of analysis to estimate its carbon footprints as a function of the total hours of all members' paid work and their average wage (weighted by the number of hours each member works). Throughout our analysis, we control for dynamics within households by including variables for household size, household composition, and the age of the reference person. However, it is still possible that our elasticity estimates vary significantly across different household types.

In Table 5, we present estimates for the elasticities of interest when our sample is stratified by household type. Column (1) presents results for households with one adult and no children, column (2) presents results for one adult and at least one child, etc. In general, we find that households' CO_2 emissions increase with their work hours and that the work hours elasticity of carbon emissions is larger than the wage elasticity. However, column (2) shows that this does not appear to hold for single parents, although we observe only 177 households with just one adult and at least one child. Columns (4) and (6) show that the work-hour elasticity and the wage elasticity are only statistically distinguishable from each other in households with at least 2 adults and at least 1 child. Long work hours seem to especially increase emissions in single-person households and households with two adults and children. Overall, the results in Table 6 suggests that our estimate of the work-hours elasticity of carbon emissions is robust to unobservable intra-household dynamics.

Table 5. Determinants of household CO_2 emissions by household type.

	(1)	(2)	(3)	(4)	(5)	(6)
Number adults	1	1	2	2	≥3	≥3
Number children	0	≥1	0	≥1	0	≥1
ln(Hh. hours)	0.322***	0.194	0.215***	0.364***	0.248***	0.271***
	(0.063)	(0.144)	(0.028)	(0.034)	(0.033)	(0.035)
ln(Hourly wage)	0.264***	0.240***	0.184***	0.210***	0.242***	0.155***
	(0.027)	(0.076)	(0.019)	(0.021)	(0.027)	(0.030)
Age controls	Cohort FE	Cohort FE	Cohort FE	Cohort FE	Cohort FE	Cohort FE
Urban density FE	Y	Y	Y	Y	Y	Y
Gender FE	Y	Y	Y	Y	Y	Y
Race FE	Y	Y	Y	Y	Y	Y
Education FE	Y	Y	Y	Y	Y	Y
Observations	1064	177	1735	1312	953	685
R-squared	0.287	0.407	0.342	0.366	0.358	0.355

Note: Results from weighted OLS regressions using the CEX's survey weights.
Standard errors in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

5.2. Decomposition of Household Work Hours

The model specified by Equation (1) simply regresses household *i*'s CO_2 emissions on its total annual work hours and its average wage. One can also decompose households' work hours into the number of workers in a household and the average hours per worker. This method makes it possible to estimate the impact of an increase in a household's annual work hours along both the *extensive* and *intensive* margins.

$$\begin{aligned} \ln(\text{hh. } CO_{2i}) =& \beta_1 \ln(\text{hh. workers}_i) + \beta_2 \ln(\text{average work hours}_i) \\ &+ \beta_3 \ln(\text{average hourly wage}_i) + \beta_3 X_i + \varepsilon_i \end{aligned} \tag{3}$$

Equation (3) provides a household-level analog to country-level or state-level models that estimate CO_2 emissions as a function of labor force participation rates, average work hours per worker, and hourly wages. Published research provides little guidance on whether the work-hours elasticity of carbon emissions is larger along the extensive or intensive margin. For example, Knight, Rosa, and Schor (2013) suggest the elasticity of emissions with respect to the labor force participation rate is greater than the elasticity with respect to average work hours, whereas Fitzgerald, Jorgenson, and Clark (2015) find that it is much lower (actually negative).

Our results, presented in Table 6, suggest that households' carbon footprints increase slightly more with the number of workers than their average annual work hours. Meanwhile, in this specification we find no statistically significant difference between our elasticities of carbon emissions with respect to average hours or average wages. This result suggests that the compositional effect highlighted above is driven primarily by increasing the number of household workers rather than increasing workers' average hours. In other words, controlling for households' average work hours, it appears that households with two or more earners purchase more carbon-intensive consumption baskets than households with one earner. This may also explain why we find a higher work-hours elasticity of emissions for households with two adults and at least one child in column (4) of Table 5. Theory provides little guidance on whether households with more workers would have smaller or larger carbon footprints, everything else equal. On the one hand, households with multiple workers may endure longer commutes to and from work. On the other hand, households in which all member

Table 6. Determinants of household CO_2 emissions, decomposing total hours.

	(1)
ln(Hh. workers)	0.292***
	(0.018)
ln(Avg. work hours)	0.232***
	(0.021)
ln(Avg. hourly wage)	0.207***
	(0.011)
Hh. controls	Hh. type
Age controls	Cohort FE
Urban density FE	Y
Gender FE	Y
Race and ethnic FE	Y
Education FE	Y
Observations	5926
R-squared	0.459

Note: Results from weighted OLS regressions using the CEX's survey weights. Standard errors in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

go to work (or school) may avoid heating and cooling their homes as aggressively. Our estimates in Table 6 suggests that the former effect may outweigh the latter.

The robustness checks illustrated in Tables 5 and 6 provide additional evidence to support our findings that carbon footprints increase with household work hours. However, we only find statistically significant evidence that works hours increase emissions through a compositional effect for households with multiple adults and children. When we decompose households' work hours into the number of workers in a household and the average work hours per household worker, it seems that the compositional effect is driven primarily by increases in the number of workers. Nevertheless, our central finding appears to be quite robust. Across a variety of samples and specifications, we find that the work-hours elasticity of carbon emissions is approximately 0.3. We consider the implications of our findings in the following section.

6. Discussion

This is the first study to analyze U.S. household data to investigate the relationship between work hours and carbon emissions. Our results indicate that Americans who work longer hours also emit significantly more CO_2 so that work time reduction policies can play a role in abating CO_2 emissions. Our analysis suggests that the work-hours elasticity of carbon emissions in the U.S. is about 0.3. We also find some evidence that work hours increase emissions through both a scale and a compositional effect. That is, long work hours may not only increase household expenditures, but also shift expenditures to more carbon-intensive goods and services.

Our results differ markedly from Nässén and Larsson's (2015) study of Swedish households, which reports a work-hours elasticity of carbon emissions of about 0.8. An advantage of our study is that we observe work hours and expenditures—and hence carbon footprints—for a large sample of households in a single survey. The discrepancy between our estimates and Nässén and Larsson's (2015) estimates may reflect important differences in the determinants of carbon footprints in the U.S. and Sweden. The results presented in this paper appear to be consistent with other studies of how household carbon footprints in the U.S. vary with household income or expenditures (Shammin and Bullard 2009; Fremstad, Underwood, and Zahran 2018). The most carbon-intensive goods are necessities like gasoline and electricity. Households with higher incomes and greater expenditures have larger carbon footprints, but their marginal dollar is less carbon-intensive than that of households with lower incomes. As a result, we would expect policies that reduce work hours and expenditures by 1 per cent to reduce emissions by substantially less than that.

Our results diverge from most analyses of country-level and state-level data, which generally estimate a work-hours elasticity of carbon emissions between 0.5 and 1.0. We see two explanations for our disagreement. First, cross-country studies ignore other policy determinants of CO_2 emissions. The difference between our household-level estimates and many country-level estimates may reflect that countries that internalize positional externalities by limiting work hours also tend to internalize carbon externalities by putting a price on fossil fuels, mandating aggressive energy efficiency standards, and investing in mass transit. Omitting these policies from a regression analysis may upwardly bias country-level estimates. For example, in the introduction we note that Germans work 23 per cent shorter hours and emit 46 per cent less carbon relative to their American counterparts. These two data points imply a work-hours elasticity of emissions of about 2, but this simplistic calculation ignores the role that German environmental policies play in achieving low per capita CO_2 emissions. Similar problems may plague larger cross-country studies, particularly cross-sectional analyses. Our results are very similar to Fitzgerald, Jorgenson, and Clark's (2015) study, which estimates the work-hours elasticity of energy use to be about 0.3 using country-level data in a model with both country and year fixed effects. Since Fitzgerald, Jorgenson, and Clark (2015) identify the elasticity based on *changes* in work hours *within* countries, it may avoid most of the problems of omitted variable bias. Of course, difference-in-difference studies may still overestimate the work-hours elasticity of carbon emissions if governments that adopt work-time-reduction policies also tend to adopt emissions reduction policies at the same time. Our elasticity estimate is markedly lower than estimates from some other fixed-effect analyses using country-level data (Knight, Rosa, and Schor 2013) and state-level data (Fitzgerald, Schor, and Jorgenson 2018).

Second, the difference between our results and country-level estimates of the work-hours elasticity of carbon emissions may reflect that countries are better than households at reducing emissions by shortening work hours. In other words, countries may 'downshift' (Schor 1999) more easily than individuals. Alesina, Glaeser, and Sacerdote (2005) hypothesize that a social multiplier could explain the substantial difference in estimates in the elasticities of labor supply *within* and *between* countries. A similar mechanism may explain the divergence between our household-level estimate and most country-level estimates of the work-hours elasticity of carbon emissions. The best opportunities for cutting CO_2 emissions probably come from collective projects, such as developing dense urban areas with efficient mass transit. It is possible that these projects are more effective in countries with shorter work hours, or that people living in countries with shorter work hours are more likely to support—or demand—serious policies to address climate change. Indeed, some research finds that leisure can promote pro-environmental preferences (Chai et al. 2015), although other research disputes this finding (Melo et al. 2018).

In the absence of a social multiplier, back-of-the-envelope calculations using our results suggest that work-time reduction policies in the U.S. would modestly reduce CO_2 emissions. If the work-hours elasticity of emissions is about 0.3, then reducing the annual work hours in the U.S. to German levels would cut U.S. CO_2 emissions by approximately 7 per cent. This would close the gap between per capita carbon footprints in the U.S. and Germany by about a sixth. Alternatively, a plan to reduce work hours in the U.S. by 0.5 per cent annually over the course of the twenty-first century—and ultimately cut work hours by 34 per cent—would abate CO_2 emissions by about 10 per cent. Carbon emission reductions of this magnitude would be very welcome, but other policies will be necessary for the U.S. do its fair share in addressing climate change.

Our study has several limitations and offers opportunities for future research. We estimate the work-hours elasticity of carbon emissions using *all* household-level variation in work hours and carbon footprints, but it may be possible to focus *exclusively* on variation in work hours that results from exogenous changes in policy. Our analysis also fails to address *why* households with shorter work hours tend to have smaller carbon footprints, which could be addressed using a decomposition methodology similar to Underwood and Fremstad (2018). This paper uses the household as the unit of analysis and 'household work hours' as the key independent variable. While this greatly simplifies the analysis, it also prevents us from studying whether carbon footprints depend on how wage work is shared among household members. Finally, The CEX does not ask how many days a week people work, so we cannot distinguish between variation in hours per day and variation in days per week. This makes it impossible to test whether different policies to reduce work time (shortening the workday or adopting a 3-day weekend, for example) have different effects on carbon emissions, as explored in King and van den Bergh (2017). We hope future research will address these shortcomings.

Although our results suggest that work hour reductions alone would have a limited impact on U.S. carbon emissions, there remains a strong case for shorter work hours. Reducing work hours still provides both social and environmental benefits, even if its effect on carbon emissions falls far short of the abatement necessary to address climate change. Besides internalizing social and environmental externalities, shorter work hours may also push the economy towards full employment (Zwickl, Disslbacher, and Stagl 2016). During the Great Recession, Germany used work-time reduction policies to lower unemployment numbers despite experiencing a more severe recession than the U.S. (Boeri and Bruecker 2011; Herzog-Stein, Lindner, and Sturn 2018). Although official unemployment rates in the U.S. are now low by historical standards, uncertainty about the future of work continues to spark interest in policies to shorten hours of work (Coote 2015).

7. Conclusion

Our analysis presents robust evidence that households with longer work hours also have significantly larger carbon footprints. We estimate the work-hours elasticity of carbon emissions to be about 0.3, which suggests that differences in annual work hours account for a small fraction of the difference between average carbon footprints in the U.S. and Germany. Our results suggest that work-time reduction policies would play a relatively minor role in helping the U.S. to meet its international climate obligations.

Nevertheless, policies to shorten work hours have the potential to reduce emissions while simultaneously limiting the social externalities created by overwork.

Disclosure Statement

No potential conflict of interest was reported by the authors.

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