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# The Environmental Impact of Sharing: Household and Urban Economies in CO2 Emissions

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## Abstract

Studies find that per capita carbon dioxide ($CO_2$) emissions decrease with household size and urban density. The demographic trends of declining household size and dense urbanization therefore produce countervailing effects with respect to emissions. We posit that both household and urban economies are driven by proximity and realized through sharing carbon-intensive goods. With detailed data from the United States Consumer Expenditure Survey, we construct a dataset of $CO_2$ emissions at the household level and leverage a unique measure of residential density to estimate household and urban economies. Our estimates show that dense urban areas have per capita emissions roughly 20 percent lower than rural areas, and that adding an additional member to a household reduces per capita emissions by about 6 percent. We also find that household economies are about twice as large in rural areas as in dense urban areas and develop an explanation for this phenomenon. In theory, the carbon benefits of dense urbanization have the potential to offset the effects of declining household size. However, using historical US Census data and extrapolating from our estimates, we find that lost household economies have outpaced increased urban economies over the past fifty years.

**Highlights**

- Household economies and urban economies in $CO_2$ emissions are significant.
- Both households and cities facilitate the sharing of carbon-intensive goods.
- Household economies are larger in rural areas than in urban areas.
- Shrinking households have offset emission reductions from urbanization.

**JEL Codes**: D1, Q5, R2, R3
**Keywords**: emissions; household size; urban density; sharing; energy

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## 1. Introduction

Studies frequently find that per capita carbon dioxide ($CO_2$) emissions are lower for people who live in multi-person households as well as for people who live in dense urban environments. We refer to these stylized facts as *household economies* and *urban economies* in $CO_2$ emissions. The former are analogous to economies of scale in production. If per capita income is held constant, then households exhibit economies of scale when increases in household size raise their members' utility. Empirical research finds that, holding per capita income constant, subjective well-being increases with household size (Rojas, 2007). Indeed, these economies of scale are taken for granted whenever equivalence scales are used to assign each household a value proportional to its needs based on its size and composition.[1] Economists attribute household economies to the existence of household public goods that are relatively non-rival in consumption. For example, housing, furniture, and appliances are shared by many household members. Consistent with this, analysis of the Consumer Expenditure Survey (CES) shows that households with more members tend to spend a smaller percentage of their income on household public goods (Salcedo et al., 2012).[2]

Recently, researchers have recognized that carbon-intensive goods tend to be household public goods. For example, residential energy and transportation are easily shared within households. Schroder et al. (2015) show that larger households tend to spend less on energy per person. Using expenditure data to calculate household carbon footprints, Underwood and Zahran (2015) find that per capita carbon dioxide ($CO_2$) emissions also decline with household size. These household economies in $CO_2$ emissions suggest that the trend towards smaller household size undermines the sharing of carbon-intensive goods within households, placing upward pressure on per capita emissions, and that people can reduce emissions by living together in large households (Ala-Mantila, Heinonen, and Junnila (2014), Schroder et al., 2015; Underwood & Zahran, 2015).

Compared to household economies, urban economies in $CO_2$ emissions are widely studied but the empirical results are mixed. Many researchers have shown that national greenhouse gas emissions increase with the share of population living in urban areas (Jorgenson et al., 2014; Ponce de Leon Barido & Marshall, 2014), but this positive effect may depend on the level of affluence and stringency of environmental policy (Martinez-Zarzoso & Maruotti, 2011; Poumanyvong & Kaneko, 2010). Meanwhile, micro-level studies show that households in dense urban environments generate significantly lower $CO_2$ emissions than their

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[1] The Organization for Economic Cooperation and Development (OECD) has used an equivalence scale that implies each additional adult needs 70% of that of a single adult, while each child needs only 50% of a single adult (OECD, 2013). More recently, both the OECD and the United States Census Bureau have used the so-called 'square-root scale' that implies, for instance, that a household of four persons has needs twice as large as one composed of a single person but does not distinguish between adults and children. The US poverty threshold assumes that additional household members (adults and children) need just 35% as much income as an adult living alone (US Department of Health and Human Services 2016).

[2] However, empirical analyses of household expenditures are not always easy to reconcile with intuition. For example, Deaton and Paxson (1998) show that per capita expenditures on food decline with household size, even though food appears to be a private good.

rural counterparts (Glaeser and Kahn, 2010; Jones and Kammen, 2011; Shammin et al. 2010). However, not all urban forms have environmental benefits. Suburban households generally have higher emissions than both rural households and dense urban households (Jones and Kammen, 2014; Glaeser and Kahn, 2010; Ottelin et al., 2015). The mixed evidence for urban economies may arise from urbanization being a weak proxy for urban density.[3] Urbanization, a rising share of the population living in urban areas, does not itself guarantee the presence of urban economies, as it often reflects industrialization, suburbanization, and sprawl.

In this paper, we argue that cities generate urban economies by providing social and technological infrastructure that facilitates sharing. In other words, urban density reduces emissions by enabling the sharing of carbon-intensive goods *between* households, analogous to the sharing of goods *within* multi-person households. Both dense urban environments and large households reduce the share of carbon-intensive expenditures, driving per capita $CO_2$ emissions downward. As Glaeser and Kahn (2004) suggest, cities can be conceptualized as the absence of physical space between people. So, too, can large households. In multi-person households, members *successively* and *simultaneously* share the household and its energy requirements (Yates, 2016). Using the same kitchen and living room means that this space is used relatively more intensively. Sharing meals, television viewing, loads of laundry, and heating and cooling allows households to reduce per capita consumption of carbon intensive goods and services (Underwood and Zahran, 2015; Yates, 2016). Like households, cities enable individuals to *successively* and *simultaneously* share the built environment and its energy requirements. For example, dense housing allows households to share home heating and cooling via shared walls. Similarly, urban infrastructure, such as sidewalks, bike lanes, and public transportation, provide city dwellers with alternatives to travelling in private vehicles. Dense urban environments may also foster the inter-household sharing of private goods. Decentralized borrowing and lending of goods may become an increasingly important in the digital economy (Fremstad, 2016), and sharing-economy platforms tend to be most successful in cities where they can better match people with underutilized assets due to improved access (Yates, 2016).

Several studies have investigated the potential for significant rebound effects associated with the environmental benefits of dense urban areas. Agglomeration economies in dense urban areas generate wealth and yield savings that can be spent on other goods and services (Glaeser and Gottlieb, 2009; Heinonen et al., 2013a, 2013b; Wiedenhofer, Lenzen, and Steinberger, 2013). It is possible that the emissions resulting from these expenditures will exceed the initial energy savings from urban density. For instance, Heinonen et al. (2013a) find that household expenditures and carbon emissions are highest in the Helsinski metropolitan area of Finland, compared to other cities, semi-urban, and rural areas. This is consistent with other studies showing that even when urban density yields lower private vehicle use and residential energy consumption, residents of large metropolitan areas (including suburbs) generate higher emissions than those in less dense areas (Jones and Kammen, 2014). In fact, Ottelin, Heinonen, and Junnila (2014) find that emissions from air travel significantly offset the gains from reduced private transport in urban areas, especially among middle-income families in large metropolitan areas. Heinonen et al. (2013a)

[3] Liddle (2013), for instance, finds that the correlation between national population density and urban density is relatively low (0.35) and that national urbanization levels are actually negatively correlated with urban density.

also show that the prevalence of summer cottages and second homes increases with urban density, in the case of the Helsinki metropolitan area. When controlling for differences in income, Heinonen et al. (2013b) find that per capita carbon footprints still fall with urban density, but only slightly. Importantly, this result is driven, in part, by smaller household sizes in dense urban areas and suggests that rebound effects do not entirely offset the initial urban economies. Since the savings from reduced expenditures on residential energy and private transport are likely to be spent on less carbon-intensive goods and services, this is the expected result (Underwood and Zahran, 2015; Wiedenhofer, Lenzen, and Steinberger, 2013). Nonetheless, these rebound effects and "concurrent consumption of service spaces in different locations" are important considerations (Heinonen et al., 2013a).

In this paper, we address the environmental benefits of sharing carbon-intensive goods by estimating household economies and urban economies in a single model, net of any rebound effects. Our work builds on Ala-Mantila, Heinonen, and Junnila (2014) which documents both household economies and urban economies in $CO_2$ emissions in and around Helsinki, Finland. Drawing on Ala-Mantila et al. (2016) we also investigate the interaction between these two effects. We move this research forward in three ways. First, we estimate our model using data from the Consumer Expenditure Survey, which provides a nationally representative pooled cross-section of household carbon dioxide emissions in the United States (US) from 2012 to 2014. Second, we develop a conceptual framework to make the case that household economies and urban economies are both the result of a similar mechanism: the sharing of carbon-intensive goods. Importantly, this allows us to develop an explanation as to *why* urban economies may have the potential to substitute for household economies. Third, we use our estimates to quantify the countervailing effects of declining household size and urbanization on US per capita $CO_2$ emissions over the last fifty years. In doing so, our paper sheds light on the extent to which increased urban density is likely to offset the declining household economies resulting from the demographic drift toward more and smaller households.

In the next section, we describe our method of calculating $CO_2$ emissions at the household level and our model for estimating household and urban economies. In Section 3, we present our results and test their robustness to several model specifications. Section 4 discusses the implications of our findings, including what they suggest about the magnitude of the increased urban economies and lost household economies in the US over the last fifty years. In Section 5, we conclude with some limitations to our analysis, suggestions for future research, and policy implications.

## 2. Data and Methods

This paper uses detailed expenditure data to estimate $CO_2$ emissions at the household level. Using data from the US Consumer Expenditure Survey (CES) from 2012-2014 we construct a nationally representative pooled cross-section of American households. The Interview Survey, used here, captures approximately 85-95 percent of household expenditures.[4] Each household can appear in the survey for no more than four

[4] The Interview Survey does not collect expenses for very frequently purchased items such as housekeeping supplies, personal care products, and nonprescription drugs that account for around 5 to 15 percent of expenditures.

consecutive quarters. CES Interview Survey data on household expenditures cover 14 broad categories: food, alcoholic beverages, housing, apparel, transportation, healthcare, entertainment, personal care, reading, education, tobacco products, cash contributions, personal insurance, and miscellaneous. These 14 categories disaggregate into 50 detailed expenditure categories that we match to estimated carbon intensities to determine household $CO_2$ emissions.

We use $CO_2$ intensities for these 50 detailed expenditure categories similar to those in Shammin & Bullard (2009) and Underwood & Zahran (2015), which are based on an economic input–output life cycle assessment (EIOLCA) model developed by Hendrickson et al. (2006) and presented in Table A.1 of the Appendix. These $CO_2$ intensities are adjusted to account for the carbon content of fuel[5] and updated to reflect current prices and energy intensities using US city-average product-specific consumer price indices where available[6], and the economy-wide reduction in energy intensity (as measured by BTU per dollar of real GDP) from 2003-2013 of 14 percent (EIA, 2017). We calculate total household $CO_2$ emissions by first determining the emissions resulting from expenditures on each of the 50 detailed categories by multiplying reported quarterly expenditures in the CES Interview Survey by the associated annual intensity in Table A.1. These disaggregated emissions are then summed over the 50 categories to obtain total quarterly household $CO_2$ emissions for the entire sample. These consumption-based estimates capture both direct and indirect (embodied) emissions associated with household expenditures (Bin & Dowlatabadi, 2005). In Table A1 we categorize these emissions somewhat differently than the CES to highlight the three primary components of household emissions: *residential energy*, *transportation,* and *food and beverages*, which together constitute 80 percent of household emissions.

Mean annualized household expenditures and emissions as well as expenditure and emissions shares are summarized in Table 1. Residential energy and gasoline account for only 11 percent of total expenditures, on average, but comprise two-thirds of total annual household $CO_2$ emissions. We estimate that the typical household in the United States emitted 32.2 metric tons annually (or 15.2 metric tons per capita) over the period 2012-2014, as shown in Table 2. As with most other consumption-based estimates, our estimates ignore government expenditures and assume that foreign and domestic goods have the same carbon content, so they are unlikely to match production-based estimates, such as the United Nations (16.7 metric tons in 2012) and the US Department of Energy (16.1 metric tons in 2013) (Boden et al., 2016; United Nations, 2016). Approximately one quarter of emissions generated to meet U.S. demand occur abroad, and since the imported share is produced using less efficient technology, this can lead to an underestimation of household emissions by up to 15% (Hertwich & Peters, 2009; Weber & Matthews, 2008). Additionally, government expenditures account for about 10% of national carbon footprints globally

[5] This adjustment, not implemented in Underwood & Zahran (2015), accounts for the differences in the carbon intensities of natural gas, gasoline, and heating fuel. The EIOLCA model captures all emissions associated with the extraction, refining, and distribution of these fuels, but does not account for the emissions released when these fuels are burned by the final consumer.

[6] For expenditure categories where product specific indices were unavailable the "all items" CPI was used. These include mortgage interest; property taxes; life and personal insurance, retirement, pensions, and Social Security; health insurance (product-specific pricing only available from 2006); and miscellaneous.

(Hertwich, 2011). With these limitations in mind, our estimate of 32 metric tons is generally in line with other recent consumption-based estimates of household emissions (Weber & Matthews, 2008; Jones & Kammen, 2014).

[Insert Table 1]

The spatial clarity provided by the CES is imprecise, largely due to its sample design, which focuses on Metropolitan Statistical Areas (MSAs) as the geographical basis for sample selection. While this method yields a nationally representative sample, the coding of the urban population is imperfect.[7] We combine information on the type of housing structure, the number of units in the structure, and the urban/rural designation in the CES to construct a novel measure of residential density. We split households into four categories: (1) rural households, comprised of rural households in single-family detached homes or mobile homes; (2) suburban households, comprised of urban households in single-family detached homes or mobile homes; (3) semi-detached urban households, comprised of urban households in multi-family structures with at least one shared wall and no more than four floors; and (4) dense urban households, comprised of urban households in row/townhouse inner units, high-rise apartments, or other apartment buildings. This method enables the classification of all but four percent of observations, yielding a sample of 72,608 quarterly observations from 28,444 unique households (consumer units).[8] The socioeconomic characteristics of the households in each density category are summarized in Table 2. As expected, households in suburban areas tend to be older, wealthier, and larger than households in dense urban areas, while rural households have incomes similar to urban households but are considerably larger.

[Insert Table 2]

We estimate the magnitude of household and urban economies in $CO_2$ emissions using a linearized STIRPAT model, in which technology and population are held constant (Liddle, 2015; York, Rosa, and Dietz, 2003). Our model assumes that a household's $CO_2$ emissions per capita are a function of per capita expenditures, but also allows them to vary with household composition and urban form. We allow for the possibility that children and adults have different effects on per capita $CO_2$ emissions, because evidence suggests that emission levels depend on age (Lugauer, Jensen, and Sadler, 2014; Zagheni, 2011). This paper

[7] According to the BLS, urban population is defined as all persons living in an MSA and in urbanized areas and urban places of 2,500 or more persons outside of MSAs. Thus, urban, defined in the CES, includes the rural populations within MSAs.

[8] Practically speaking, a consumer unit can be considered a household; however, technically it is defined by the BLS as: (1) all members of a particular household who are related by blood, marriage, adoption, or other legal arrangements; (2) a person living alone or sharing a household with others or living as a roomer in a private home or lodging house or in permanent living quarters in a hotel or motel, but who is financially independent; or (3) two or more persons living together who use their income to make joint expenditures.

uses household expenditures rather than income as its measure of affluence, because expenditures provide a better measure of a household's permanent income (Mathur and Morris, 2014). Our basic model is:

$$\ln(hh\ CO_2\ emission\ per\ capita)_{it} = \beta_0 + \beta_1 \ln(pc\ expenditures)_{it} + \beta_2 adults_{it} + \beta_3 children_{it} + \beta_4 suburban_{it} + \beta_5 semidetached\ urban_{it} + \beta_6 dense\ urban_{it} + [\beta X_{it}] + \varepsilon_{it} \quad (1)$$

where $i$ denotes each household and $t$ denotes each quarter. Note that our estimates of household and urban economies are net of any rebound effect, since any savings from sharing will generally be spent on other goods. We estimate this model using population weights for all 72,608 households-quarter observations with standard errors clustered at the household level. The vector $X_{it}$ includes all our control variables, including year fixed effects. If people do *not* share carbon-intensive goods like home heating and cooling or transportation *within* or *between* households, then our estimates of $\beta_2$ through $\beta_6$ will be equal to zero. However, if there are household economies or urban economies in $CO_2$ emissions, then these coefficients will be negative. Since we estimate these parameters simultaneously, we can compare the relative size of these coefficients to net the countervailing effects of declining household size and dense urbanization in the United States.

## 3. Results

Table 3 presents our baseline results. Column (1) simply regresses emissions per capita on expenditures per capita. We find that a 10 percent increase in household expenditures per capita is associated with a 7.2 percent increase in per capita emissions. This model ignores the possibility of sharing goods that generate emissions within households and between households. Column (2) includes the number of adults and children in the household to estimate the effect of intra-household sharing on emissions. Consistent with Underwood and Zahran (2015), results indicate that adding an additional adult to a household while maintaining the same per capita expenditures reduces per capita emissions by about 1.6 percent, while adding a child reduces per capita emissions by 6.4 percent.[9]

[Insert Table 3]

We estimate urban economies by including indicator variables for suburban, semi-detached urban, and dense urban households. Compared to rural households, Column (3) reports a small environmental benefit to living in a suburban setting but substantial benefits to living in urban environments. Living closer to neighbors presumably reduces emissions, because shared walls reduce heating and cooling costs and urban density reduces carbon-intensive forms of transportation. Controlling for this local measure of residential density also increases our estimate of household economies of scale in $CO_2$ emissions, with an additional adult or child now reducing per capita emissions by 4.7 or 7.1 percent, respectively. Our finding

[9] Using the standard formula for computing the exact percentage change, $= 100 \times (e^{\beta} - 1)$.

that carbon-intensive goods are more easily shared with children than with adults is consistent with the OECD equivalence scale, which assumes kids need fewer resources than adults.

Since our estimates of household emissions are expenditure-derived, one potential confounding factor is that many renters do not directly pay for energy because utilities are included in rental agreements. Households that have utilities included in rent may report zero expenditures on natural gas, electricity, or heating oil when in fact they are still consuming these goods (Levinson and Niemann, 2004). In our sample, 37 percent of households are renters, of which 53 percent live in dense urban areas. Moreover, 30 percent of renters report that natural gas, electricity, or heat is included in their rent. Instead of imputing the energy expenditures embedded in rental payments like Glaeser & Kahn (2010), we add a set of renter controls. Column (4) includes indicator variables for whether a household is a renter and whether specific utilities are included in rent. The environmental benefit of living in an urban setting remains substantial, but the effect is reduced by a one-third compared with the results in Column (3), which confirms that ignoring these embedded utility payments yields an overestimation of urban economies.[10] We find similar urban economies to those reported in Column (4) when we estimate the effect separately for renters and non-renters. To maintain the largest possible sample, we keep these rental controls in all subsequent analysis.

Table (4) tests the robustness of our baseline results. Previous research suggests there are substantial differences in both total emissions and suburb-city differences in emissions across different regions and metropolitan areas (Glaeser and Kahn, 2010; Jones and Kammen, 2011; Sovacool and Brown, 2010). We introduce geographical controls to account for any bias introduced by this regional heterogeneity in the number of heating and cooling degree-days, the age of the housing stock, transportation infrastructure, and relative prices. Column (1) includes regional fixed effects denoting the four US Census regions (Northeast, Midwest, South, and West) which we can identify for the entire sample. Column (2) includes state fixed effects for the 39 states identified in the CES. Column (3) includes MSA fixed effects, which are only identified for urban households in one of the 21 MSAs with populations greater than 1.5 million people identified in the CES. In Columns (2) and (3) we estimate the effect of living in an urban household relative to living in a suburban household.[11] Given our robust finding that suburban households emit about 5 percent less than rural households, our results in Columns (2) and (3) are consistent with the results in Column (1). The robustness of our results to the inclusion of these different geographical controls suggests that spatial heterogeneity is not generating significant bias in our estimates. In subsequent analyses, we include regional fixed effects to account for regional differences while retaining the largest number of observations. Given the consistency of our estimates in Columns (1) – (3) we see no loss of generality in this specification.

Research also raises the possibility that the correlation between urban form and consumption behavior reflects sorting (Duranton & Turner, 2016). Households and individuals in dense urban areas may

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[10] This reduction in the urban economies suggests that our estimates of household emissions in Table 2 are likely downwardly biased due to inclusion of these utilities in rental agreements.

[11] Although our sample includes 3,371 rural households, none of them are in an MSA, and only 318 of them have a state-level identifier. Since all the rural households with a state identifier are in Kentucky, we drop them from our analysis in Column (2).

be different from those in less dense settings and these differences may explain our results rather than urban form *per se*. Indeed, it is possible that environmentally-conscious individuals self-select to live in more densely populated areas. A similar argument can be made with regards to household size. While environmental concern is not observable, we address the possibility of sorting by controlling for consumer behavior and a range of demographic characteristics. Environmentally-minded individuals may choose to reduce their carbon footprints by forgoing car ownership or living in smaller dwellings. In our sample, 87 percent of households own a vehicle and the average dwelling has 5.9 rooms (excluding bathrooms). As illustrated in Table 2, both vehicle ownership and dwelling size decrease with residential density. Column (4) estimates household and urban economies controlling for vehicle ownership and dwelling size. As we might expect, owning a vehicle is associated with substantially greater emissions, but dwelling size has a small effect on emissions. Conditional on vehicle ownership and number of rooms, we estimate slightly smaller urban economies and slightly larger household economies. These results are consistent with Duranton & Turner (2016), who also find very little difference between their OLS and IV estimates. Sorting does not appear to be driving our estimates of either household or urban economies. Since both vehicle ownership and home size are potentially channels by which household size and urban form affect $CO_2$ emissions, our preferred specification omits these controls. Next, we control for demographic characteristics that are known to be correlated with environmental concern (Franzen and Vogl, 2013). Column (5) reports our results when we control for the gender, race, age, and education of the reference person.[12] Our estimates of household and urban economies are virtually unchanged, suggesting that this demographic heterogeneity is not a source of bias in our model. Our conclusion from Table 4 is that regional heterogeneity and individual sorting cannot explain away our main results.

[Insert Table 4]

Across all models in Table 4, we consistently find strong evidence for both household and urban economies in $CO_2$ emissions. Our point estimates suggest that increasing household size by one person reduces per capita $CO_2$ emissions by about 6 percent (5.4 percent for an adult and 7.2 percent for a child). Moreover, households in dense urban settings have per capita $CO_2$ emissions around 20 percent lower than households in rural settings, while households in less dense (semi-detached) urban settings have per capita $CO_2$ emissions about 14 percent lower, consistent with previous research on the effects of urban density (Brownstone & Golab, 2009; Glaeser & Kahn, 2010; Jones & Kammen, 2011). Our estimates of both household and urban economies in $CO_2$ emissions are also very similar to Ala-Mantila, Heinonen, and Junnila (2014)'s analysis of emissions in and around Helsinki, Finland. This suggests that the environmental benefit of sharing carbon-intensive goods may be quite similar across developed countries, despite substantial differences in climate, infrastructure, and institutions.

We argue that these household and urban economies are generated through sharing carbon-intensive goods, which is facilitated by reductions in space between people. Given our operationalization

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[12] We specifically allow for household per capita emissions to vary with the reference person's: gender, race (with six racial-ethnic categories), age (age and age-squared), and education (with nine education categories).

of residential density that leverages shared walls, sharing serves as a mechanism that drives down per capita emissions in both household and urban economies. Larger households are able to share expenditures on residential energy with other members of the household, shifting expenditures towards less carbon-intensive goods and services and reducing per capita emissions. In much the same fashion that household members share goods, households in dense urban areas are able to share expenditures on residential energy and transportation with other households through shared walls and alternatives to private transport, shifting expenditures towards less carbon-intensive expenditures and reducing per capita emissions. Figure 1 shows how the fraction of household expenditures devoted to residential energy and transportation (including gasoline) varies with both household size and density. Increasing urban density [Figure 1, Panel (a)] reduces both the residential energy and transportation share of expenditures, while increasing household size [Panel (b)] acts to reduce only the share of expenditures on residential energy. Both household economies and urban economies shift consumption towards less carbon-intensive expenditures through sharing. The difference is that cities, through the provision of social and technological infrastructure, can provide opportunities for sharing unavailable to a household.

[Insert Figure 1]

Table 4 shows that relocating a rural household to a dense urban area would reduce per capita emissions by over three times as much as adding an additional adult to the household, holding all other variables constant. This suggests that harnessing urban economies may, in fact, offset the lost household economies associated with declining household size. However, our results in Table 4 implicitly assume that household and urban economies are additive, and that there is no interaction between these two forms of sharing carbon-intensive goods. If these effects are both driven by proximity and realized through sharing, then dense urban areas may, to some extent, act as functional substitutes for large households. In other words, since cities reduce the space between households, they may also erode household economies, as Ala-Mantila et al. (2016) find in Finland. To investigate this possibility, we estimate a model in which household economies are allowed to vary by urban density:

$$\begin{aligned}
\ln(hh\ CO_2\ emission\ per\ capita)_{it} \\
&= \beta_0 + \beta_1 \ln(pc\ expenditures)_{it} + \beta_2 adults_{it} + \beta_3 children_{it} + \beta_4 suburban_{it} \\
&+ \beta_5 semidetached\ urban_{it} + \beta_6 dense\ urban_{it} + \delta_1 (adults \times suburban)_{it} \\
&+ \delta_2 (adults \times semidetached\ urban)_{it} + \delta_3 (adults \times dense\ urban)_{it} \\
&+ \delta_4 (children \times suburban)_{it} + \delta_5 (children \times semidetached\ urban)_{it} \\
&+ \delta_6 (children \times dense\ urban)_{it} + [\beta X_{it}] + \varepsilon_{it}
\end{aligned} \tag{2}$$

where all terms carry from Eq. (1). Consistent with Ala-Mantila et al. (2016), our results in Table 5 show that household economies in rural areas are substantially larger than those in dense urban areas. While adding an adult to a rural household reduces per capita emissions by about 8 percent, adding an adult to a dense urban household reduces them by about 3 percent. We find similar results for children, and the difference in household economies between rural and dense urban households is statistically significant at the 1 percent level. Our estimates of household economies in suburban and semi-detached urban areas also fall neatly between our estimates for rural and dense urban areas, providing evidence that household economies of scale in $CO_2$ emissions depend on urban form.

[Insert Table 5]

We see a simple explanation for why this is the case. Both household and urban economies are driven by proximity and realized through sharing. Household economies are driven mostly by the ability of members to share carbon-intensive goods such as transportation and home heating and cooling (Underwood and Zahran, 2015). In rural and suburban areas, adding an additional person to a household opens up opportunities for households to save energy by carpooling and increasing the number of shared walls. As illustrated in Table 6, an adult living alone in the suburbs generates emissions of 14,543 kg, 38 percent higher than the per capita emissions from a family of six in the suburbs of 10,529 kg. In dense urban areas, these household economies are smaller because cities provide even better ways of sharing transportation and home heating and cooling. According to our estimates, this same adult living alone in a dense urban area would generate per capita emissions only 23 percent higher (11,949 kg) than the family of six in a dense urban area (9,697 kg). Walking, cycling, and mass transit reduce the benefit of intra-household carpooling while apartment buildings and fully-attached row homes reduce the benefit of sharing walls within households. The similar mechanism generating these scale economies means that *between* household sharing is somewhat substitutable for *within* household sharing, as reflected in the one adult/family of six emissions ratio that declines with residential density and the rural/dense urban emissions ratio that declines with household size in the last row and column of Table 6, respectively. Therefore, these results are consistent with the hypothesis that increasing urban density has the potential to offset the upward pressure placed on per capita emissions by declining household size.

[Insert Table 6]

# 4. Discussion

Studies routinely find that $CO_2$ emissions increase with the growth of population and per capita income, according to the STIRPAT model (Liddle, 2015; York, Rosa, and Dietz, 2003), but also that the scale of these effects vary greatly depending on how those populations are organized (Rosa and Deitz, 2012; Underwood and Zahran, 2015). In this paper we argue that household size and urban density, in determining the level of sharing within and between households, are two primary factors in establishing the impact of rising population and affluence. Demographic modernization is generally characterized by declining household size, rising affluence, and urbanization. From 1960 to 2010 the number of households in the United States increased 74 percent faster than population, with mean household size decreasing 29 percent, from 3.3 to 2.6 members (Vespa et al., 2013). Over the same period, the percentage of one-person households doubled, from 13 to 27 percent, and today 35 million adults in the United States live alone. Meanwhile, the percent of the US population living in urban areas grew from under 70 percent in 1960 to over 80 percent in 2010. Small households, including solo-dwellers, tend to cluster in dense urban areas. In New York City over one million people live alone, and in Manhattan nearly 50 percent of all residences are one-person dwellings (Klinenberg, 2012). Over the past 50 years, our results suggest that the shift towards smaller households exacerbated $CO_2$ emissions while the increase in dense urbanization mitigated them. Our estimates of household and urban economies can shed light on which countervailing effect was dominant in the United States.

The US Census provides data on how household size and urban form evolved from 1960 to 2010. We generate a proxy for our residential density variable using Census data on whether a household is located in a metropolitan area, and whether the household is in 1-family structure, a 2-family structure, or a 3-or-more-family structure.[13] The Census data shows that average household size declined by 20 percent over this period and that the largest declines occurred in rural households. Meanwhile the fraction of rural households decreased by about 50 percent and the fraction of dense urban households increased by about 50 percent. Extrapolating from our point estimates in Table 5, we calculate the total effect of these demographic changes on per capita $CO_2$ emissions holding other factors constant. This exercise suggests that, over this period, the lost household economies were nearly three times as large as the new urban economies. Everything else equal, declining household size increased per capita emissions by about 9 percent while dense urbanization decreased per capita emissions by about 3 percent. Going forward, the net effect of these demographic forces will depend on the relative rates of change in urban density and household size. However, if household size continues to fall, dense urbanization will likely need to occur at a faster pace than it has to fully offset the declining household economies in $CO_2$ emissions.

It should be noted that the challenge of reducing per capita $CO_2$ emissions in light of these demographic trends is not uniquely American. The growth in the number of households is outpacing population growth worldwide. Liu (2013) finds that 79 percent of 172 countries had population growth lower than growth in the number of households from 1985 to 2000 and by 2030 the single-person household will the most common household type globally (Jennings et al., 2000). Meanwhile, the global urban population has grown rapidly since 1950, from 746 million to 3.9 billion in 2014, now comprising 54 percent of the world's population, according to the United Nations. Today, 78 percent of the population in developed nations live in urban areas while just 48 percent of developing nations do.[14] By 2050, these figures are projected to be 85 and 63 percent, respectively, meaning the majority of expected population growth over the next few decades will occur in cities of the developing world (United Nations, 2014). In this challenge may come opportunity, where cities of the developing world can avoid the "lock-in of high

[13] This definition is not perfect, and cannot categorize 29 percent of households in 1960, 2 percent in 1980, 3 percent in 1990, and 9 percent in 2010. However, we consistently find recent losses in household economies were 2-3 times as large as the gains in urban economies, regardless of which year we use as our starting point.

[14] As classified by the United Nations. Developed (more-developed) regions include Europe, North America, Australia/New Zealand and Japan, while developing (less developed) regions includes all regions of Africa, Asia (excluding Japan), Latin America and the Caribbean plus Melanesia, Micronesia and Polynesia

carbon emission patterns for travel" that characterize many urban areas of the developed world (Creutzig et al., 2015). Our results suggest that whether or not the combination of these global demographic trends puts upward or downward pressure on per capita emissions worldwide will depend on how effectively cities can facilitate sharing.

## 5. Conclusion

Some previous work has analyzed both household and urban economies in $CO_2$ emissions, but little research has addressed both these effects in the same model. We argue that proximity is the root cause of economies of scale in both multi-person households and dense cities. Building upon Ala-Mantila, Heinonen, and Junnila (2014) and Ala-Mantila et al. (2016) we construct a large nationally-representative dataset of $CO_2$ emissions at the household level and develop a unique measure of residential density to estimate urban economies, net of any rebound effects. We posit that both multi-person households and dense urban areas reduce the space between individuals and provide opportunities to share carbon-intensive goods, yielding both urban and household economies in $CO_2$ emissions. We find that dense urban areas have per capita emissions 20 percent lower than rural areas and that adding an additional member to the household reduces per capita emissions by about 6 percent.

This work is not without limitations. Despite our unique measure of residential density, our spatial clarity is still somewhat imprecise. Our estimates of urban economies likely capture the effect of high-density housing on emissions but may miss the full impact of proximity to employment, commerce, and public amenities. As a result, our estimates of urban economies may be biased downward and future research could utilize household expenditure data with finer geographical coding to improve upon our results.

The carbon intensities used in the analysis are also a source of some uncertainty. We employ intensities updated from Shammin & Bullard (2009) and Underwood and Zahran (2015) using a combination of changes in the energy intensity of GDP and product-specific price indices. These updates assume these changes in energy intensity and prices apply uniformly across the United States. Given the prevalence of higher prices in metropolitan areas and differential access to more efficient technologies, these assumptions are a source of additional uncertainty. In the case of prices, this likely leads to an over-estimation of emissions in urban areas (due to higher prices) but the impact of energy intensity is less certain. Future research could explore replicating these results using newly-derived carbon intensities.

Based on our understanding of the sharing mechanism generating these scale economies we also show that the magnitude of household economies depends on residential density, and that adding an adult or child to a household reduces per capita emissions by about twice as much in rural areas as in dense urban areas. Our point estimates suggest that relocating to a dense urban area would reduce per capita emissions by over three times as much as adding an adult to a household, assuming per capita expenditures remain constant. Over the past half century, households have become smaller and more affluent, especially in urban areas. As a result, the decline in household economies of scale outpaced the increase in urban economies in the United States.

The literature would also be enhanced by a formal model explaining how proximity facilitates successive and simultaneous sharing (Yates, 2016) and why household economies and urban economies are partial substitutes, as this paper and Ala-Mantila et al. (2016) document. Finally, careful empirical work could identify which types of goods are most amenable to sharing within and between households, while recognizing that consumers substitute between expenditure categories. While our results suggest the size of these rebound effects are small in comparison to the urban economies generated by sharing, other researchers have found significant effects elsewhere (Heinonen et al., 2013a; Ottelin, Heinonen, and Junnila, 2014). Future research could explore the prevalence and size of these effects and the degree to which they differ around the world.

Finally, our paper suggests that cities can potentially reduce carbon emissions by better mimicking how households share non-rival goods. This provides a defense for public investment in libraries, parks, and mass transportation. There is also a role for cities to adopt policies that facilitate new forms of peer-to-peer sharing. Research shows that individuals can meaningfully reduce emissions through a series of "reasonably achievable" behaviors like car-pooling and the purchase of secondhand goods (Dietz et al., 2009; Yates, 2016). Online platforms associated with the sharing economy thrive in areas that are geographically dense and digitally connected, so US cities should work to provide Wi-Fi in public spaces (Orsi et al., 2013) and bridge the digital divide between rich and poor (Fremstad, forthcoming). Peer-to-peer sharing requires a high level of trust between participants, and cities may have a role in bringing credibility to online reputations (McLaren and Agyeman, 2015). Although cities should not simply acquiesce to the demands of powerful platform monopolies, policymakers should carefully consider revising regulations around licensing, insurance, zoning, and taxation to facilitate beneficial forms of sharing (McLaren and Agyeman, 2015). For example, cities could encourage people to rent out their homes when they are away, while still preventing people from converting long-term rental properties into *de facto* hotels (Orsi et al., 2013). If cities can provide the social and technological infrastructure that facilitate these behavioral changes, then it is possible that dense cities can help people leverage the benefits of sharing in the 21st century in much the same way that large households have done so in the past.

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## Table 1

Table 1: Expenditure and Emissions Shares

| Expenditure Category | Annualized Mean Expenditures (US dollars) | Mean Expenditure Share (%) | Annualized Mean Emissions (kg $CO_2$) | Mean Emissions Share (%) |
|---|---|---|---|---|
| Total Expenditures | $50,308 | 100.0% | 32,168 | 100.0% |
| Residential Energy | $1,990 | 5.3% | 12,327 | 39.1% |
| Natural Gas | $272 | 1.0% | 2,677 | 8.0% |
| Electricity | $977 | 4.0% | 9,110 | 29.8% |
| Heating Oil and other fuels | $95 | 0.3% | 539 | 1.3% |
| Transportation | $8,865 | 14.0% | 11,038 | 30.7% |
| Gasoline and motor oil | $2,638 | 6.1% | 9,228 | 27.2% |
| Vehicle Purchases, Maintenance, and Services | $5,654 | 7.0% | 1,220 | 2.0% |
| Air Travel | $367 | 0.5% | 477 | 1.0% |
| Public and other transportation (bus, taxi, rail) | $206 | 0.4% | 113 | 0.4% |
| Food and Beverages | $7,568 | 18.3% | 2,763 | 10.3% |
| Other Expenditures | $31,886 | 62.5% | 6,041 | 20.0% |
| Housing | $10,308 | 22.4% | 1,542 | 6.3% |
| Indirect Utilities | $1,828 | 4.5% | 453 | 1.6% |
| Domestic Services | $1,172 | 2.1% | 220 | 0.7% |
| Household Equipment | $1,249 | 2.1% | 705 | 1.9% |
| Clothing and Footwear | $1,001 | 1.9% | 461 | 1.4% |
| Personal Insurance | $5,742 | 10.0% | 601 | 1.8% |
| Healthcare | $4,005 | 8.2% | 424 | 1.4% |
| Entertainment | $2,300 | 4.3% | 742 | 2.3% |
| Education | $1,206 | 1.5% | 174 | 0.5% |
| Alcohol and Tobacco | $695 | 1.7% | 141 | 0.5% |
| Miscellaneous | $2,380 | 3.8% | 577 | 1.6% |

Notes. Total expenditures include residential energy, transportation, food and beverages, and other. Residential energy includes natural gas, electricity, and heating oil. Transportation includes gasoline, vehicle purchases, services, and public transit. N = 72,608.

## Table 2

Table 2: Mean Household Characteristics by Residential Density

| Density | Rural | Suburban | Semi-detached urban | Dense urban | Overall |
|---|---|---|---|---|---|
| Household income (US $) | $51,234 | $76,842 | $47,466 | $45,346 | $65,715 |
| Income per capita (US $) | $23,987 | $32,272 | $25,557 | $26,411 | $29,866 |
| Annualized total household expenditures (US $) | $41,914 | $56,763 | $40,864 | $38,089 | $50,308 |
| Annualized per capita expenditures (US $) | $20,390 | $24,794 | $22,830 | $22,906 | $23,918 |
| Age of reference person (years) | 54 | 52 | 45 | 45 | 50 |
| Household size (number of persons) | 2.45 | 2.70 | 2.27 | 2.04 | 2.50 |
| Vehicle ownership (% of households) | 93.6 | 93.1 | 80.8 | 67.9 | 86.5 |
| Size of dwelling (number of rooms, excluding baths) | 6.2 | 6.7 | 4.7 | 4.1 | 5.9 |
| $CO_2$ intensity (kg/$) | 0.91 | 0.78 | 0.69 | 0.63 | 0.75 |
| Annualized total household $CO_2$ emissions (kg) | 32,142 | 36,936 | 25,057 | 21,345 | 32,168 |
| Annualized per capita $CO_2$ emissions (kg) | 15,846 | 16,258 | 13,737 | 12,413 | 15,166 |
| Observations | 3,235 | 46,047 | 6,018 | 17,308 | 72,608 |

Notes: Means are calculated using population weights. The size of the dwelling is unreported for 544 household-quarters, thus the mean is based on 72,064 observations with a spatial distribution of 3,210 rural, 45,613 suburban, 5,989 semi-detached urban, and 17,252 dense urban.

# Table 3

Table 3: Baseline Model

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Log expenditures per capita | 0.728*** | 0.688*** | 0.665*** | 0.644*** |
| | (0.004) | (0.005) | (0.005) | (0.005) |
| Number of adults | | -0.017*** | -0.048*** | -0.0598*** |
| | | (0.003) | (0.005) | (0.006) |
| Number of children | | -0.066*** | -0.074*** | -0.0808*** |
| | | (0.003) | (0.003) | (0.002) |
| Suburban | | | -0.066*** | -0.0594*** |
| | | | (0.010) | (0.009) |
| Semi-detached urban | | | -0.246*** | -0.177*** |
| | | | (0.013) | (0.012) |
| Dense urban | | | -0.374*** | -0.252*** |
| | | | (0.011) | (0.011) |
| Renter | | | | -0.032*** |
| | | | | (0.005) |
| Natural gas in rent | | | | -0.058*** |
| | | | | (0.011) |
| Heat in rent | | | | -0.132*** |
| | | | | (0.009) |
| Electricity in rent | | | | -0.416*** |
| | | | | (0.014) |
| Year fixed effects | Y | Y | Y | Y |
| Observations | 72,608 | 72,608 | 72,608 | 72,608 |
| R-squared | 0.638 | 0.648 | 0.687 | 0.720 |

Notes: Columns (3) and (4) compare the emissions of suburban and urban households to rural households. All regression results use population weights. Standard errors are clustered at the consumer unit, with robust standard errors in parentheses. *** $p < 0.01$

# Table 4

Table 4: Robustness

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| Log expenditures per capita | 0.652*** | 0.663*** | 0.687*** | 0.624*** | 0.671*** |
| | (0.005) | (0.005) | (0.007) | (0.005) | (0.005) |
| Number of adults | -0.056*** | -0.048*** | -0.033*** | -0.071*** | -0.056*** |
| | (0.006) | (0.006) | (0.008) | (0.006) | (0.006) |
| Number of children | -0.079*** | -0.073*** | -0.066*** | -0.089*** | -0.075*** |
| | (0.002) | (0.003) | (0.004) | (0.003) | (0.003) |
| Suburban | -0.046*** | | | -0.043*** | -0.045*** |
| | (0.010) | | | (0.010) | (0.010) |
| Semi-detached urban | -0.157*** | -0.090*** | -0.080*** | -0.138*** | -0.151*** |
| | (0.012) | (0.008) | (0.011) | (0.012) | (0.012) |
| Dense urban | -0.236*** | -0.172*** | -0.155*** | -0.197*** | -0.226*** |
| | (0.011) | (0.007) | (0.009) | (0.011) | (0.011) |
| Own car | | | | 0.199*** | |
| | | | | (0.008) | |
| Number of rooms | | | | 0.009*** | |
| | | | | (0.001) | |
| Renter controls | Y | Y | Y | Y | Y |
| Geographical controls | Region | State | PSU | Region | Region |
| Gender controls | N | N | N | N | Y |
| Race controls | N | N | N | N | Y |
| Education controls | N | N | N | N | Y |
| Age controls | N | N | N | N | Y |
| Year fixed effects | Y | Y | Y | Y | Y |
| Observations | 72,608 | 63,686 | 32,004 | 72,064 | 72,608 |
| R-squared | 0.725 | 0.735 | 0.752 | 0.735 | 0.729 |

Notes: All columns compare the emissions of suburban and urban households to rural households, except (2) and (3), which compare urban households to suburban households (because the only rural households with state identifiers are in Kentucky, and because there are no rural households in any PSU -- see text for details). All regression results use population weights. Standard errors are clustered at the consumer unit, with robust standard errors in parentheses. *** $p < 0.01$

## Table 5

| Table 5: Household Economies Across Density | |
|---|---|
| | (1) |
| Log expenditures per capita | 0.676*** |
| | (0.005) |
| Number of adults | -0.081*** |
| | (0.011) |
| Number of children | -0.113*** |
| | (0.008) |
| Suburban | -0.116*** |
| | (0.029) |
| Semi-detached urban | -0.235*** |
| | (0.030) |
| Dense urban | -0.346*** |
| | (0.028) |
| Suburban×num. adults | 0.021** |
| | (0.013) |
| Semi-detached urban×num. adults | 0.025* |
| | (0.013) |
| Dense urban×num. adults | 0.047*** |
| | (0.012) |
| Suburban×num. children | 0.035*** |
| | (0.009) |
| Semi-detached urban×num. children | 0.059*** |
| | (0.011) |
| Dense urban×num. children | 0.063*** |
| | (0.009) |
| Renter controls | Y |
| Geographical controls | Region |
| Gender controls | Y |
| Race controls | Y |
| Education controls | Y |
| Year fixed effects | Y |
| Observations | 72,608 |
| R-squared | 0.730 |

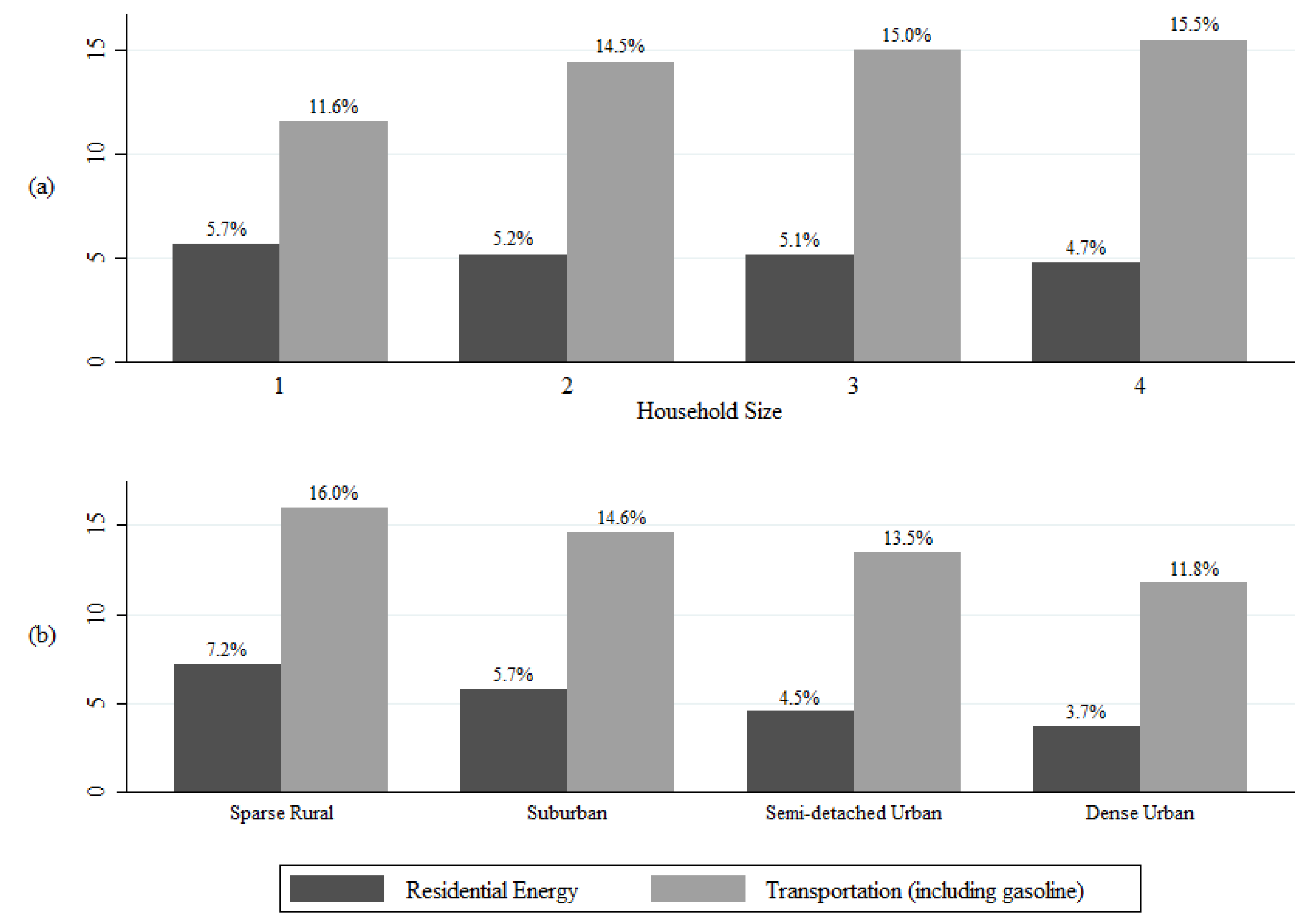
Notes: The comparison group is rural households. All regression results use population weights. Standard errors are clustered at the consumer unit, with robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

## Table 6

| Table 6: Estimated per capita $CO_2$ Emissions (kg) by Residential Density and Household Composition | | | | | |
|---|---|---|---|---|---|
| Household Composition | Rural | Suburban | Semi-detached urban | Dense urban | $\frac{Rural}{Dense\ Urban}$ |
| one adult | 15,599 | 14,543 | 13,042 | 11,949 | *1.31* |
| one adult, one child | 14,789 | 14,019 | 12,713 | 11,668 | *1.27* |
| two adults | 14,393 | 13,788 | 12,344 | 11,551 | *1.25* |
| two adults, one child | 13,645 | 13,291 | 12,033 | 11,280 | *1.21* |
| one adult, two children | 13,210 | 12,972 | 12,044 | 11,095 | *1.19* |
| three adults | 13,280 | 13,072 | 11,683 | 11,167 | *1.19* |
| four adults | 12,253 | 12,393 | 11,057 | 10,795 | *1.14* |
| two adults, two children | 12,189 | 12,298 | 11,399 | 10,725 | *1.14* |
| two adults, three children | 10,888 | 11,380 | 10,799 | 10,198 | *1.07* |
| two adults, four children | 9,726 | 10,529 | 10,230 | 9,697 | *1.00* |
| $\frac{One\ adult}{Two\ adults,\ four\ children}$ | *1.60* | *1.38* | *1.27* | *1.23* | |

Notes: Estimates are based on Equation (2) with all other covariates fixed at the overall sample mean and produced using a consistent estimator for per capita emissions, given the logarithmic functional form of the dependent variable: $\hat{y} = [\exp(\hat{\sigma}^2/2) * \exp(\widehat{\ln y})]$.

**Figure 1.** **Residential Energy and Transportation Expenditure Shares by Household Size (a) and Urban Density (b)**



# Appendix

## Table A.1

Table A1: Carbon Intensity by Expenditure Category

| Expenditure Category | 2012 | 2013 | 2014 |
|---|---|---|---|
| | | (kg $CO_2$/$) | |
| Residential Energy | | | |
| Natural gas | 7.092 | 6.772 | 6.326 |
| Electricity | 6.465 | 6.332 | 6.111 |
| Fuel oil and other fuels | 3.808 | 3.852 | 3.774 |
| Transportation | | | |
| Gasoline and motor fuel | 3.385 | 3.485 | 3.625 |
| New and used cars and trucks | 0.527 | 0.525 | 0.526 |
| Other vehicles | 0.727 | 0.724 | 0.725 |
| Vehicle finance charges | 0.145 | 0.145 | 0.145 |
| Maintenance and repairs | 0.245 | 0.241 | 0.237 |
| Vehicle insurance | 0.059 | 0.057 | 0.054 |
| Vehicle rental, leases, licenses, and other charges | 0.141 | 0.14 | 0.14 |
| Air Travel | 1.32 | 1.28 | 1.30 |
| Public and other transportation | 0.55 | 0.54 | 0.54 |
| Food and Beverage | | | |
| Food at home | 0.396 | 0.392 | 0.383 |
| Food away from home | 0.319 | 0.312 | 0.305 |
| Other | | | |
| Housing | | | |
| Mortgage interest | 0.137 | 0.135 | 0.133 |
| Property taxes | 0.000 | 0.000 | 0.000 |
| Maintenance, repairs, insurance, and other expenses | 0.861 | 0.835 | 0.797 |
| Rent payments | 0.224 | 0.218 | 0.211 |
| Other lodging | 0.327 | 0.324 | 0.31 |
| Indirect Utilities | | | |
| Telephone | 0.183 | 0.183 | 0.184 |
| Water and other public services | 0.422 | 0.404 | 0.39 |
| Domestic services and household operations | | | |
| Domestic services excluding child care | 0.171 | 0.168 | 0.164 |
| Babysitting and child care | 0.148 | 0.145 | 0.142 |
| Other household expenses | 0.238 | 0.234 | 0.228 |
| Household equipment and supplies | | | |
| Household textiles | 0.746 | 0.774 | 0.791 |
| Furniture | 0.503 | 0.509 | 0.523 |
| Floor coverings | 0.524 | 0.546 | 0.545 |
| Major appliances | 0.489 | 0.501 | 0.533 |

| Expenditure Category | 2012 | 2013 | 2014 |
|---|---|---|---|
| | | (kg $CO_2$/$) | |
| Small appliances and miscellaneous housewares | 0.485 | 0.493 | 0.504 |
| Miscellaneous household equipment | 0.592 | 0.613 | 0.641 |
| Clothing and footwear | | | |
| Apparel and services | 0.472 | 0.467 | 0.467 |
| Footwear | 0.43 | 0.42 | 0.418 |
| Personal Insurance | | | |
| Life and other personal insurance | 0.106 | 0.105 | 0.103 |
| Retirement, pensions, and Social Security | 0.106 | 0.105 | 0.103 |
| Healthcare | | | |
| Health insurance | 0.061 | 0.06 | 0.059 |
| Medical services | 0.145 | 0.14 | 0.137 |
| Prescription drugs | 0.197 | 0.196 | 0.189 |
| Medical supplies | 0.209 | 0.208 | 0.203 |
| Personal care | 0.254 | 0.251 | 0.247 |
| Entertainment | | | |
| Fees and admissions | 0.015 | 0.015 | 0.015 |
| Televisions, radios, and sound equipment | 0.355 | 0.354 | 0.354 |
| Pets, toys, and playground equipment | 0.644 | 0.659 | 0.684 |
| Other entertainment | 0.391 | 0.389 | 0.388 |
| Education and reading | | | |
| Reading | 0.234 | 0.226 | 0.221 |
| Education | 0.141 | 0.136 | 0.132 |
| Alcohol and tobacco | | | |
| Alcoholic beverages | 0.307 | 0.302 | 0.299 |
| Tobacco and smoking supplies | 0.083 | 0.081 | 0.079 |
| Miscellaneous | | | |
| Miscellaneous expenditures | 0.258 | 0.254 | 0.25 |
| Cash contributions | 0.243 | 0.239 | 0.236 |