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DISCUSSION PAPER SERIES

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ABSTRACT

Green Commuting and Gasoline Taxes in the United States

This paper analyzes how gasoline tax rates are related to the time workers in the United States spend commuting by private car, public transport, or with other physical modes of transport. Our identification strategy relies on both between-state differences and time variations in gasoline taxes. Using the American Time Use Surveys for the years 2003 to 2015, we find that higher gasoline tax rates are related with less time spent in commuting. Furthermore, higher gasoline taxes are related to a lower proportion of commuting by private car, and higher proportions of commuting by public transport and/or a physical mode of transport (e.g., walking, cycling). Our results highlight the importance of gasoline taxes (and prices) on the consumption of energy for personal transport, as higher gasoline taxes are related to a greater use of "green" modes of transport, showing that fuel taxes are important for good management of the environment.

JEL Classification: D1, Q4, R4

Keywords: commuting time, public transport, walking/cycling, gasoline taxes

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1. Introduction

In this paper, we analyse the relationship between the commuting behaviour of workers in the United States and gasoline taxes, with a focus on driving and "green" modes of personal transport (e.g, public transport and walking/cycling). The United States is among the countries with the highest consumption of gasoline in the world (over 130 billion gallons of gasoline annually, Gilligham et al., 2015), representing around one-third of the US greenhouse gas (GHG) emissions of the country (EPA, 2014). In order to implement efficient policies aimed at decreasing the consumption of energy, GHG emissions, and better management of the environment, policymakers need to know the effects of different policy measures, such as increasing fuel taxes orthe Zero Emissions Vehicle (ZEV) mandate, both of which critically depend on the behavior of consumers. Thus, it is important to analyse the consumer responses to changes in fuel taxes in their private transport decisions, and we focus on the relationship between commuting time and gasoline taxes.

Despite that consumers may respond differently to changes in taxes than to changes in prices (Li et al., 2014), it is expected that consumers will respond similarly to changes in gasoline prices and taxes. In this sense, prior research has found negative price elasticities for the consumption of gasoline, based on driving behavior (Dahl and Sterner, 1991; Greening et al, 2000; Small and Van Dender, 2007; Hughes et al., 2008; Burke and Nishitateno, 2013; Gillighan, 2014; Hymel and Small, 2015; Chen, Russell and Zhank, 2018), and similar evidence has been found for the relationship between gasoline taxes and the consumption of gasoline (Dahl, 1979; Goel, 1994; Bento et al., 2005; Li et al., 2014, Liu, 2015). But the research to date has focused on the effect of gasoline taxes/prices on driving, leaving aside other modes of transport. This analysis is relevant, as it has implications for GHG emissions. For instance, the use of public transport may be beneficial for the environment in comparison to private vehicles, as it helps to reduce GHG emissions (Stanley and Watkiss, 2003; Chapman, 2007; Gôssling and Choy, 2015; Holian and Kahn, 2015). Also, the use of physical modes of transport contribute more to the reduction of GHG emissions as they are, ultimately, 'zero carbon' and an environmentally friendly solution for personal transport (Chapman, 2007). Thus, in order to have a complete view of the effect of tax instruments, we need to ask whether the reduction in driving due to an increase in fuel taxes devolves to a greater use of public transport, if it results in more walking/cycling, or both.

Within this framework, we analyze how the time workers spend driving to/from work (commuting), and using "green" modes of transport, such as public transport and walking/cycling, are affected by gasoline tax rates.To that end, we use the 2003-2015 American Time Use Survey (ATUS) to measure the commuting time of workers in the US. Millions of workers in the US commute every working day (on average 45 minutes per day, according to Gimenez-Nadal and Molina, 2016, and Gimenez-Nadal, Molina and Velilla, 2018a, 2018b), representing an important activity in that it contributes to the consumption of energy. Gasoline tax rates differ by State, and may also change over time at the State level, which allows us to analyze how differences over time and across States in gasoline taxes are related to consumer behavior. We analyze the relationship between the time devoted to commuting during a working say, and gasoline taxes. We also analyze the relationship between gasoline taxes and the proportion of daily commuting that is carried out by three different modes of transport: private, public transport, and physical. The latter analysis allows us to determine whether reductions in the driving time of workers due to higher gasoline taxes are related to more time in commuting by public transport or physical modes of transport, or both.

We find that higher gasoline taxes are related to less time spent in commuting. To the extent that most of the commuting in the US is done by car, our results can be interpreted as a negative relationship between private car usage and gasoline taxes, which is consistent with prior evidence on the intensive margin of driving. We also observe that higher gasoline taxes are related to a lower proportion of commuting time by private car, and to a higher proportion of commuting time by both public transport and physical modes of transport. Thus, higher gasoline tax rates are related to a substitution from driving to alternative "green" modes of transport.

Our contribution to the literature is twofold. First, we contribute to the analysis of the effect of gasoline taxes on driving for commuting to/from work, complementing prior analyses. To the best of our knowledge, time-use data has not previously been used in this context, and results point to a negative effect of gasoline taxes on driving (negative price elasticity). Second, we add a new perspective to the analysis of fuel taxes and energy consumption, by including in the analysis "green" modes of personal transport that may substitute for driving. Our results shed light on the importance of considering the analysis of these modes of transport in policy analysis, as adding them to the assessment of policies is important in gaining a complete view of the effects of gasoline taxes on energy consumption and the management of the environment. Our results opens a very promising line of research.

The rest of the paper is organized as follows. Section 2 describes the data and the variables of interest. Section 3 describes the empirical strategy, and Section 4 presents the main results. Finally, Section 5 sets out our main conclusions.

2. Data

We use the 2003-2015 American Time Use Survey (ATUS) to measure the commuting time of workers in the US. Respondents are asked to fill out a diary summarizing episodes of the preceding day, and thus the ATUS provides us with information on individual time use, based on diary questionnaires in which individuals report their activities throughout the 24 hours of the day. The ATUS includes a set of activities, defined as the activity individuals were engaged in throughout the day, and thus we are able to add up the time devoted to any given reference activity (e.g., paid work, leisure, TV watching). The ATUS is administered by the US Bureau of Labor Statistics, and is considered the official time use survey of the country. More information can be found at http://www.bls.gov/tus/.

Several advantages of the use of time use surveys are relevant to our purpose. First, time use surveys allow for a more accurate measure of commuting time, in comparison with other datasets. For example, they allow us to distinguish pure commuting episodes from other episodes that are not done as commuting but as an ancillary activity (e.g., pick up children from school). Time use surveys provide information on duration, departure and arrival times, location, and mode of transport, and despite that they are inferior in comparison to other datasets, such as National Travel Surveys, time use surveys can serve as a complement to National Travel Surveys (Kitamura and Fuji, 1997). The use of time-use surveys in transportation research has become a common practice (Gimenez-Nadal and Molina, 2014; 2016; Jara-Díaz and Rosales-Salas, 2015; Gimenez-Nadal, Molina and Velilla, 2018a, 2018b).

We restrict our sample to workers on their working days, defined as days individuals spend 60 minutes or more working (excluding commuting) and where commuting time is the time devoted to the activity “commuting to/from work”, coded as “180501” in the ATUS codebook. We restrict the analysis to working days to avoid computing zero minutes of commuting for any worker who filled out the time use diary on a non-working day. The final sample consists of 115,923 workers who devote 43.12 minutes per working day to commuting, with a standard deviation of 39.91 (See Table A1 in the appendix for means and standard deviations of variables of interest).

The ATUS also allows us to compute the commuting time and the percentage of total commuting time that is done using different modes of transport. The modes of transport are the following: Car, truck or motorcycle (driver); Car, truck or motorcycle (passenger); Walking; Bus; Subway, train; Bicycle; Boat, ferry; Taxi, limousine service; Airplane; and Other mode of transportation. From this classification, we consider three main modes of transport: by private transport (by Car, truck or motorcycle as driver, or bycar, truck or motorcycle as passenger), by public transport (by bus, subway, train, boat, ferry, taxi, limousine service, or airplane) and by physical mode of transport (walking or bycicle). Our analysis thus focuses on the proportion of commuting by the three modes of transport: by private transport (mainly car), by public transport, and by physical mode. In our sample, the average proportions of commuting by private car, public transport and physical mode is 91.61%, 2.70%, and 3.21%, respectively.

In the US, a federal tax rate of 18.4 cents/gallon is applied to gasoline (since 1993) in all States, and each State has the freedom to establish itsown (additional) tax rate on gasoline. Thus, there exist between-State differences in state gasoline tax rates, and we exploit these differences in our analysis. Information on gasoline tax rates for each state and year are obtained from the the Highway Statistics Series Publications, released by the Federal Highway Administration, US Department of Transportation. State gasoline tax rates are shown in Table 1 for each state and year in the period 2003-2015, showing that there are between-State and over-time variations in gasoline tax rates. For instance, in 2003, the highest tax rates are found in Connecticut and Rhode Island, while the lowest tax rates are found in Alaska, New Jersey and Wyoming. Furthermore, while in some States tax rates have decreased, as in Oregon, Pennsylvania, and Idaho, in other States tax rates have been held constant (e.g., Arizona, Michigan, and Oklahoma) or increased (e.g., Maine, Nebraska, and Georgia) during the period. Thus, gasoline tax rates present variability across States and over time, which allows us to relate changes in gasoline tax rates with changes in the commuting behavior of individuals.

Figure 1 plots the average commuting time by gasoline tax rate. That is, for each gasoline tax rate existing in our sample, we compute the average commuting time devoted by workers. In this computation, we use survey weights to make our calculations representative of the population of workers in the United States, and correct it by the number of observations used for this computation out of the total sample, in order to have the tax rates be representative of their importance (shown with different sizes of dots). We add a linear fit to see the extent to which dots are distributed following a linear trend. There is a negative relationship between commuting time and gasoline tax rates as the slope of the linear fit is negative, corresponding to a correlation coefficient of -0.20. Thus, higher gasoline tax rates are negatively related to commuting time, which is important in the US, where most commuting is done using private modes of transport, especially by car. Thus, we present evidence of the effect of gasoline taxes on the commuting behavior of individuals, with higher gasoline taxes leading to lower commuting, and likely to a reduction of GHG emissions.

Figure 2 plots the average percentage of commuting time by private transport, public transport, and physical mode of transport, by gasoline tax rate. As in Figure 1, for each gasoline tax rate in our sample, we compute the average percentage of commuting time by each mode of transport, using weights to make our calculations representative of the number of observations used for this computation and also adding a linear fit. We observe a negative relationship between gasoline tax rates and the percentage of commuting by car, given the negative slope of the linear fit and the negative correlation (-0.14). On the contrary, we observe positive slopes, and positive correlations, between gasoline tax rates, on the one hand, and the percentage of transport by public transport (0.09) and by physical mode of transport (0.20).

In sum, we find that higher gasoline tax rates are associated with less time spent in commuting, and with a lower proportion of commuting time by private transport and a higher proportion of commuting by public transport or physical mode of transport. Thus, the evidence suggests that gasoline taxes could be used as a policy instrument to reduce GHG emissions, given the reduction in commuting time of workers and the shift towards green commuting modes that include public transport and physical modes of transport. However, this analysis does not take into account differences in worker characteristics, nor in States regarding traffic density and highway development. Thus, in the following Sections, we develop a more in-depth analysis.

3. Empirical strategy and variables

We estimate OLS regressions on the time devoted to commuting, a model that has often been applied in prior research using time use data on commuting (Gimenez-Nadal and Molina, 2014; 2016: Gimenez-Nadal, Molina and Velilla, 2018a,2018b). The statistical model is as follows: for a given individual "i", let C_{ijk} represent the (log) daily hours individual "i" living in State "j" (j=1,2…51) in year "t" (t=2003, 2004…2015) devotes to commuting, let $TaxRate_{jt}$ be the (log) gasoline tax rate in State "j" at year "t", let X_i be a vector of socio-demographic characteristics of individual "i" in State "j" and year "t", and let ε_{ijt} be random variables that represent unmeasured factors. We estimate the following equation:

$$\log(C_{ijt}) = \alpha + \beta\log(TaxRate_{jt}) + \gamma X_{ijt} + \partial TPI_j + \vartheta Year_{ij} + \vartheta State_{it} + \varepsilon_{ijt} \quad (1)$$

where C_{ijt} represents the time devoted to commuting. We transform both the dependent variable and gasoline tax rates to their log form so that the coefficient β from this regression can be interpreted in terms of elasticity: the percent change in commuting time when gasoline tax rates increase by one percent.[1] We also include variables to measure time ($Year_{ij}$) and State ($State_{it}$) fixed effects, as the commuting behavior of individuals may differ, depending on factors such as weather conditions (Connolly, 2008) or economic conditions (Burda and Hamermesh, 2010; Aguiar, Hurst and Karabarbounis, 2013)

The vector X_{ijt} includes various characteristics of workers that may have a direct relationship to the time devoted to commuting. Given prior research showing that men and women have different commutes (Gimenez-Nadal and Molina, 2014, 2016), we take into account the gender of the worker. Other variables that may affect the time devoted to commuting by workers are age of respondents, wages, education, whether the respondent lives in couple, labour status of spouse/partner, the number of children in the household and the age of the youngest child in the household (see Gimenez-Nadal and Molina, 2016, Gimenez-Nadal, Molina and Velilla, 2018b, for a review of the expected relationships between socio-demographic characteristics and commuting time).

[1]We transform commuting time, adding unity in order to avoid missing values that would correspond to zero commuting. Figure A1 in appendix shows the distribution of the log-transformed variable of commuting time, using kernel-density distributions. We observe that the transformed variable concentrates its values around 3.5, and the two tails resemble the shapeof a normal distribution (added to the figure).

We include age and its square (divided by 100) to allow for the non-linear effects of age on commuting time. The variable for gender is a dummy variable that takes value "1" if respondent "i" is male, and value "0" otherwise. The variable measuring education is obtained from the variable "peeduca" in the ATUS, which is coded as follows: 31 "Less than 1st grade", 32 "1st, 2nd, 3rd, or 4th grade", 33 "5th or 6th grade", 34 "7th or 8th grade", 35 "9th grade", 36 "10th grade", 37 "11th grade", 38 "12th grade - no diploma," 39 High school graduate - diploma or equivalent (GED)", 40 "Some college but no degree," 41 "Associate degree - occupational/vocational", 42 "Associate degree - academic program", 43 "Bachelor's degree (BA, AB, BS, etc.)", 44 "Master's degree (MA, MS, MEng, MEd, MSW, etc.)", 45 "Professional school degree (MD, DDS, DVM, etc.)", and 46 "Doctoral degree (PhD, EdD, etc.)". A higher value of the variable measuring education represents a higher level of education for individual "i". The variable measuring whether respondent "i" lives in couple takes value "1" if respondent "i" is married or cohabiting, and "0" otherwise. For those living in couple, we also control for whether the respondent's partner is working (1) or not (0), and also computing value "0" to those who do not live in couple. We also control for the number of children under 18 years old in the household and the age of the youngest child.

The ATUS also includes information on labor earnings, which allows us to compute the hourly wage of workers. We have defined the hourly earning (wage rate) directly as earnings per hour, if this data is available from ATUS; in other cases, we have defined it as earnings per week divided by the usual weekly working hours. It is important to control for the wages of workers, given prior evidence showing a positive relationship between commuting and wages (Leigh, 1986; Zax, 1991, White, 1999, Ross and Zenou, 2008, Fu and Ross, 2013, Mulalic, van Ommeren, and Pilegaard, 2014; Gimenez-Nadal, Molina and Velilla, 2017a). Thus, we need to control for the labor income of workers to net out the effect of tax rates on commuting from other effects (Shapiro and Stigliz, 1984).[2] We include the wage rate and its square (divided by 100) to allow a non-linear relationshipbetween commuting and wages.

We also include the Transportation Performance Index (TPI), developed by the US Chamber of Commerce, which is part of the Infrastructure Performance Index series, a

[2] Table A1 shows averages and standard deviations for our sample of workers. 55% are male workers, with an average level of education of "some college but not degree" and average age of 38.66. Furthermore, 67% of the sample lives in couple and 49% have a working partner, the average number of children per household is 1.23 and the average age of the youngest child is 4.32 years. Finally, the average wage rate of workers in the sample is $19.51/hour.

groundbreaking endeavor of the Chamber's 'Let's Rebuild America' (LRA) initiative. For each State, a value is assigned on this index, in order to measure the performance of transportation infrastructures. The index is based on a well-defined methodology, uses existingpublicly-available data, and incorporates the major infrastructure sectors. The TPI is composed of 25 measures (e.g., route-miles per 10,000 population, fatalities per 100 million Vehicle Miles Traveled, Runway incursions per million operations), which are classified in three main categories: Supply, Quality of Service, and Utilization. Thus, the TPI synthetizes performance of infrastructures in these 3 dimensions, which have been identified as important in shaping the transport behavior of individuals. The different measures are combined to give a single value, with higher values of the TPI indicating better performance of infrastructures. More information on the TPI can be found athttps://www.uschamber.com/issue-brief/transportation-performance-index. The more recent TPI available at the State level is from the year 2010, which we use for our analysis. The highest values of the TPI correspond to North and South Dakota, and Nebraska, and the lowest values correspond to the District fo Columbia, New Jersey, and Hawaii (Table A2 in the Appendix shows the values assigned to the TPI for each State). When we compute the correlation between time spent commuting and the TPI, the correlation coefficient is -0.10 and statistically significant at the 99% level, indicating that workers devote less time to commuting, ceteris paribus, in States where the TPI is higher (e.g., better performance), that is, in States with higher performance in their infrastructures, workers need less time to go to their work places.

For the percentage of time commuting in each mode of transport, we also estimate OLS models, given the continuous nature of the dependent variables. In this sense, given that we compute the time workers spend during the daily commute using a private, public and physical mode of transport, any of the three variables can in principle take values from zero to one. The statistical model is as follows: for a given individual "i", let P_{ijk} represent the (log) percentage of time individual "i" living in State "j" (j=1,2…51) in year "t" (t=2003, 2004…215) spends commuting, by the reference mode of transport, let $TaxRate_{jk}$ be the (log) gasoline tax rate in State "j" at year "t", let X_i be a vector of socio-demographic characteristics of individual "i" in State "j" and year "t", and let ε_{ijt} be random variables that represent unmeasured factors. We estimate the following equation:

$$\log(P_{ijt}) = \alpha + \beta \log(Tax\_Rate_{jt}) + \gamma X_{ijt} + \partial TPI_j + \vartheta Year_{ij} + \vartheta State_{it} + \varepsilon_{ijt} \quad (2)$$

where $\log(P_{ijt})$ represents the (log+1)percentage of time in commuting spent in the reference mode of transport. The explanatory variables included in Equation (1) are also included in this analysis, and results can also be interpreted in terms of elasticity.

4. Results

Table 2 shows the results of estimating Equation (1) of the (log) time devoted to daily commuting on gasoline tax rates. Column (1) shows the results when only the variable measuring (log) gasoline taxes is included as explanatory variable. Column (2) shows results when socio-demographic characteristics are also included in the analysis (X_{ijt}), and Column (3) shows the results when the *Transportation Performance Index* (TPI_j), and year ($Year_{ij}$) and state ($State_{it}$) fixed effects, are included in the analysis. We introduce these variables sequentially in order to check whether the main results changesignificantly. We observe that results are consistent in the three models, as the coefficient for gasoline taxes is negative and statistically significant at the 99% significance level, and the coefficient remains unchanged. That is, we observe a negative relationship between commuting time and gasoline tax rates, showing that a one percent increase in the gasoline tax rate is related to a 0.07% decrease in average daily commuting time (see Column 3). This result is consistent with the existing literature showing negative gasoline price elasticities for driving of around 0.10%.

Table 3 shows the results of estimating Equation (2) on the proportion of commuting by private transport, public transport, and physical modes of transport, on gasoline tax rates. Columns (1), (4) and (7) show results when only gasoline tax rates are included in the model, Columns (2), (5) and (8) show results when we include socio-demographic characteristics (X_{ijt}), and Columns (3), (6) and (9) show the results when the Transportation Performance Index (TPI_j), and year ($Year_{ij}$) and state ($State_{it}$) fixed effects, are included in the analysis. Again, results are robust to the inclusion of socio-demographic, transportation infrastructure, year, and State controls. We find that higher gasoline taxes are related to a decrease in the proportion of commuting by car, while being related to increases in the proportion of commuting by public transport or physical modes of transport. A one-percent increase in the gasoline tax rate is related to a 0.35% decrease in the proportion of daily driving commuting time (see Column 3), and with increases of 0.16% and 0.26% in the proportion of daily commuting time using public transport or a physical mode of transport (see Columns 6 and 9), respectively.

In sum, we find a negative price elasticity of commuting time on gasoline tax rates, as higher taxes are related to less commuting time. Furthermore, higher gasoline taxes are negatively related o the proportion of driving, while they are positively related to the proportion of commuting using public transport or physical modes of transport. Thus, our results shed light on the effects of public policies, based on fuel taxes, on the driving behavior of workers. We highlight that the reduction in driving from higher gasoline taxes is in part compensated for by more time walking or cycling, but also by a greater use of public transport. If the reduction in driving were fully compensated for by more time walking or cycling, public policies focusing on fuel taxes would certainly have more impact on energy consumption and GHG emissions than when public transport is also used. In order to design public policies aimed at decreasing energy consumption and GHG emissions, the extent to which driving is substituted by public transport or physical modes must be fully considered.

Other results

Regarding the time devoted to commuting (Table 2), we observe that male workers devote more time to commuting than do female workers, consistent with prior research showing gender differences in commuting behavior (Gimenez-Nadal and Molina, 2016). Years of education are not related to the time devoted to commuting. Although this result may be surprising (Gimenez-Nadal and Molina, 2016), the effect of education on commuting can be partially captured by wage rates, which we include in our regressions. In fact, we observe an inverted u-shaped relationship between wage rates and commuting, indicating that higher wage rates are positively related to commuting, to a maximum where the relationship turns negative. This inverted u-shaped relationship between commuting and wages can be explained by physical constraints, as higher wages are initially related toincreased commuting, until physical capability constraints come into play (Schwanen and Dijst, 2002; Gimenez-Nadal and Molina, 2014).

Furthermore, age has a u-shaped relationship to commuting time, when commuters reach a maximum of daily commuting in their mid-forties and early-fifties. Regarding household characteristics, we observe that, if workers live in couple they devote more time to commuting, but only if the partner does not work. If the partner works, commuters reduce the amount of commuting time. Finally, the presence of children under age 18 in the household presents a negative relationship to commuting time, especially when the children are young, consistent with the Household Responsibilities Hypothesis (i.e., parents, especially mothers, accept jobs closer to home in order to increase their availability for childcare responsibilities, Gimenez-Nadal and Molina, 2016).

Focusing on the proportion of commuting by the different modes of transport, this analysis is interesting per se in order to set a profile of those individuals who are more likely to use alternative modes of transport, such as public or physical. We observe in Table 3 that males have, in comparison to women, a lower probability of using public transport, as the relationship between the gender dummy (male) and the proportion of commuting by public transport is negative. Gimenez-Nadal and Molina (2016) show that this may be due to the Household Responsibilties Hypothesis, as responsibilities for childcare make women more dependant on public transport. Regarding education, a higher level of education is related to a greater use of private and physical modes of transport.

Age and its square has an inverted u-shaped relationship to the proportion of commuting by public transport, and a u-shaped relationship to the proportion of commuting using physical modes of transport. Thus, for those who choose alternative modes of transport, such as public and physical, in younger individuals there is a substitution from the use of physical modes of transport to the use of public transport, but the opposite happens as individuals grow older, when there is a substitution from the use of public transport to the use of physical modes of transport.

Those living in couple use private transport in a higher proportion, and a lower proportion of use of both public and physical modes of transport, while those who have a working spouse have a greater probability of using private transport, to the detriment of physical modes of transport. The presence of children in the household is related to a greater use of public and physical modes of transport, to the detriment of private transport, although the younger the child, the greater the use of private transport. Thus, it appears that childcare responsibilities condition the choice of mode of transport, and the presence of young children makes working parents rely more on private modes of transport. Finally, a higher value of the TPI is related to a greater use of private transport, and a lesser use of public and physical modes of transport. When the quality of infrastructure is better, workers will probably drive more often, which increases driving to/from work

5. Conclusion and Policy Implications

The consumer response to changing gasoline prices has long interested economists and policymakers, as it has important implications for the effects of gasoline taxation and vehicle energy-efficiency policy. In this paper, we analyse the relationship between the commuting behaviour of workers in the United States and gasoline tax rates, introducing the analysis of "green" modes of transport as an important focus of research. Prior research has focused on the effect of gasoline taxes/prices on driving, leaving aside other modes of transport, and if a complete view of the effect of tax instruments is needed, the analysis of whether a reduction in driving is due to an increase in fuel taxes is essential.

We use the 2003-2015 American Time Use Survey (ATUS), and the between-State and over-time variations in gasoline taxes, to identify the effecton the time devoted to commuting. We find that higher gasoline taxes are related to less time spent in commuting, that higher gasoline taxes are related to a lower proportion of commuting by private car, and to a higher proportion of commuting by both public transport and physical modes of transport. Thus, higher gasoline taxes may lead to a substitution from driving to alternative "green" modes of transport.

Our results may be of interest for policymakers in the design of efficient policies aimed at decreasing energy consumption and GHG emissions. Increasing gasoline taxes is politically challenging, although the results show that increasing gasoline tax rates would result in substantial energy efficiency improvements, as other modes of transport come into play as substitutes for driving. Despite prior studies finding that gasoline consumption is quite inelastic to changes in prices (Liu et al., 2014; Gillingham et al., 2015), the results shown in this paper may help to design more efficient policies.

The present study presents some limitations. First, the ATUS is a cross-section of individuals, which does not allow us to identify the relationship between commuting and gasoline tax rates net of (permanent) individual heterogeneity in preferences. Thus, we cannot claim any causality. Second, road freight is not included in the analysis of commuting. It would be interesting to focus on the travel patterns of those who work in the logistic sector, who spend time driving while working, given that the ATUS contains information on the mode of transport. Third, we leave out of our analysis travel for other purposes, such as for leisure, personal care, or childcare responsibilities. Time spent travelling for these other purposes is not a negligible part of daily life, and it would be interesting to see how travel patterns change with fluctuations in gasoline tax rates. We leave this analysis for future research.

DECLARATION OF INTEREST: NONE

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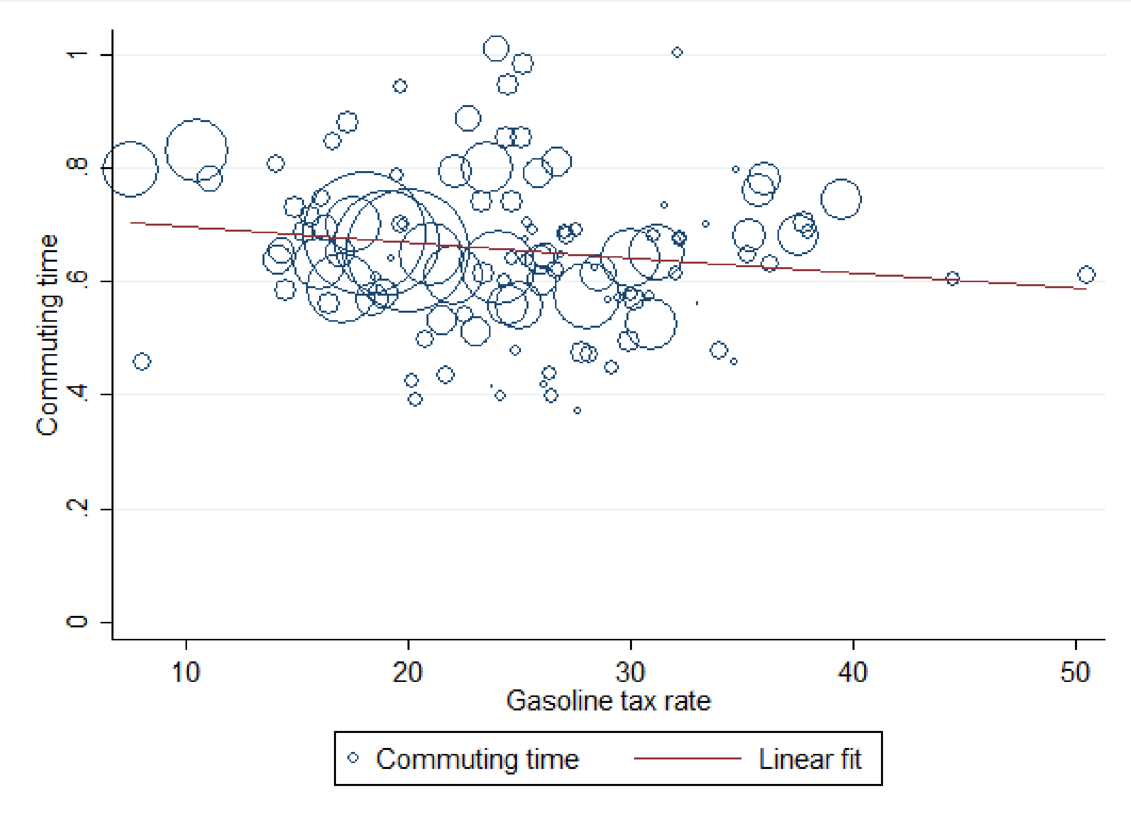
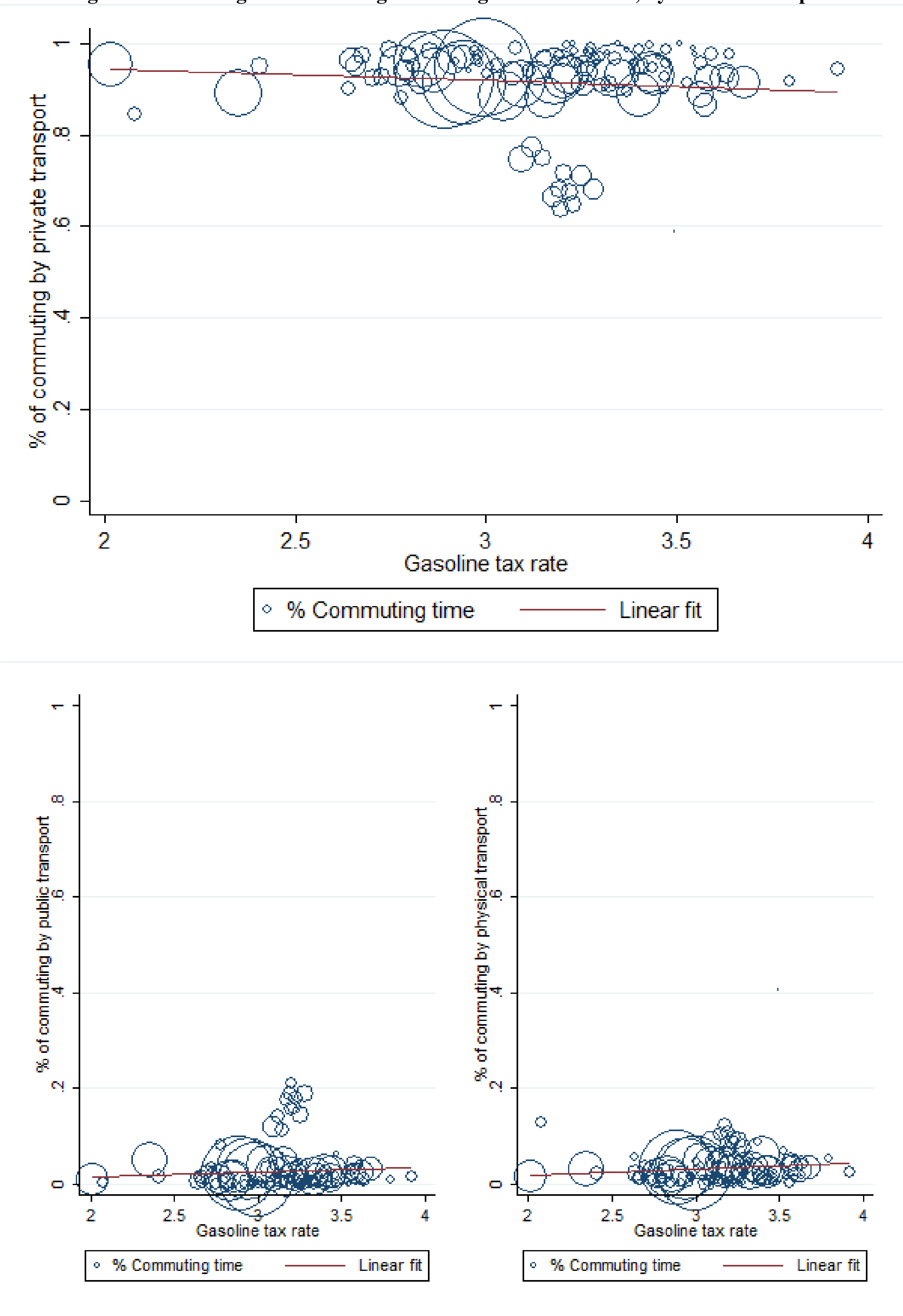
Figure 1. Commuting time and gasoline tax rates



Notes: Data come from the American Time Use Survey 2003-2015. Sample is restricted to workers who spent at least 60 minutes in market work activities, excluding commuting. Commuting time is measured as the log of the time devoted to the activity "180501" in the ATUS codebook. Size of dots is proportional to the number of observations included for the calculation of average commuting time for the reference gasoline tax rate.

Figure 2. Percentage of commuting time and gasoline tax rates, by mode of transport



Notes: Data come from the American Time Use Survey 2003-2015. Sample is restricted to workers who spent at least 60 minutes in market work activities, excluding commuting. The percentage of commuting time by mode of transport is measured as the proportion of time devoted to the activity "180501" by the reference mode of transport out of total commuting time throughout the day. Size of dots is proportional to the number of observations included for the calculation of average commuting time for the reference gasoline tax rate.

Table 1. State gasoline tax rates, by state and year

STATE	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2011	2013	2014	2015
Alabama	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
Alaska	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
Arizona	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
Arkansas	19.50	19.50	21.70	21.70	21.70	21.70	21.50	21.50	21.50	21.50	21.50	21.50	21.50	21.50	21.50	21.50
California	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	35.30	35.70	36.00	39.50	39.50	30.00
Colorado	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00
Connecticut	32.00	32.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
Delaware	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00
Dist. of Columbia	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	23.50	23.50	23.50	23.50	23.50	23.50	23.50
Florida	13.30	13.60	13.90	14.10	14.30	14.50	14.90	15.30	15.60	16.10	16.00	16.20	16.60	16.90	16.90	17.30
Georgia	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	26.00
Hawaii	16.00	16.00	16.00	16.00	16.00	16.00	16.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00
Idaho	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	32.00
Illinois	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00
Indiana	15.00	15.00	15.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
Iowa	20.00	20.00	20.10	20.10	20.30	20.70	20.70	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	30.80
Kansas	20.00	20.00	21.00	23.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00
Kentucky	16.40	16.40	16.40	16.40	16.40	18.50	19.70	21.00	22.50	24.10	25.60	26.40	28.50	30.90	30.90	24.60
Louisiana	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00
Maine	19.00	19.00	22.00	22.00	25.20	25.90	26.80	27.60	28.40	29.50	29.50	29.50	30.00	30.00	30.00	30.00
Maryland	23.50	23.50	23.50	23.50	23.50	23.50	23.50	23.50	23.50	23.50	23.50	23.50	23.50	23.50	23.50	32.10
Massachusetts	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	24.00	24.00	24.00
Michigan	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00
Minnesota	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	22.50	27.10	27.50	28.00	28.50	28.50	28.50	28.50
Mississippi	18.40	18.40	18.40	18.40	18.40	18.40	18.40	18.40	18.40	18.40	18.40	18.40	18.40	18.40	18.40	18.40
Missouri	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00
Montana	27.75	27.75	27.75	27.75	27.75	27.75	27.75	27.75	27.75	27.75	27.75	27.75	27.75	27.75	27.75	27.75
Nebraska	23.90	24.50	24.50	24.60	24.80	25.30	27.10	27.00	26.00	26.40	27.10	26.30	26.20	26.30	26.30	26.10
Nevada	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00
New Hampshire	19.50	19.50	19.50	19.50	19.50	19.50	19.60	19.60	19.60	19.60	19.60	19.63	19.63	19.63	19.63	23.83
New Jersey	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50
New Mexico	18.50	18.88	18.88	18.88	18.88	18.88	18.88	18.88	18.88	18.88	18.88	18.88	18.88	18.88	18.88	17.00
New York	21.45	22.05	22.65	22.05	22.65	23.25	23.95	24.65	24.45	25.15	24.35	25.05	25.85	26.65	26.65	25.85
North Carolina	22.00	24.30	24.20	23.40	24.30	26.60	29.90	29.95	30.15	30.15	32.15	35.25	37.95	37.75	37.75	36.25
North Dakota	21.00	21.00	21.00	21.00	21.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00
Ohio	22.00	22.00	22.00	24.00	26.00	28.00	28.00	28.00	28.00	28.00	28.00	28.00	28.00	28.00	28.00	28.00
Oklahoma	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00
Oregon	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	30.00	30.00	30.00	30.00	30.00
Pennsylvania	25.90	26.00	26.60	25.90	26.20	30.00	31.20	31.20	30.00	30.00	31.20	31.20	31.20	31.20	31.20	50.50

Rhode Island	29.00	29.00	29.00	29.00	30.00	30.00	30.00	30.00	30.00	30.00	32.00	32.00	32.00	32.00	32.00	33.00
South Carolina	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00
South Dakota	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	30.00
Tennessee	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00
Texas	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00
Utah	24.50	24.50	24.50	24.50	24.50	24.50	24.50	24.50	24.50	24.50	24.50	24.50	24.50	24.50	24.50	24.50
Vermont	19.00	19.00	19.00	19.00	19.00	19.00	19.00	20.00	21.00	20.00	20.00	20.00	20.00	19.20	19.20	19.20
Virginia	17.50	17.50	17.50	17.50	17.50	17.50	17.50	17.50	17.50	17.50	17.50	17.50	17.50	11.10	11.10	16.20
Washington	23.00	23.00	23.00	28.00	28.00	31.00	34.00	36.00	37.50	37.50	37.50	37.50	37.50	37.50	37.50	44.50
West Virginia	25.35	25.35	25.65	25.35	25.35	27.00	27.00	31.50	32.20	32.20	32.20	32.20	33.40	34.70	34.70	34.60
Wisconsin	25.80	26.40	27.30	28.10	28.50	29.10	29.90	30.90	30.90	30.90	30.90	30.90	30.90	30.90	30.90	30.90
Wyoming	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	24.00	24.00	24.00

Notes: Gasoline tax rates are obtained from the Highway Statistics Series Publications, released by the Federal Highway Administration, US Department of Transportation (https://www.fhwa.dot.gov/policyinformation/statistics.cfm). Gasoline tax rates are measured in cents/gallon.

Table 2. Commuting time and gasoline tax rates

Commuting Time	(1)	(2)	(3)
Gasoline tax rate	-0.08***	-0.07***	-0.07***
	(0.01)	(0.01)	(0.01)
Male	-	0.21***	0.21***
	-	(0.01)	(0.01)
Years of education	-	-0.00**	0.00
	-	(0.00)	(0.00)
Age	-	0.03***	0.03***
	-	(0.00)	(0.00)
Age squared	-	-0.03***	-0.03***
	-	(0.00)	(0.00)
In couple	-	0.07***	0.08***
	-	(0.01)	(0.01)
Spouse working	-	-0.10***	-0.09***
	-	(0.01)	(0.01)
Number of children<18	-	-0.02***	-0.02***
	-	(0.00)	(0.00)
Age youngest child	-	-0.00***	-0.00***
	-	(0.00)	(0.00)
Hourly wage	-	0.01***	0.01***
	-	(0.00)	(0.00)
Hourly wage squared	-	-0.00***	-0.00***
	-	(0.00)	(0.00)
Transport Performance Index	-	-	-0.01***
	-	-	(0.00)
Constant	3.68***	2.94***	-7.20***
	(0.03)	(0.07)	(1.75)
Observations	115,923	115,923	115,923
R-squared	0.001	0.054	0.062

*Notes:*Robust standard errors in parenthesis. Data come from the American Time Use Survey 2003-2015. Sample is restricted to workers who spent at least 60 minutes in market work activities, excluding commuting. Columns (2) and (3) also include dummy variables for the day of the week (ref.: Friday), and indicators to control for year and state fixed effects. The Transport Performance Index is obtained from the US Chamber of Commerce. Original survey weights are included in regressions. *Significant at the 10% level; **significant at the 5% level; ***significant at the 1% level.

Table 3. Proportion of commuting time by mode of transport and gasoline tax rates

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Percentage commuting by car			Percentage commuting by public transport			Percentage commuting by physical mode		
Gasoline tax rate	-0.35***	-0.34***	-0.36***	0.16***	0.16***	0.16***	0.23***	0.22***	0.26***
	(0.04)	(0.04)	(0.04)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
Male	-	0.00	0.00	-	-0.02***	-0.02***	-	0.00	0.00
	-	-0.01	-0.01	-	(0.01)	(0.01)	-	(0.01)	(0.01)
Years of education	-	0.01***	0.00**	-	0.00	0.00	-	0.00	0.00**
	-	0.00	0.00	-	(0.00)	(0.00)	-	(0.00)	(0.00)
Age	-	0.00	0.00	-	0.01***	0.01***	-	-0.01***	-0.01***
	-	0.00	0.00	-	(0.00)	(0.00)	-	(0.00)	(0.00)
Age squared	-	0.00	0.00	-	-0.01***	-0.01***	-	0.01***	0.01***
	-	0.00	0.00	-	(0.00)	(0.00)	-	(0.00)	(0.00)
In couple	-	0.18***	0.18***	-	-0.14***	-0.13***	-	-0.09***	-0.09***
	-	-0.02	-0.02	-	(0.01)	(0.01)	-	(0.01)	(0.01)
Spouse working	-	0.03**	0.02**	-	0.00	0.00	-	-0.03***	-0.03***
	-	-0.01	-0.01	-	(0.01)	(0.01)	-	(0.01)	(0.01)
Number of children<18	-	-0.01*	-0.01*	-	0.01**	0.01**	-	0.01**	0.01**
	-	-0.01	-0.01	-	(0.00)	(0.00)	-	(0.00)	(0.00)
Age youngest child	-	0.01***	0.01***	-	-0.00***	-0.00***	-	-0.00***	-0.00***
	-	0.00	0.00	-	(0.00)	(0.00)	-	(0.00)	(0.00)
Hourly wage	-	-0.00***	0.00	-	0.00***	0.00***	-	0.00***	0.00***
	-	0.00	0.00	-	(0.00)	(0.00)	-	(0.00)	(0.00)
Hourly wage squared	-	0.00	0.00	-	-0.00***	-0.00***	-	0.00	0.00
	-	0.00	0.00	-	(0.00)	(0.00)	-	(0.00)	(0.00)
Transport Performance Index	-	-	0.01***	-	-	-0.02***	-	-	-0.01***
	-	-	0.00	-	-	0.00	-	-	(0.00)
Constant	4.70***	4.30***	4.69**	-0.02	-0.11	3.08*	-0.03	0.06	7.27***
	(0.04)	(0.10)	(2.30)	(0.03)	(0.07)	(1.61)	(0.03)	(0.08)	(1.95)
State FE	No	No	Yes	No	No	Yes	No	No	Yes
Year FE	No	No	Yes	No	No	Yes	No	No	Yes
Observations	115,923	115,923	115,923	115,923	115,923	115,923	115,923	115,923	115,923
R-squared	0.00	0.01	0.02	0.00	0.01	0.02	0.00	0.01	0.01

Notes: Robust standard errors in parenthesis. Data come from the American Time Use Survey 2003-2015. Sample is restricted to workers who spent at least 60 minutes in market work activities. Columns (2), (3), (5), (6), (8) and (9) also include dummy variables for the day of the week (ref.: Friday), and indicators to control for year and state fixed effects. The Transport Performance Index is obtained from the US Chamber of Commerce. Original survey weights are included in regressions. *Significant at the 10% level; **significant at the 5% level; ***significant at the 1% level.

APPENDIX

Table A1
Summary Statistics of socio-demographic characteristics

Variables	(1)	(2)
Dependent variables	**Mean**	**Std. Dev.**
Commuting time	43.12	(39.91)
Proportion of commuting by private vehicle	91.61%	(25.51)
Proportion of commuting by public transport	2.70%	(14.27)
Proportion of commuting by physical mode	3.21%	(15.67)
Socio-demographic variables		
Male	0.55	(0.50)
Years of education	40.34	(2.77)
Age	38.66	(12.89)
In couple	0.67	(0.47)
Spouse working	0.49	(0.50)
Number of children<18	1.23	(1.31)
Age youngest child	4.32	(5.44)
Hourly wage	19.51	(15.49)
N. Observations	115,923	

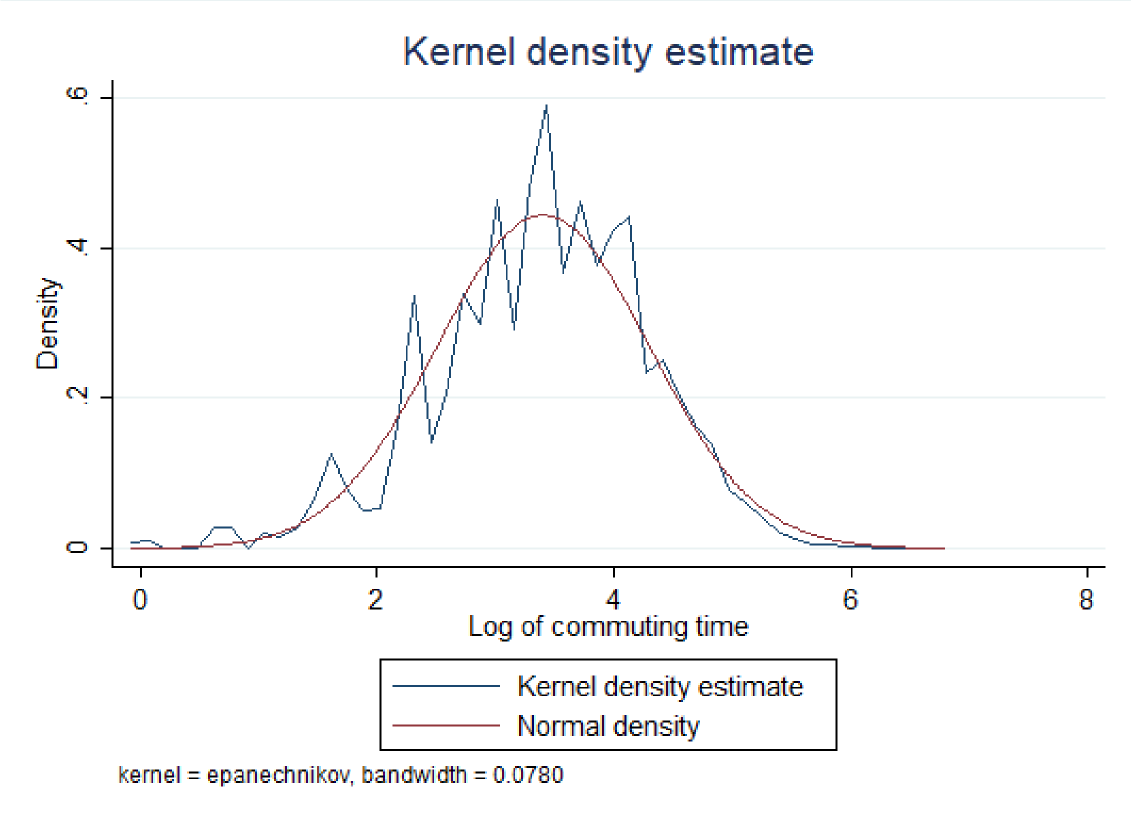
Notes: Data come from the American Time Use Survey 2003-2015. Sample is restricted to workers who spent at least 60 minutes in market work activities, excluding commuting. Original survey weights are included in computations.

Table A2
Values of the Transportation Performance Index, by State

North Dakota	85.12	**Colorado**	61.52	**Wisconsin**	57.26
South Dakota	74.47	**Indiana**	61.32	**Louisiana**	56.37
Nebraska	71.66	**Arizona**	61.05	**Pennsylvania**	56.16
Montana	70.89	**Michigan**	60.67	**Arkansas**	55.52
Iowa	67.65	**Alabama**	60.48	**Florida**	55.26
Kansas	66.78	**Tennessee**	60.44	**New York**	55.19
Vermont	66.26	**South Carolina**	60.38	**Connecticut**	53.81
Maine	66.15	**Georgia**	59.72	**North Carolina**	53.39
Wyoming	65.56	**Ohio**	59.64	**New Mexico**	52.59
Minnesota	65.02	**Missouri**	59.6	**Massachusetts**	52.19
Oregon	64.72	**Kentucky**	59.51	**California**	51.76
Virginia	63.77	**New Hampshire**	59.48	**Nevada**	51.64
Utah	63.37	**Texas**	59.46	**Hawaii**	49.98
Idaho	63.06	**Maryland**	58.57	**New Jersey**	46.71
Alaska	62.7	**Illinois**	58.33	**Dist. of Col.**	35.08
Oklahoma	62.34	**West Virginia**	57.76		
Washington	62.06	**Delaware**	57.43		
Mississippi	61.68	**Rhode Island**	57.29		

Source: US Chamber of Commerce, 2011. States are ordered by decreasing order of the value of the *Transportation Performance Index*.

Figure A1
Distribution of (log) commuting time



*Notes:*Data come from the American Time Use Survey 2003-2015. Sample is restricted to workers who spent at least 60 minutes in market work activities, excluding commuting. Original survey weights are included in computations.