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WHAT IF COMMUTING HAS DEMERIT PROPERTIES?

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Abstract

People spend a lot of their time commuting. Research in health economics indicates that spending time in traffic has long run adverse consequences for mental and physical health. Literature suggests that, when making decisions about commuting, the individual might underestimate these long run consequences and take them insufficiently into consideration. For this reason, we argue that commuting has demerit properties, a so-called internality is involved: decisions at some point in life influence well-being at a later point in life. From a policymaker's perspective, on top of the demerit aspect, commuting is also associated with an externality. If commuters underestimate the impact on their welfare of commuting, this aggravates also the externality. We propose a way in which both these demerit considerations and the externality can be incorporated into marginal costs of funds (MCF) formulae. The externality in our model both has a direct impact and a behavioural impact on other households' welfare. We calculate MCF for the United States to apply the model. We show that the demerit considerations cause rank switches in over half of the States and that an increase in the taxes on commuting accompanied by a decrease in other taxes benefits social welfare.

1 Introduction

This paper focuses on decisions to commute by car when agents suffer a behavioural bias: at the time they decide where to live and work, they underestimate the impact on their mental and physical health of spending time in the car. Consequently, agents make decisions against their own long term well-being by living too far from work and commuting too much. In this sense, commuting has demerit properties (Besley, 1988; Schroyen, 2010). These decisions based on a bad judgment lead to internalities (Allcott et al., 2014; Farhi and Gabaix, 2020), long term costs that are not considered by the individual when making his decision where to live and work.

One reason for the demerit properties is that future traffic is hard to predict. Traffic might increase over time and this information is not available at the moment the agent buys a house. Both in Europe and the US Commuting time has increased considerably over the last decades. Americans who commute by car spend on average 50 minutes per day driving (Roberts et al. 2011; Wener and Evans 2011). People might have bought a house some time ago, only to realise with time that traffic has increased and they lose more time in traffic than anticipated. Over time they suffer unforeseen negative health consequences.

The negative health impacts of spending time in the car have been abundantly documented in the literature. There appears to be an impact both on short run and long run physical health (e.g. obesity) and mental health (e.g. stress, fatigue). Gottholmseder et al. (2009) and Hansson et al. (2011) investigate the short run effects of commuting on stress, fatigue and other negative health outcomes. Perceived stress has been found to increase with the duration of commuting, its variability, lack of predictability, lack of control, effort and crowding (congestion). The negative health outcomes are related to shorter sleeping time or having less time to exercise. Commuting and congestion elevate blood pressure and can lead to higher absenteeism (Wener and Evans, (2011)). Hilbrecht et al. (2014) show that time spent commuting leads to an increased sense of time pressure. Related to this, Roberts et al. (2011) report that women suffer more from commuting than men, which is due to the fact that they are more involved in household chores, such as picking up children from school or grocery shopping. Wener and Evans (2011) have shown that effort and unpredictability are considerably higher for commuting by car than for commuting by train. Edwards (2008), Humphreys et al. (2013), Martin et al. (2014) and Lades et al. (2020) show that physical well-being increases when workers commute in an active way.

Commuting may also negatively impact on subjective well-being. Commuters often find it a burden to be in traffic, for instance Kahneman and Krueger (2006) show that commuting is one of the least pleasant activities people experience. Stutzer and Frey (2008), Hilbrecht et al. (2014) and Ingenfeld et al. (2019) provide evidence that commuting by car leads to lower subjective well-being, and St-Louis et al. (2014) show that pedestrians and cyclists have higher levels of life satisfaction than car drivers.

The question is whether workers take these long run physical and mental health effects into consideration when they decide where to live and work. They trade-off the time loss due to commuting against having a higher wage or a bigger or better quality house (Clark et al., 2003; Ingenfeld et al., 2019). Workers might underestimate the negative health effects of commuting due to limited foresight or behave time-inconsistently (Gruber and Koszegi, 2004). Calastri et al., (2019) analyse modal choice when individuals are boundedly rational and imitate others when they take decisions. Another reason could be that they discount the future too much, have insufficient information at their disposal about commuting time or about its consequences on health, or that future congestion is unpredictable due to increased car use. If any of these is the case, commuting has demerit properties and a social planner could improve upon the decisions individuals make.

An important complication associated with commuting is congestion. One commuter's behaviour influences other commuters' time spent commuting. In other words, there is an externality. As a result, the behavioral consequences of demerit arguments of commuting not only affect the commuter himself, but also the other commuters. Consequently, congestion exacerbates the demerit problem, as it causes commuters to spend even more time in traffic. The demerit problem leads to more congestion and congestion increases demerit problems.

When designing tax policy, both the demerit and the externality problem, and their interaction, should be taken in consideration. This type of policy is to some extent paternalistic as the policy-maker does not fully accept individuals' preferences as they are revealed at the moment of decision. But in the long run they improve well-being, as these policies have positive benefits for long run physical and mental health.

In this article we develop a model incorporating explicitly both the demerit / internality considerations and the externality considerations (see also Allcott et al. (2014)). We show formally that car use entails an externality in two ways. First, commuting has a direct impact on other car users' utility: others suffer annoying time loss. Second, commuting has consequences for behaviour as commuting increases the time cost to be in traffic and hence changes the trade-off between leisure and working time. Both effects deserve attention and both effects need to be corrected for demerit considerations. The direct effect of an externality is present in types of externality problems, but not always. An example could be a passive smoker spending time with a smoking friend. The passive smoker experiences a direct nuisance. At the same time, the passive smoker loses more time washing clothes. So smoking changes the relative price of newly washed clothes for passive smokers. This induces the passive smoker to spend more time and money on washing clothes.

We derive marginal costs of funds (MCF) expressions for three policy instruments: the income tax, a tax on commuting and a poll transfer. Our work builds on Mayeres and Proost (2001), who take into account an externality in the MCF, and Schroyen (2010), who considers an internatlity. We proceed by calculating the marginal costs of funds for three different instruments in this non-welfarist setting. We provide numerical estimates of the MCF for the 50 U.S. States, using time use data from the American Time Use Survey (ATUS). This will allow us to judge whether state specific tax reforms can be organised that increase social welfare, and to what extent that judgment depends on the demerit arguments we make.

Section 2 develops the framework and derives the MCF formulae, in section 3 the numerical application is provided and section 4 concludes.

2 Framework

We first introduce the model of household behaviour for a single earner household in the absence of taxation, and show how the traffic externality affects each household's budget constraint.[1] Next we explain how the demerit effect is incorporated and we analyze the social welfare function. Finally we introduce taxation and derive the marginal cost of funds.

2.1 Household behaviour

There are N households in the economy, indexed by $h \in \{1, \ldots, N\}$. Households spend their time either working, H^h, in leisure, L^h, or commuting, C^h.[2] As their total time endowment is normalized to 1, we have that

$$H^h + L^h + C^h = 1. \tag{1}$$

We assume that the time spent commuting is a fraction of the time not spent on leisure. This fraction is increasing in a congestion externality E, such that

$$C^h = c^h(E)\left[1 - L^h\right], \tag{2}$$

with $c^h(E)$ an increasing function. Combining (1) and (2) gives

$$H^h = \left(1 - c^h(E)\right)\left[1 - L^h\right]. \tag{3}$$

Clearly, $c^h(E)$ creates a wedge between working time and leisure time. The function $c^h(E)$ is determined by the household's characteristics such as the distance from the household's home to work or the type of roads used to commute.[3] We assume that households do not take into consideration the impact of their own commuting on E: they take the externality as given.

Household h's preferences over consumption, x^h, leisure time and commuting time can be represented by a differentiable and quasi concave utility function

$$u^h\left(x^h, L^h, C^h\right).$$

This function is increasing in x^h and L^h, and decreasing in C^h. As a consequence, using (2), household preferences can also be represented in two dimensions through the utility function

$$v^h(x^h, L^h) = u^h\left(x^h, L^h, c^h(E)\left[1 - L^h\right]\right), \tag{4}$$

which is increasing in its arguments x^h and L^h:

$$\frac{\partial v^h}{\partial x^h} = \frac{\partial u^h}{\partial x^h} > 0, \tag{5}$$

$$\frac{\partial v^h}{\partial L^h} = \frac{\partial u^h}{\partial L^h} - \frac{\partial u^h}{\partial C^h} c^h(E) > 0. \tag{6}$$

The household faces a budget constraint. It has two sources of income: income from work and non-labour income T^h. The wage the household earns if it spends its entire day working is w^h. Income can be spent on consumption of the good x^h with price normalized to 1, and commuting with price p^h. We assume that all commuting is done by car. The price of commuting includes gasoline and car purchase, and is household specific. This results in the household's budget constraint:

$$x^h + p^h C^h \leq w^h H^h + T^h.$$

[1] The two earner household is analysed in appendix C.

[2] In the basic model the household only contains one working individual. In appendix C the model is extended to households in which two people are working.

[3] Our analysis is a short run analysis. In the short run transaction costs related to moving house or changing jobs prevent the household to adapt to changes in policy variabels. Hence we don't consider these margins of adjustment.

After substituting (2) and (3) the budget constraint can be written as

$$x^h + \left[w^h - c^h(E)\left[w^h + p^h\right]\right] L^h = w^h - c^h(E)\left[w^h + p^h\right] + T^h. \tag{7}$$

In (7) the inequality sign has been replaced by an equality sign: (5) and (6) show that utility is increasing in both x^h and L^h such that the budget constraint always holds with equality. The right-hand side of expression (7) is the income a household would generate if it had no leisure and spends all its time working and commuting. The price of leisure

$$p_R^h = w^h - c^h(E)\left[w^h + p^h\right], \tag{8}$$

the wage rate corrected for the fact that work requires commuting, and commuting is both time consuming ($c^h(E)w^h$) and gasoline consuming ($c^h(E)p^h$). Hence $c^h(E)$ decreases the relative price of leisure. The budget constraint in the $L^h \times x^h$- plane is given by

$$x^h = p_R^h\left[1 - L^h\right] + T^h. \tag{9}$$

Maximizing $v^h(x^h, L^h)$ with respect to x^h and L^h subject to budget constraint (9), yields the following first order conditions:

$$\frac{\frac{\partial v^h}{\partial x^h}}{\lambda^h} = 1, \tag{10}$$

$$\frac{\frac{\partial v^h}{\partial L^h}}{\lambda^h} = p_R^h, \tag{11}$$

with λ^h the Lagrangian multiplier associated with the budget constraint; λ^h equals household h's marginal utility of income. The left hand side of expressions (10) and (11) measures household h's marginal willingness to pay (in monetary terms) for consumption and leisure. From the first order conditions above, in the optimum, the marginal rate of substitution between consumption and leisure is equal to the relative price of consumption and leisure

$$\frac{\frac{\partial v^h}{\partial L^h}}{\frac{\partial v^h}{\partial x^h}} = p_R^h. \tag{12}$$

The solution to the optimization problem yields the Marshallian demands for x^h and L^h and can be written as:

$$x^h = x^h\left(p_R^h, T^h\right), \tag{13}$$

$$L^h = L^h\left(p_R^h, T^h\right), \tag{14}$$

while commuting time C^h and working time H^h follow from (2), (3) and (14).

2.2 Traffic externality

While individual households take the traffic externality as given, the social planner takes the externality into account when designing policy. Hence to find the socially optimal policy, we need to specify how the externality is determined. We assume that the total amount of traffic is an increasing function of all households' commuting time:

$$E = E\left(C^1, \ldots, C^N\right). \tag{15}$$

From (15) and (4) it is clear that a decrease in commuting by household h directly decreases the commuting time and hence the utility cost of commuting for *all* households. Moreover, if a household decreases its commuting time, E decreases, and (8) implies that p_R^h increases. From budget constraint (9) it follows that every household's budget constraint rotates upwards in the $L^h \times x^h$- plane, through

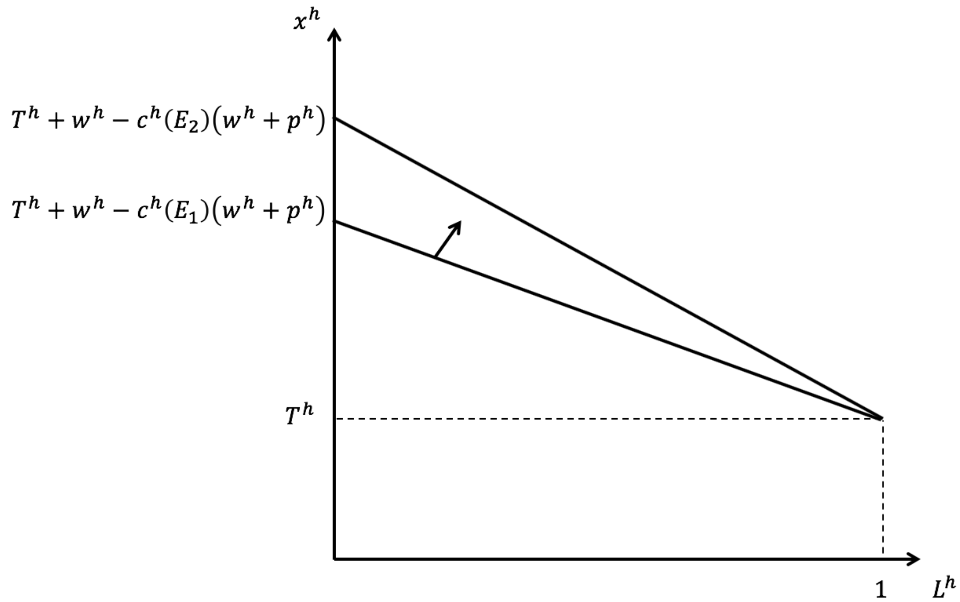

Figure 1: The budget constraint.

the point with ordinates $(1, T^h)$. Figure 1 illustrates this rotation of the budget constraint, when E decreases form E_1 to E_2.

Both the decreased utility cost of commuting and the expansion of the budget set make every houshehold better off. The decrease in the amount of commuting time also affects preferences between x^h and L^h - see (4). As a result of the change in preferences and the expansion of the budget set every household's Marshallian demand for consumption and leisure changes.

2.3 demerit effect

As argued in the introduction, we assume that according to the planner commuting has demerit properties due to its adverse short run and long run health effects. We proceed as in Schroyen (2005, 2010), who applies the approach to a private (de)merit good. The planner rejects consumer sovereignty: he judges the households' preferences as faulty and that households suffer more from commuting than they are aware of. Instead of (4) the planner uses the following utility function to evaluate household h's well-being.

$$V^h(x^h, L^h) = v^h\left(x^h, L^h\right) - d^h\left(c^h(E)\left[1 - L^h\right]\right), \tag{16}$$

such that the increasing function $d^h\left(c^h(E)\left[1 - L^h\right]\right)$ gives the demerit effect of commuting on well-being. The derivatives of $V^h(x^h, L^h)$ with respect to its arguments are

$$\begin{aligned}
\frac{\partial V^h\left(x^h, L^h\right)}{\partial x^h} &= \frac{\partial v^h\left(x^h, L^h\right)}{\partial x^h}, \\
\frac{\partial V^h\left(x^h, L^h\right)}{\partial L^h} &= \frac{\partial v^h\left(x^h, L^h\right)}{\partial L^h} + \frac{\partial d^h\left(c^h(E)\left[1 - L^h\right]\right)}{\partial C^h} c^h(E).
\end{aligned}$$

Consequently, the planner's marginal rate of substitution between consumption and leisure for well-being of individual h is

$$\frac{\frac{\partial V^h}{\partial L^h}}{\frac{\partial V^h}{\partial x^h}} = \frac{\frac{\partial v^h}{\partial L^h}}{\frac{\partial v^h}{\partial x^h}} + \frac{\frac{\partial d^h\left(c^h(E)\left[1 - L^h\right]\right)}{\partial C^h}}{\frac{\partial v^h}{\partial x^h}} c^h(E). \tag{17}$$

Define

$$S^P_{x^h,C^h} = \frac{\frac{\partial d^h\left(c^h(E)\left[1-L^h\right]\right)}{\partial C^h}}{\frac{\partial v^h}{\partial x^h}}, \tag{18}$$

the (planner's) marginal rate of substitution between the demerit effect of commuting and consumption of household h. It measures how many units of consumption of household h the planner is willing to give up to reduce the demerit caused by household h's commuting with one unit such that the household's welfare as measured by the planner remains constant. Use of (18) and (12) in (17) yields

$$\frac{\frac{\partial V^h}{\partial L^h}}{\frac{\partial V^h}{\partial x^h}} = p^h_R + c^h(E) \cdot S^P_{x^h,C^h} > p^h_R, \tag{19}$$

such that in the household's chosen optimum, the indifference curve used by the planner is steeper than the slope of the household's indifference curve which equals the slope of the budget constraint, p^h_R, implying that the planner would like the household to have more leisure.[4] The difference between the slope of both indifference curves is the second term behind the equality in (19), the product of $c^h(E)$ and $S^P_{x^h,C^h}$.

2.4 Social welfare

Now we take the step from the private value to the social value of commuting and leisure by taking into account both demerit and externality considerations. Suppose the planner evaluates social welfare using an additive Bergson-Samuelson social welfare function W, with $\gamma^h > 0$ the welfare weight attributed to household h:

$$W = \sum_{h=1}^{N} \gamma^h V^h\left(x^h, L^h\right). \tag{20}$$

Substitution of (16) and (4) into this expression yields

$$W = \sum_{h=1}^{N} \gamma^h \left[u^h\left(x^h, L^h, c^h(E)\left[1-L^h\right]\right) - d^h(c^h(E)\left[1-L^h\right])\right]. \tag{21}$$

The derivative of expression (21) with respect to x^h is, using (5) and (10),

$$\frac{\partial W}{\partial x^h} = \gamma^h \frac{\partial u^h}{\partial x^h} = \gamma^h \lambda^h. \tag{22}$$

The derivative of expression (21) with respect to L^h is

$$\begin{aligned}\frac{\partial W}{\partial L^h} &= \gamma^h \left[\frac{\partial u^h}{\partial L^h} - c^h(E)\left[\frac{\partial u^h}{\partial C^h} - \frac{\partial d^h}{\partial C^h}\right]\right] \\ &+ \sum_{k=1}^{N} \gamma^k \left[\frac{\partial u^k}{\partial C^k} - \frac{\partial d^k}{\partial C^k}\right]\left[1-L^k\right] \frac{\partial c^k(E)}{\partial E}\frac{\partial E}{\partial C^h}\left(-c^h(E)\right) \\ &+ \sum_{k=1}^{N} \gamma^k \left[\frac{\partial u^k}{\partial x^k}\frac{\partial x^k}{\partial p^k_R} + \left[\frac{\partial u^k}{\partial L^k} - \left[\frac{\partial u^k}{\partial C^k} - \frac{\partial d^k}{\partial C^k}\right] c^k(E)\right]\frac{\partial L^k}{\partial p^k_R}\right]\frac{\partial p^k_R}{\partial L^h}.\end{aligned} \tag{23}$$

[4] As pointed out by Capéau and Ooghe (2003) and Schroyen (2005), this is not guaranteed in the alternative approach proposed by Besley (1988). See appendix A.

Using (5) and (6) in the first and third line of (23), we get

$$\begin{aligned}
\frac{\partial W}{\partial L^h} &= \gamma^h \left[\frac{\partial v^h}{\partial L^h} + c^h(E)\frac{\partial d^h}{\partial C^h}\right] \\
&+ \sum_{k=1}^{N} \gamma^k \left[\frac{\partial u^k}{\partial C^k} - \frac{\partial d^k}{\partial C^k}\right]\left[1-L^k\right]\frac{\partial c^k(E)}{\partial E}\frac{\partial E}{\partial C^h}\left(-c^h(E)\right) \\
&+ \sum_{k=1}^{N} \gamma^k \left[\frac{\partial v^k}{\partial x^k}\frac{\partial x^k}{\partial p_R^k} + \frac{\partial v^k}{\partial L^k}\frac{\partial L^k}{\partial p_R^k} + \frac{\partial d^k}{\partial C^k}c^k(E)\frac{\partial L^k}{\partial p_R^k}\right]\frac{\partial p_R^k}{\partial L^h}.
\end{aligned}$$

The first order conditions (10) and (11) allow us to rewrite this as

$$\begin{aligned}
\frac{\partial W}{\partial L^h} &= \gamma^h\lambda^h \left[p_R^h + \frac{1}{\lambda^h}c^h(E)\frac{\partial d^h}{\partial C^h}\right] \\
&+ \sum_{k=1}^{N} \gamma^k \left[\frac{\partial u^k}{\partial C^k} - \frac{\partial d^k}{\partial C^k}\right]\left[1-L^k\right]\frac{\partial c^k(E)}{\partial E}\frac{\partial E}{\partial C^h}\left(-c^h(E)\right) \\
&+ \sum_{k=1}^{N} \gamma^k\lambda^k \left[\frac{\partial x^k}{\partial p_R^k} + p_R^k\frac{\partial L^k}{\partial p_R^k} + \frac{1}{\lambda^h}\frac{\partial d^k}{\partial C^k}c^k(E)\frac{\partial L^k}{\partial p_R^k}\right]\frac{\partial p_R^k}{\partial L^h}.
\end{aligned} \tag{24}$$

Differentiating the budget constraint for household k (expression (7) with h replaced by k) with respect to p_R^k we find that

$$\frac{\partial x^k}{\partial p_R^k} + p_R^k\frac{\partial L^k}{\partial p_R^k} = 1 - L^k.$$

Using this in expression (24), we find

$$\begin{aligned}
\frac{\partial W}{\partial L^h} &= \gamma^h\lambda^h \left[p_R^h + c^h(E)\frac{\frac{\partial d^h}{\partial C^h}}{\lambda^h}\right] \\
&+ \sum_{k=1}^{N} \gamma^k\lambda^k \left[-\frac{\frac{\partial u^k}{\partial C^k}}{\lambda^k} + \frac{\frac{\partial d^k}{\partial C^k}}{\lambda^k}\right]\left[1-L^k\right]\frac{\partial c^k(E)}{\partial E}\frac{\partial E}{\partial C^h}c^h(E) \\
&+ \sum_{k=1}^{N} \gamma^k\lambda^k \left[\left(1-L^k\right) + \frac{\frac{\partial d^k}{\partial C^k}}{\lambda^k}c^k(E)\frac{\partial L^k}{\partial p_R^k}\right]\frac{\partial p_R^k}{\partial L^h}.
\end{aligned} \tag{25}$$

Household k's marginal rate of substitution between commuting and consumption is given by

$$S^k_{x^k,C^k} = -\frac{\frac{\partial u^k}{\partial C^k}}{\lambda^k}, \tag{26}$$

and measures the consumption household k is willing to give up to decrease commuting by one unit. Using (18) and (26), (25) becomes

$$\begin{aligned}
\frac{\partial W}{\partial L^h} &= \gamma^h\lambda^h \left[p_R^h + c^h(E)\cdot S^P_{x^h,C^h}\right] \\
&+ \sum_{k=1}^{N} \gamma^k\lambda^k \left[S^k_{x^k,C^k} + S^P_{x^k,C^k}\right]\left[1-L^k\right]\frac{\partial c^k(E)}{\partial E}\frac{\partial E}{\partial C^h}c^h(E) \\
&+ \sum_{k=1}^{N} \gamma^k\lambda^k \left[\left(1-L^k\right) + S^P_{x^k,C^k}\cdot c^k(E)\frac{\partial L^k}{\partial p_R^k}\right]\frac{\partial p_R^k}{\partial L^h}.
\end{aligned} \tag{27}$$

Observe that, from (8), the effect of L^h on p_R^k is given by

$$\frac{\partial p_R^k}{\partial L^h} = \left[w^k + p^k\right]\frac{\partial c^k(E)}{\partial E}\frac{\partial E}{\partial C^h}c^h(E) > 0.$$

The interpretation of the terms on the different lines of expression (27) goes as follows. Ignore, for the time being, the externality (terms depending on utility levels of other households than h) and the demerit effect ($S^P_{x^k,C^k}$). The term on the first line gives the effect of L^h on the planner's evaluation of the well being of household h and thereby on W. It is the product of the welfare weight of household h and household h's willingness to pay for leisure, p^h_R. The only social value of leisure time is the household's own valuation of it. Now consider the externality. The second and the third line run through the externality: the increase in L^h decreases C^h and lowers E. The second line gives the direct effect the increase in E has on the planner's evaluation of the utility levels of all households. If household h takes more leisure, all households directly benefit from that because they will lose less time in traffic. The effect is transformed in monetary terms by multiplying it with the marginal rate of substitution between commuting and leisure and the welfare weight of each household. The third line is the effect of the decrease of E on the price of leisure of each households, which in turn leads to behavioural change and so influences the planner's evaluation of the utility levels of all households. As $\frac{\partial p^k_R}{\partial L^h} > 0$, the effect on the planner's valuation of an increase in L^h is positive. It shifts in every household's budget line upwards, as illustrated in Figure 1.[5]

This price effect in the third line is specific to our commuting problem. It is absent in most other externality settings such as those dealing with carbon dioxide emissions or pollution as these types of externality only have a minor influence on prices in the economy. In the context of passive smoking, the direct effect could refer to the hindrance the passive smoker experiences when other people smoke, the price effect could refer to the passive smoker's behavioural change due to the fact that passive smoking changes the value of time spent with a smoker (e.g. it is necessary to wash clothes more often, the passive smoker might avoid to meet the smoker...).

Now we consider the demerit considerations. In each of the lines of expression (27) the demerit effect plays its role through $S^P_{x^h,C^h}$. In the first line the effect on the demerit adjustment of an increase in L^h is positive for the planner's evaluation of individual h's utility. The reason is that an increase in L^h decreases C^h, which decreases the demerit adjustment d^h, such that $V^h(x^h, L^h)$ increases. In the second and third line the demerit effect arises because of the externality: if L^h increases, C^h decreases such that E decreases. This, in turn, has two effects. The demerit effect on the second line gives the direct positive effect the decreased externality has on the planner's evaluation of every individual's well being through the smaller demerit adjustment d^k. The demerit effect on the third line quantifies the effect of the externality through the change in behavior caused by the change in the relative price of leisure. The relative price of leisure increases, and if this increases (decreases) household k's demand for leisure, household k's commuting time decreases (increases), which reduces (increases) the size of the demerit adjustment d^k and increases (decreases) the well being assigned by the planner to household k. The sign of this last term thus depends on the behavioral response of household k's leisure time to the increase of the price of leisure.

2.5 Taxation

We introduce 3 tax rates in the model: a lump sum tax T that affects households' non-labour income, a proportional tax on earnings t_w and a proportional tax on commuting time t_C. As a result the household's budget constraint becomes

$$x^h + \left[p^h + t_C\right] C^h = [1 - t_w]\, w^h H^h + T^h - T,$$

which can be written as

$$x^h = p^h_R \left[1 - L^h\right] + T^h - T, \tag{28}$$

with

$$p^h_R = [1 - t_w]\, w^h - c^h(E) \left[[1 - t_w]\, w^h + p^h + t_C\right]. \tag{29}$$

[5]Note that the effect on W depends on the sign of $\left(\frac{\partial x^k}{\partial p^k_R} + p^k_R \frac{\partial L^k}{\partial p^k_R}\right) \frac{\partial p^k_R}{\partial L^h}$. In our commuting problem, this will be a positive number. Situations in which this is a negative number are also conceivable.

Denote the social planner's revenue as $R(t)$:

$$R(t) = \tilde{R} - NT + t_C \sum_{h=1}^{N} c^h (E) \left(1 - L^h\right) + \sum_{h=1}^{N} t_w w^h H^h,$$

with $\tilde{R}$ exogenous revenue. Now we derive the consequences for revenue of the three policy instruments. The derivative of R with respect to the three policy instruments are

$$\begin{aligned}
\frac{\partial R}{\partial t_C} &= \sum_{h=1}^{N} c^h (E) \left(1 - L^h\right) + \sum_{h=1}^{N} t_C \left(1 - L^h\right) \frac{\partial c^h}{\partial E} \frac{\partial E}{\partial t_C} - \sum_{h=1}^{N} c^h (E) \frac{\partial L^h}{\partial P_R^h} \frac{\partial P_R^h}{\partial t_C} \\
&\quad + \sum_{h=1}^{N} t_w \frac{\partial H^h}{\partial P_R^h} \frac{\partial P_R^h}{\partial t_C}, \qquad (30) \\
\frac{\partial R}{\partial t_w} &= \sum_{h=1}^{N} w^h H^h + t_C \sum_{h=1}^{N} \left(1 - L^h\right) \frac{\partial c^h}{\partial E} \frac{\partial E}{\partial t_w} \\
&\quad - t_C \sum_{h=1}^{N} c^h (E) \frac{\partial L^h}{\partial P_R^h} \frac{\partial P_R^h}{\partial t_w} + \sum_{h=1}^{N} t_w \frac{\partial H^h}{\partial P_R^h} \frac{\partial P_R^h}{\partial t_w}, \qquad (31) \\
\frac{\partial R}{\partial T} &= -N + t_C \sum_{h=1}^{N} \left(1 - L^h\right) \frac{\partial c^h}{\partial E} \frac{\partial E}{\partial T} - t_C \sum_{h=1}^{N} c^h (E) \frac{\partial L^h}{\partial T} + \sum_{h=1}^{N} w^h t_w \frac{\partial H^h}{\partial T}. \qquad (32)
\end{aligned}$$

2.6 Marginal Costs of Funds

Marginal cost of funds can be calculated for a variety of tax instruments, as in Ahmad and Stern (1984); Brendemoen and Vennemo (1996); Schöb (1996); Mayeres and Proost (2001); Dahlby and Ferede (2012). They measure the cost, in terms of social welfare, of a change of a number of tax rates yielding one dollar of tax revenue:

$$MCF_{t_i} = -\frac{\frac{\partial W}{\partial t_i}}{\frac{\partial R}{\partial t_i}}. \qquad (33)$$

We calculate, at state level, MCF_i for our three taxes t_C, t_w and T to illustrate the size of demerit and externality effects in a commuting setting in the United States. If the MCF_i differ, a budget neutral welfare increasing tax reform can be proposed at state level by increasing the tax which has the lowest marginal cost of funds and decreasing the tax with the highest marginal cost of funds.

The denominators of expression (33) are found in (30), (31) and (32). The numerators are given by the derivatives of social welfare function (20) with respect to each of the three tax instruments:

$$\begin{aligned}
\frac{\partial W}{\partial t_C} &= \sum_{h=1}^{N} \frac{\partial W}{\partial x^h} \frac{\partial x^h}{\partial p_R^h} \frac{\partial p_R^h}{\partial t_C} + \sum_{h=1}^{N} \frac{\partial W}{\partial L^h} \frac{\partial L^h}{\partial p_R^h} \frac{\partial p_R^h}{\partial t_C}, \qquad (34) \\
\frac{\partial W}{\partial t_w} &= \sum_{h=1}^{N} \frac{\partial W}{\partial x^h} \frac{\partial x^h}{\partial p_R^h} \frac{\partial p_R^h}{\partial t_w} + \sum_{h=1}^{N} \frac{\partial W}{\partial L^h} \frac{\partial L^h}{\partial p_R^h} \frac{\partial p_R^h}{\partial t_w}, \qquad (35) \\
\frac{\partial W}{\partial T^h} &= \sum_{h=1}^{N} \frac{\partial W}{\partial x^h} \frac{\partial x^h}{\partial T^h} + \sum_{h=1}^{N} \frac{\partial W}{\partial L^h} \frac{\partial L^h}{\partial T^h}. \qquad (36)
\end{aligned}$$

Before calculating the marginal costs of funds, we pay attention to its building blocks. It is clear that there is only one price in the model: the relative price of leisure p_R^h. The effects of the taxes on p_R^h will play an important role in the calculations. The derivatives of p_R^h with respect to t_C and t_w can be found from equation (29). This yields the following expressions:

$$\begin{aligned}\frac{\partial p_R^h}{\partial t_C} &= -c^h(E) - \left[w^h(1-t_w) + p^h + t_C\right]\frac{\partial c^h}{\partial E}\frac{\partial E}{\partial t_C},\\ \frac{\partial p_R^h}{\partial t_w} &= -w^h\left(1-c^h(E)\right) - \left[w^h(1-t_w) + p^h + t_C\right]\frac{\partial c^h}{\partial E}\frac{\partial E}{\partial t_w}.\end{aligned}$$

Note that the terms $\frac{\partial E}{\partial t_C}$ and $\frac{\partial E}{\partial t_w}$ measure the impact of the taxes through the commuting behaviour of other commuters. An increase in t_c might reduce commuting, which in turn might attract extra commuters. Mayeres and Proost (2001) refer to the effect as the externality feedback loop. Using appendix E, the expressions can be written as

$$\frac{\partial p_R^h}{\partial t_C} = -c^h(E) + \left[w^h(1-t_w) + p^h + t_C\right]\frac{\partial c^h}{\partial E}\frac{\sum_{k=1}^N \frac{\partial E}{\partial C^k}\frac{\partial C^k}{\partial L^k}\frac{\partial L^k}{\partial p_R^k}\frac{\partial p_R^k}{\partial t_C}\Big|_{\bar{E}}}{1-\sum_{k=1}^N \frac{\partial E}{\partial C^k}\frac{\partial C^k}{\partial L^k}\frac{\partial L^k}{\partial p_R^k}\frac{\partial p_R^k}{\partial c^k}\frac{\partial c^k}{\partial E}}, \tag{37}$$

$$\frac{\partial p_R^h}{\partial t_w} = -w^h\left(1-c^h(E)\right) + \left[w^h(1-t_w) + p^h + t_C\right]\frac{\partial c^h}{\partial E}\frac{\sum_{k=1}^N \frac{\partial E}{\partial C^k}\frac{\partial C^k}{\partial L^k}\frac{\partial L^k}{\partial p_R^k}\frac{\partial p_R^k}{\partial t_w}\Big|_{\bar{E}}}{1-\sum_{k=1}^N \frac{\partial E}{\partial C^k}\frac{\partial C^k}{\partial L^k}\frac{\partial L^k}{\partial p_R^k}\frac{\partial p_R^k}{\partial c^k}\frac{\partial c^k}{\partial E}}. \tag{38}$$

The price of leisure p_R^h, together with the household's non labour income T^h, influences the household's choice of leisure time

$$L^h = L^h\left(p_R^h, T^h\right).$$

The derivative of L^k with respect to P_R^h is calculated in appendix D as

$$\frac{\partial L^k}{\partial p_R^k} = -\left(\frac{1}{1-c^k}\right)^2 \frac{1}{1-t_w}\varepsilon_H^{wk}\frac{H^k}{w^k}. \tag{39}$$

From the budget constraint (28),

$$x^h = p_R^h\left(1 - L^h\left(p_R^h, T^h\right)\right) + T^h - T.$$

Consequently, the derivative of x^h with respect to p_R^h is (see appendix D)

$$\frac{\partial x^h}{\partial p_R^h} = \left(1-L^h\right) - p_R^h\left[-\left(\frac{1}{1-c^k}\right)^2\frac{1}{1-t_w}\varepsilon_H^{wk}\frac{H^k}{w^k}\right]. \tag{40}$$

3 Numerical application

Now, solving the systems of simultaneous equations with typical equations defined by (37) and (38), and using (22), (25), (33), (34), (35), (36), (39), (40), (30), (31), (32), the marginal cost of funds of the three instruments can be calculated. In the numerical application we calculate these three Marginal Costs of Funds for the United States in order to analyse the impact of an increase in the demerit parameter.

3.1 Data

In order to calculate the marginal cost of funds, three types of information are needed. First, we need information on the sizes of the behavioral responses $\frac{\partial L^h}{\partial P_R^h}$ and $\frac{\partial L^h}{\partial T^h}$, and the effect of the externality on the fraction of time spent commuting, $\frac{\partial c^h}{\partial E}$. Second, we need information on time use of different types of households in the United States. Third, we need information on tax rates on income and commuting.

3.1.1 Wage elasticity of labour supply

The size of the behavioural response is taken from the overview article of Bargain et al. (2014), who provide information on own wage elasticity of labour supply, cross-wage elasticity of labour supply for couples in which two members are working and income elasticity of labour supply. These elasticities are provided separately for men and women, with and without children, single and married. This allows us to distinguish several types of families. B.3 provides overview statistics. The own wage elasticity for women is larger than for men, and larger for singles than for individuals in a family. Income elasticities of labour supply are very small and are negative for singles and positive for individuals in a family. These elasticities are transformed into derivatives in appendix D.

3.1.2 Time use data and socio-demographic information

We rely on time use information from the American Time Use Survey (ATUS) 2003-2022, a continuous survey on time use in the United States with the purpose to develop nationally representative estimates of how American people spend their time. This dataset contains information on both the sampled households' socio-demographic characteristics from the CPS (Current Population Survey) and time use of one member of each sampled household who kept track of his or her time use during one so-called diary day.[6] We focus only on individuals who reported to be working on the diary day, who reported on a week day, who commuted to work by car, and for whom no data missings were found. This means that students, retired people, househusbands or housewives are eliminated from the sample. This results in a total of 19,999 observations. The sample contains 5,675 singles, 3,192 singles with children, 1,062 one earner couples without children, 1,610 one earner couples with children, 3,049 two earner couples without children, and 5,411 two earner couples with children. A household is considered to have children if the children stay under the same roof.

We retrieved information on working time H^h, leisure time L^h and commuting time C^h for each household in the sample. See appendix B for an overview of all time use information in the ATUS. Table B.2 provides summary statistics of time use per state per household type, expressed as a percentage of a full day of 24 hours (1440 minutes). On average individuals in the sample spend around 64% of their day on leisure (including sleeping), around 33% (i.e. 8 hours) working and a bit less than 2.70% (i.e. around 40 minutes) commuting. Commuting time C^h is travel time related to work.

Average commuting time from home to work, according to the US Census Bureau, is about 25 minutes (one way) per day in 2017, so 50 minutes go and return. In our dataset, average commuting time is a bit lower, around 40 minutes. This may be due to several reasons. The first one is that the ATUS only counts travel after work as commuting only if it is home-bound travel. If the worker chooses to visit friends or family underway, or goes grocery shopping, ATUS commuting time might underestimate actual commuting. The second reason has to do with the fact that not all commuting is done by car, while in our dataset we only focus on commuters by car.

The variable c^h, the fraction of commuting time in non leisure time is computed as

$$c^h = \frac{C^h}{1 - L^h}.$$

In order to calculate P_R^h, information is needed on w^h, c^h and p^h - see (29). Information on w^h and c^h can be retrieved from the ATUS dataset, see table B.2 for summary statistics. The former

[6] ATUS respondents are randomly drawn from a subset of households that completed the CPS. They are interviewed only once about their activities the previous day, where they spend their time and with whom. The sampling happens in three stages. In the first stage of selection, the CPS oversample in the less-populous States is reduced. The CPS sample is subsampled to obtain the ATUS sample, which is distributed across the States approximately equal to the proportion of the national population each one represents. In the second stage of selection, households are stratified based on these characteristics: the race/ethnicity of the householder, the presence and age of children, and the number of adults in adults-only households. In the third stage of selection, an eligible person from each household selected in the second stage is randomly selected to be the designated person for ATUS. An eligible person is a civilian household member at least 15 years of age. The response rate is around 50-60 percent and the time lag between CPS and ATUS is between 2 and 4 months. The ATUS sample is randomized by day, with 50 percent of the sample reporting about weekdays, Monday through Friday, and 50 percent reporting about Saturday and Sunday.

is the income each ATUS respondent would earn if she worked a full day (24 hours) on the job done during the diary day. The latter is calculated as above. The cost of driving a full day, p^h, is based on information from the US Energy Information Administration (EIA). It is calculated as follows. First, the price of driving one mile is calculated as the (state specific) price of one gallon of gasoline divided by fuel efficiency (the average number of miles that can be driven with one gallon of gasoline). Second, this number is multiplied by an average speed of 27.08 miles per hour, which is the average commute speed according to the 2017 national household travel survey of the US Department of Transportation.[7] This yields a dollar cost per hour, which is multiplied by 24 to have a price per day. The information on gasoline prices and fuel efficiency is retrieved from the Energy Information Administration and from the US Department of Transportation.[8] Summary statistics for P_R^h are provided in table B.2.

3.1.3 The externality

Congestion measures used in the literature often depend on the distance between the commuter's work and home. For instance, two common measures are the average journey to work travel time and the travel delay index (see, e.g., Jin and Rafferty (2018)). We cannot compute such measures as they are location dependent and the ATUS does not contain information on the individual's residence and work address.

Our measure of traffic congestion experienced by household h is the average commuting time in household h's state:

$$E^h = \bar{C^h}, \tag{41}$$

This is calculated as

$$\bar{C^h} = \frac{1}{N_{S^h}} \sum_{k \in S^h} C^k,$$

where S^h is the set of commuting households living in the same state as household h and N_{S^h} is the number of households in that set.

In order to calculate the MCF_i, we need information on the magnitude of the behavioural impact of a change in the externality E^h on c^h. Different specifications are estimated of the type

$$lnc^h = \beta_0 + \beta_1 ln\bar{C}^h + \beta_2 X^h + \epsilon^h, \tag{42}$$

where X^h are characteristics of household h. We estimate the determinants of c^h separately for each of the household types. The reference category in each estimation is a one member household.

Expression (42) is estimated with OLS. The parameter estimates are provided in table D.1. Based on the estimations the results are taken into account to calculate $\frac{\partial c^h}{\partial \bar{C}^h}$ from the MCF formulae as

$$\frac{\partial c^h}{\partial \bar{C}^h} = \beta_1 \frac{c^h}{\bar{C}^h} \tag{43}$$

3.1.4 Tax rates

The US income tax system consists of a federal income tax and a state income tax. There is a progressive federal income tax rate ranging between 10% and 37%, tax brackets depend on whether or not an individual files together with the spouse. The state tax rates vary greatly and range between 0% in some states (e.g. Alaska or Texas) to over 10% for higher tax brackets. In some

[7] https://www.fhwa.dot.gov/policyinformation/documents/2017_nhts_summary_travel_trends.pdf

[8] Gasoline prices from the Energy Information Administration (https://www.eia.gov/dnav/pet/pet_pri_gnd_dcus_nus_a.htm.) are expressed in dollars per million British thermal unit (MMBtu). Using the fact that there are 5.253 MMBtu per barrel (until 2006, starting from 2007 it is 5.222 MMBtu per barrel), and one barrel contains 42 gallons, prices per gallon (on gallon is 3.78 liters) gasoline can be calculated. Fuel efficiency data (how many miles can be driven per gallon) were collected from the US Department of Transportation. Using these data, a price per mile can be calculated. Finally, using data on the percentage gasoline costs per mile driven, full prices per mile can be calculated. These include gasoline, but also taxes, car purchase, car repair, insurance... (http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/national_transportation_statistics/html/table_03_17.html

states (New York, Nebraska, Alabama...) the state tax rates are progressive, in other states there is a flat rate (e.g. North Carolina). Gelber et al. (2012) and Blomquist and Simula (2019) use marginal tax rates at the household's income level. In this article we calculate average tax rates per household. This means that we will calculate the MCF for a proportional tax rate change (as in Mayeres and Proost (2001) and Kleven and Kreiner (2006)), not a marginal tax rate change.

Finally, we need information on the tax on commuting t_C. Information on gasoline and income taxes per state are provided in table B.4, based on information from the Bureau of Transportation Statistics.[9] The federal gasoline tax rate amounts to 18.4 cents per gallon. Each state levies, on top of that, a state specific tax rate per gallon. In order to calculate the amount of tax an individual would pay for driving a full day, we apply the same reasoning as above for calculating p^h: we assume that a car can drive 20 miles per gallon and that the average speed is 27.08 miles per hour.[10] Dividing the sum of the federal and state tax per gallon by 20 and multiplying by 30 and taking into consideration that there are 24 hours per day, t_C per state can be calculated. These tax rates are expressed as the total amount paid by someone who spends an entire day commuting. Information on the federal and state income tax system comes from IRS, NBER and the Tax Foundation.

3.2 MCF calculation

Three remarks must be made on the way we compute the marginal cost of funds. First, we deal with the way the demerit effect is taken into consideration in the MCF in the following way. Equation (27) shows that the demerit effect affects the welfare cost through $S^P_{x^h,C^h}$, the planner's marginal rate of substitution between consumption and the demerit caused on household h's welfare by commuting. We assume that the planner's marginal rate of substitution is proportional to the household's own marginal rate of substitution between commuting and consumption:

$$S^P_{x^h,C^h} = d \cdot S^h_{x^h,C^h}.$$

The parameter $d \geq 0$ measures the percentage by which every household's marginal valuation of commuting should be increased to arrive at planner's assessment of the effect of commuting on the well being of the household. In the calculations below we simulate d between 0% and 150 %

Second, for simplicity we impose that $\gamma^h \lambda^h = 1$, so that the social marginal utility of income is the same for all households; there is no inequality aversion and all households get the same weight in the social welfare function irrespective of their income level. Third, we take into consideration the behavioural reactions of the different types of households shown in table B.4. The impacts of the policy instruments on W and R per state take into account the number of households of each type in each state.[11] In the case of two earner households, the impact of the policy instruments on both workers' leisure time is taken into consideration (see appendix C). Fourth, for the two-earner households, expression (C.36) and (C.37) are used to calculate the marginal costs of funds. All calculations are performed in Python (pandas).

Third, we focus on the state level, as the income taxes and commuting taxes are levied at that level. From the point of view of commuting, this choice is less evident, as traffic varies greatly between cities and the countryside. We also do not take into consideration cross-state commuting as we do not have data on that.

Table 1 provides the rankings of the marginal costs of funds in our calculations, in different cases. Case (1) and (2) focus on the situation without the externality. Case (1) only focuses on consumption, in case (2) leisure time is added. Cases (3), (4), and (5) contain only the demerit consideration, not the externality. The last three cases take into consideration the externality. In case (6) only the externality is taken into consideration, not the demerit considerations. This means that the social planner accepts the valuation of time loss in traffic by the households. Cases (7) and (8) take into consideration the demerit considerations with d equal to 50% and 100%. The table

[9] https://taxfoundation.org/state-gas-tax-rates-2019/

[10] US department of Transportation:https://www.fhwa.dot.gov/policyinformation/documents/2017_nhts_summary_travel_trends.pdf

[11] ATUS provides individual weights, as some categories of households are oversampled and others undersampled. We take into consideration these ATUS weights when calculating the MCF.

contains information on which MCF is in the lowest position (L) and which one is in the highest position (H).

Case (1) shows that, if only consumption X^h matters, that for most states the cheapest way to raise taxes is by decreasing the lump sum tax T. For most states, raising tax money by increasing t_w is the most costly way. This a naive way to judge the tax system, as leisure time does not play a role and social welfare depends on nothing more than consumption. Even in this situation, for five states the MCF of t_C is in the lowest position.

In cases (2)-(8), leisure time L^h is considered in the MCF. Note that the step from (1) to (2) immediately pushes the MCF of T to the highest position and -in most cases- t_w to the lowest position. Taking into account the effects on leisure time has a big influence, as the wage elasticity from Bargain et al. (2014) is bigger than the income elasticity. Increasing t_w or t_C leads to lower consumption and lower utility, but this welfare cost is compensated by an increased amount of leisure time, pushing the MCF of t_w and t_C down relative to the MCF of T.

Now we focus on cases (3)-(5), in which only the demerit considerations are at play, but not the externality. It is clear that, as the demerit parameter increases, the MCF of t_C tends to move to the bottom position. In case (3) in a total of 10 states (Alaska, Arizona, Arkansas, Forida, Illinois, Maine, Missouri, Nebraska, North Carolina, and West Virginia) the MCF moves to the lowest position compared to case (2). In case (4), five extra states follow (Minnesota, Nevada, New Jersey, New York, and Vermont). In case (5) five more states follow (Maryland, Massachusetts, Oklahoma, Oregon, and Virginia).

Cases (6)-(8) contain the externality and allow for the demerit considerations. It can be seen from the table that taking into consideration the externality moves the MCF of t_C to the lowest position in all but two states (North and South Dakota). When demerit considerations are added in cases (7) and (8), the MCF of t_C is in the lowest position in all states.

Now we take into consideration both the externality and demerit aspects of commuting, in columns marked with (3), (4), and (5). It is clear that in all cases / states the MCF_{t_C} is in the bottom position. This means that a welfare increasing tax reform could envisioned in which the tax on commuting is increased and the poll tax T^h is decreased.

4 Conclusions

We developed a model in which commuting has both an externality and a demerit component. We argued that this demerit component has to do with the fact that commuters underestimate the consequences of commuting for their physical and mental health when deciding where to live and work. Our model combining both demerit and externality considerations is new. One specific feature of our model is that one individual's behaviour both has a direct impact on other households' utilities via congestion (being in traffic is annoying) and an indirect impact via the budget constraint (traffic congestion increases the value of leisure time and reduces the time available to all households to do other things such as working or enjoying leisure). The demerit considerations exacerbate both components. We illustrated the model empirically using the ATUS dataset and behavioural reactions (wage elasticities) derived from Bargain et al. (2014), based on which we determined behavioural responses to tax changes. We calculated marginal costs of funds for three policy instruments for all US states. The results show that taking into account the externality causes rank switches between the MCF of the instruments, it reduces the MCF of raising the tax on commuting in almost all states. Incorporating the demerit component of congestion causes rank switches in the remaining U.S. states.

There are several avenues for future research. First, in our model, we did not focus on inequality aversion. Incorporating inequality aversion would require different welfare weigths for households of different sizes with a different number of working individuals. Second, we only focus on working households and households commuting by car, households who are in traffic without working (elderly, students) are not incorporated in the social welfare function. Third, the decision whether or not to work and whether or not to commute by car is not explicitly modelled. Both could depend on the tax rates. Finally, U.S. states are considered as one homogeneous territory, no distinction is made

Table 1: Marginal Costs of Funds per state

case	(1)		(2)		(3)		(4)		(5)		(6)		(7)		(8)	
incorporated	X^h		X^h, L^h		X^h, L^h		X^h, L^h		X^h, L^h		X^h,L^k		X^h,L^k		X^h,L^k	
demerit parameter d	0		0		0.5		1.0		1.5		0		0.5		1.0	
	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H
Alabama	T	t_w	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T
Alaska	T	t_w	t_w	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T
Arizona	T	t_w	t_w	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T
Arkansas	T	t_w	t_w	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T
California	T	t_w	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T
Colorado	T	t_w	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T
Connecticut	T	t_w	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T
Delaware	T	t_w	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T
Washington DC	T	t_C	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T
Florida	T	t_w	t_w	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T
Georgia	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T
Hawaii	t_C	t_w	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T
Idaho	T	t_w	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T
Illinois	T	t_w	t_w	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T
Indiana	T	t_w	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T
Iowa	T	t_w	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T
Kansas	T	t_w	t_w	T	t_w	T	t_w	T	t_w	T	t_C	T	t_C	T	t_C	T
Kentucky	T	t_w	t_w	T	t_w	T	t_w	T	t_w	T	t_C	T	t_C	T	t_C	T
Louisiana	T	t_w	t_w	T	t_w	T	t_w	T	t_w	T	t_C	T	t_C	T	t_C	T
Maine	T	t_w	t_w	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T
Maryland	T	t_w	t_w	T	t_w	T	t_w	T	t_C	T	t_C	T	t_C	T	t_C	T
Massachusetts	T	t_w	t_w	T	t_w	T	t_w	T	t_C	T	t_C	T	t_C	T	t_C	T
Michigan	T	t_w	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T
Minnesota	T	t_w	t_w	T	t_w	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T
Mississippi	T	t_w	t_w	T	t_w	T	t_w	T	t_w	T	t_C	T	t_C	T	t_C	T
Missouri	T	t_w	t_w	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T
Montana	T	t_w	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T
Nebraska	T	t_w	t_w	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T
Nevada	T	t_w	t_w	T	t_w	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T
New Hampshire	T	t_w	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T
New Jersey	T	t_w	t_w	T	t_w	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T
New Mexico	T	t_w	t_w	T	t_w	T	t_w	T	t_w	T	t_C	T	t_C	T	t_C	T
New York	T	t_w	t_w	T	t_w	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T
North Carolina	T	t_w	t_w	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T
North Dakota	t_C	t_w	t_w	T	t_w	T	t_w	T	t_w	T	t_w	T	t_w	T	t_C	T
Ohio	t_C	t_w	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T
Oklahoma	T	t_w	t_w	T	t_w	T	t_w	T	t_C	T	t_C	T	t_C	T	t_C	T
Oregon	T	t_w	t_w	T	t_w	T	t_w	T	t_C	T	t_C	T	t_C	T	t_C	T
Pennsylvania	T	t_w	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T
Rhode Island	T	t_w	t_w	T	t_w	T	t_w	T	t_w	T	t_C	T	t_C	T	t_C	T
South Carolina	T	t_w	t_w	T	t_w	T	t_w	T	t_w	T	t_C	T	t_C	T	t_C	T
South Dakota	T	t_w	t_w	T	t_w	T	t_w	T	t_w	T	t_w	T	t_w	T	t_C	T
Tennessee	t_C	t_w	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T
Texas	T	t_w	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T
Utah	T	t_w	t_w	T	t_w	T	t_w	T	t_w	T	t_C	T	t_C	T	t_C	T
Vermont	T	t_w	t_w	T	t_w	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T
Virginia	T	t_w	t_w	T	t_w	T	t_w	T	t_C	T	t_C	T	t_C	T	t_C	T
Washington	T	t_w	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T
West Virginia	T	t_w	t_w	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T
Wisconsin	T	t_w	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T	t_C	T
Wyoming	T	t_w	T	t_C	T	t_C	T	t_C	t_w	T	t_C	T	t_C	T	t_C	T
Number of times t_C	5	1	20	1	30	1	35	1	40	0	49	0	49	0	51	0
Number of times t_w	0	49	30	0	20	0	15	0	11	0	2	0	2	0	0	0
Number of times T	46	1	1	50	1	50	1	50	0	51	0	51	0	51	0	51

between cities and countryside. With better data this could be accommodated.

A Besley's (1988) approach

Besley (1988), proposed a frameworh where the planner uses the following utility function to evaluate household h's well-being.

$$B^h(x^h, L^h) = u^h\left(x^h, L^h, \delta c^h(E)\left[1 - L^h\right]\right), \tag{A.1}$$

with the parameter $\delta > 1$, as a given amount of commuting is considered to be worse for household well-being than the household is aware off. The larger is δ, the more the disutility of commuting according to the planner deviates from the consumer's perceived disutility of commuting. Hence δ is a demerit parameter.

The derivatives of $B^h(x^h, L^h)$ with respect to its arguments are

$$\frac{\partial B^h\left(x^h, L^h\right)}{\partial x^h} = \frac{\partial u^h\left(x^h, L^h, \delta c^h(E)\left[1 - L^h\right]\right)}{\partial x^h}, \tag{A.2}$$

$$\frac{\partial B^h\left(x^h, L^h\right)}{\partial L^h} = \frac{\partial u^h\left(x^h, L^h, \delta c^h(E)\left[1 - L^h\right]\right)}{\partial L^h} - \delta \frac{\partial u^h\left(x^h, L^h, \delta c^h(E)\left[1 - L^h\right]\right)}{\partial C^h} c^h(E) \tag{A.3}$$

Equation (A.2) shows that, with $\delta > 1$, the marginal social utility of consumption for household h is evaluated at a larger quantity of commuting time than the one chosen by the household. If consumption and commuting are complements ($\frac{\partial^2 u^h}{\partial x^h \partial C^h} > 0$), then the social marginal utility of consumption will be greater than the private marginal utility of consumption. The opposite occurs when they are substitutes. Something similar happens with the first term in (A.3): if leisure and commuting are complements ($\frac{\partial^2 u^h}{\partial L^h \partial C^h} > 0$), then this term will be greater than the private marginal utility of leisure. The opposite occurs when they are substitutes. In addition, however, there is the second term which increases the value the planner assigns to leisure. This term captures that increased leisure leads to less commuting, and this pushes the planner's evaluation of the individual's leisure upwards compared to the household's own evaluation of leisure. In case leisure and commuting are complements, both terms push in the same direction and the planner will value leisure more than the household. If they are substitutes, the first terms has a negative effect, such that they go in opposite directions.

The demerit argument implies that the planner does not agree with the household's choice: judged by the utility function used by the planner, households make sub-optimal choices. It is natural to require that in the household's chosen optimum, the slope of the indifference curve used by the planner should be steeper than the slope of the household's indifference curve, which equals the slope of the budget constraint - see (12):

$$\frac{\frac{\partial B^h}{\partial L^h}}{\frac{\partial B^h}{\partial x^h}} > \frac{\frac{\partial v^h}{\partial L^h}}{\frac{\partial v^h}{\partial x^h}} = w^h - c^h(E)\left(w^h + p^h\right). \tag{A.4}$$

If this holds true, the planner would like the household to have more leisure (and commute less) than it actually does. The problem with Besley's approach is that it does not guarantee this to be the case. Whether (A.4) holds true depends on the whether consumption and commuting time on the one hand, and leisure and commuting time on the other hand, are complements or substitutes. This criticism of Besley's approach was already made in Capéau and Ooghe (2003) and Schroyen (2005).

B Summary of the data

This section contains the data categories of the ATUS questionnaire used in the article, which are provided in table B.1 below. All time spent amounts to 24 hours per day. Working time H^h is all time in category 05. As we only looked at individuals who are working, those who spend time only on category 0504 - Job Search and Interviewing are not in the sample. Commuting time C^h is all time in category 1805. Note that travel time is counted as time related to a future activity (i.e. work), except homebound travel, which is related to the previous activity. Leisure time is all remaining time. Table B.2 below contains averages per state for a number of sociodemographic variables. Table B.3 contains the labour supply elasticities from Bargain et al. (2014). Table B.4 contains information on tax rates per state, on commuting and income.

Table B.1: American Time Use Survey categories

Code	ATUS name	For instance
01	Personal Care	Sleeping, grooming
02	Household Activities	Housework, cooking
03	Caring For & Helping Household Members	Children, household adults
04	Caring For & Helping Nonhousehold Members	Family, neighbours
05	Work & Work-Related Activities	
0501	*Working*	
0502	*Work-Related Activities*	
0503	*Other Income-generating Activities*	
0504	*Job Search and Interviewing*	
0599	*Work and Work-Related Activities, n.e.c.*	
06	Education	Taking class, studying...
07	Consumer Purchases	Shopping, trying clothes
08	Professional & Personal Care Services	Going to the bank, lawyer, hairdresser
09	Household Services	Using interior cleaning, gardening... service
10	Government Services & Civic Obligations	Using government services, civic participation
11	Eating and Drinking	Taking dinner
12	Socializing, Relaxing, and Leisure	Attending events, relaxing, thinking
13	Sports, Exercise, and Recreation	Participating and attending
14	Religious and Spiritual Activities	Attending religious services
15	Volunteer Activities	Administrative, social and care services
16	Telephone Calls	Your mother
18	Traveling	
1801	*Travel Related to Personal Care*	
1802	*Travel Related to Household Activities*	
1803	*Travel Related to Caring For & Helping HH Members*	
1804	*Travel Related to Caring For & Helping Nonhh Members*	
1805	*Travel Related to Work*	
1806	*Travel Related to Education*	
1807	*Travel Related to Consumer Purchases*	
1808	*Travel Related to Using Professional and Personal Care Services*	
1809	*Travel Related to Using Household Services*	
1810	*Travel Related to Using Govt Services & Civic Obligations*	
1811	*Travel Related to Eating and Drinking*	
1812	*Travel Related to Socializing, Relaxing, and Leisure*	
1813	*Travel Related to Sports, Exercise, & Recreation*	
1814	*Travel Related to Religious/Spiritual Activities*	
1815	*Travel Related to Volunteer Activities*	
1816	*Travel Related to Telephone Calls*	
1818	*Security Procedures Related to Traveling*	
1899	*Traveling, n.e.c.*	
50	Unable to code	

Table B.2: Sociodemographic information per state

					family size and type							
State	code	P_R^h	C^h	c^h	size	(1)	(2)	(3)	(4)	(5)	(6)	w_{hourly}^h
Alabama	1	371.76	0.028	0.068	2.34	0.27	0.17	0.07	0.07	0.16	0.26	16.90
Alaska	2	514.98	0.021	0.060	2.92	0.2	0.08	0.02	0.14	0.14	0.42	23.16
Arizona	4	399.56	0.029	0.072	2.3	0.35	0.14	0.06	0.09	0.14	0.23	18.26
Arkansas	5	329.49	0.023	0.061	2.44	0.28	0.21	0.05	0.07	0.13	0.26	14.88
California	6	471.29	0.032	0.080	2.6	0.29	0.15	0.05	0.12	0.13	0.25	21.79
Colorado	8	429.90	0.027	0.069	2.56	0.27	0.17	0.05	0.08	0.15	0.28	19.61
Connecticut	9	492.42	0.027	0.069	2.34	0.32	0.15	0.05	0.07	0.17	0.25	22.39
Delaware	10	430.65	0.026	0.065	2.73	0.17	0.14	0.03	0.07	0.24	0.36	19.43
Washington DC	11	457.63	0.041	0.090	1.55	0.70	0.05	0.00	0.05	0.15	0.05	21.45
Florida	12	389.03	0.032	0.077	2.31	0.31	0.18	0.07	0.07	0.16	0.22	17.90
Georgia	13	399.00	0.031	0.076	2.36	0.32	0.18	0.05	0.07	0.17	0.22	18.34
Hawaii	15	452.05	0.032	0.079	2.78	0.19	0.21	0.03	0.10	0.16	0.32	20.94
Idaho	16	371.91	0.023	0.059	2.6	0.28	0.17	0.04	0.10	0.19	0.22	16.76
Illinois	17	424.6	0.029	0.072	2.54	0.27	0.17	0.06	0.07	0.17	0.27	19.46
Indiana	18	386.8	0.027	0.069	2.5	0.26	0.16	0.07	0.08	0.14	0.29	17.63
Iowa	19	389.14	0.022	0.056	2.61	0.25	0.18	0.04	0.06	0.17	0.3	17.42
Kansas	20	376.18	0.022	0.059	2.34	0.35	0.19	0.05	0.08	0.14	0.19	16.96
Kentucky	21	369.19	0.025	0.064	2.46	0.29	0.14	0.06	0.09	0.12	0.29	16.70
Louisiana	22	377.57	0.027	0.063	2.2	0.4	0.15	0.05	0.09	0.15	0.16	17.08
Maine	23	416.47	0.024	0.064	2.52	0.23	0.12	0.04	0.10	0.24	0.27	18.83
Maryland	24	489.85	0.035	0.085	2.26	0.33	0.18	0.07	0.07	0.13	0.22	22.81
Massachusetts	25	501.41	0.034	0.082	2.6	0.25	0.16	0.04	0.07	0.15	0.34	23.25
Michigan	26	434.95	0.027	0.067	2.58	0.26	0.16	0.05	0.07	0.16	0.31	19.76
Minnesota	27	443.14	0.028	0.069	2.63	0.23	0.12	0.05	0.08	0.18	0.33	20.15
Mississippi	28	364.33	0.025	0.064	2.56	0.29	0.2	0.05	0.06	0.08	0.32	16.49
Missouri	29	383.77	0.025	0.067	2.51	0.30	0.17	0.05	0.06	0.14	0.28	17.42
Montana	30	398.59	0.022	0.059	2.8	0.24	0.12	0.02	0.08	0.20	0.34	17.91
Nebraska	31	371.85	0.023	0.064	2.68	0.24	0.2	0.05	0.06	0.15	0.31	16.84
Nevada	32	454.37	0.028	0.069	2.54	0.29	0.14	0.05	0.11	0.14	0.28	20.73
New Hampshire	33	454.84	0.030	0.070	2.47	0.31	0.09	0.05	0.07	0.15	0.34	20.81
New Jersey	34	475.71	0.034	0.081	2.49	0.3	0.12	0.07	0.07	0.13	0.31	22.00
New Mexico	35	401.57	0.024	0.066	2.51	0.27	0.14	0.08	0.12	0.15	0.24	18.24
New York	36	448.58	0.030	0.075	2.55	0.26	0.14	0.06	0.07	0.15	0.31	20.63
North Carolina	37	365.35	0.028	0.072	2.38	0.3	0.17	0.04	0.07	0.17	0.25	16.76
North Dakota	38	371.66	0.019	0.05	2.31	0.29	0.12	0.06	0.09	0.24	0.21	16.50
Ohio	39	398.27	0.026	0.068	2.4	0.30	0.19	0.04	0.05	0.14	0.27	18.13
Oklahoma	40	348.94	0.026	0.067	2.41	0.32	0.17	0.06	0.10	0.15	0.20	15.84
Oregon	41	452.26	0.024	0.065	2.59	0.25	0.13	0.05	0.06	0.17	0.34	20.42
Pennsylvania	42	424.55	0.028	0.071	2.48	0.28	0.13	0.06	0.08	0.16	0.28	19.40
Rhode Island	44	457.97	0.027	0.068	2.31	0.35	0.12	0.01	0.08	0.17	0.27	20.84
South Carolina	45	384.09	0.026	0.067	2.2	0.34	0.15	0.07	0.06	0.15	0.23	17.48
South Dakota	46	383.39	0.020	0.051	2.87	0.21	0.18	0.02	0.04	0.13	0.41	17.05
Tennessee	47	368.43	0.028	0.067	2.45	0.3	0.17	0.05	0.08	0.14	0.27	16.78
Texas	48	378.55	0.03	0.075	2.58	0.28	0.18	0.05	0.11	0.13	0.25	17.41
Utah	49	400.20	0.024	0.07	3.04	0.2	0.16	0.03	0.12	0.13	0.37	18.27
Vermont	50	445.56	0.029	0.075	2.59	0.22	0.1	0.04	0.08	0.2	0.35	20.53
Virginia	51	428.26	0.030	0.072	2.35	0.32	0.16	0.06	0.07	0.15	0.25	19.58
Washington	53	478.57	0.031	0.076	2.56	0.25	0.16	0.06	0.10	0.17	0.27	22.02
West Virginia	54	364.97	0.031	0.07	2.47	0.25	0.1	0.04	0.10	0.26	0.25	16.69
Wisconsin	55	423.80	0.024	0.064	2.57	0.24	0.15	0.04	0.05	0.22	0.30	19.20
Wyoming	56	405.03	0.023	0.063	2.59	0.32	0.17	0.06	0.08	0.11	0.25	18.39

Notes: These numbers provide the averages for a number of variables at the state level. The table contains averages for P_R^h, commuting time relative to one day C^h, commuting time relative to non leisure time c^h, average household size, the frequencies of all 6 family types, and average hourly wage in all states.

Table B.3: Behavioural responses: wage, cross-wage and income elasticities of labour supply in the US

Elasticities		own wage	cross-wage	income
Single no children (1)	Female	0.23		-0.0040
	Male	0.18		-0.0059
single with children (2)	Female	0.24		-0.0040
	Male	0.20		-0.0059
1 earner couple no children (3)	Female	0.13		0
	Male	0.08		0.0012
1 earner married with children (4)	Female	0.15		0
	Male	0.08		0.0012
2 earner with children (5)	Female	0.15	0.02	0
	Male	0.08	0.01	0.0012
2 earner no children (6)	Female	0.13	0.02	0
	Male	0.08	0.01	0.0012

Note: Elasticities are taken from Bargain et al. (2014)

C Two earner household

In this appendix, we extend the model to show how we deal with two earner households.

C.1 The household

The household faces two time endowment constraints, one for each earnerr.

$$H_1^h + L_1^h + C_1^h = 1, \tag{C.1}$$
$$H_2^h + L_2^h + C_2^h = 1, \tag{C.2}$$

where subscript i refers to earner i ($i = 1$ or 2). For each earner the time spent commuting is a fraction of the time not spent on leisure. This fraction is increasing in a congestion externality E, such that

$$C_1^h = c_1^h(E) \cdot \left[1 - L_1^h\right] \tag{C.3}$$
$$C_2^h = c_2^h(E) \cdot \left[1 - L_2^h\right], \tag{C.4}$$

with $c_i^h(E), i = 1, 2$ an increasing function. Combining (C.1) and (C.3), and (C.2) and (C.4) gives

$$H_1^h = \left(1 - c_1^h(E)\right)\left[1 - L_1^h\right] \tag{C.5}$$
$$H_2^h = \left(1 - c_2^h(E)\right)\left[1 - L_2^h\right]. \tag{C.6}$$

The household's preferences are given by

$$u^h\left(x^h, L_1^h, L_2^h, C_1^h, C_2^h\right).$$

This function is increasing in x^h, L_1^h and L_2^h, and decreasing in C_1^h and C_2^h. As a consequence, using (C.3) and (C.4), household preferences can also be represented by the utility function

$$v^h(x^h, L_1^h, L_2^h) = u^h\left(x^h, L_1^h, L_2^h, c_1^h(E)\left[1 - L_1^h\right], c_2^h(E)\left[1 - L_2^h\right]\right) \tag{C.7}$$

which is increasing in its arguments x^h, L_1^h and L_2^h:

$$\frac{\partial v^h}{\partial x^h} = \frac{\partial u^h}{\partial x^h} > 0, \tag{C.8}$$
$$\frac{\partial v^h}{\partial L_1^h} = \frac{\partial u^h}{\partial L_1^h} - \frac{\partial u^h}{\partial C_1^h} c_1^h(E) > 0, \tag{C.9}$$
$$\frac{\partial v^h}{\partial L_2^h} = \frac{\partial u^h}{\partial L_2^h} - \frac{\partial u^h}{\partial C_2^h} c_2^h(E) > 0. \tag{C.10}$$

Table B.4: Tax rates per state

state	code	t_C^{fed}	t_C^{state}	t_C	t_w^{fed}	t_w^{state}	t_w
Alabama (AL)	1	0.184	0.212	12.872	0.117	0.049	0.166
Alaska (AK)	2	0.184	0.147	10.743	0.120	0	0.120
Arizona (AZ)	4	0.184	0.190	12.154	0.121	0.025	0.146
Arkansas (AR)	5	0.184	0.218	13.063	0.113	0.034	0.147
California (CA)	6	0.184	0.612	25.867	0.126	0.030	0.156
Colorado (CO)	8	0.184	0.220	13.128	0.122	0.044	0.166
Connecticut (CT)	9	0.184	0.421	19.663	0.132	0.046	0.178
Delaware (DE)	10	0.184	0.230	13.453	0.116	0.048	0.163
Washington DC (DC)	11	0.184	0.235	13.616	0.141	0.051	0.192
Florida (FL)	12	0.184	0.420	19.624	0.118	0	0.118
Georgia (GA)	13	0.184	0.352	17.402	0.117	0.056	0.173
Hawaii (HI)	15	0.184	0.483	21.659	0.128	0.066	0.195
Idaho (ID)	16	0.184	0.330	16.703	0.119	0.058	0.177
Illonois (IL)	17	0.184	0.550	23.846	0.122	0.049	0.171
Indiana (IN)	18	0.184	0.466	21.129	0.119	0.031	0.151
Iowa (IA)	19	0.184	0.325	16.540	0.118	0.049	0.168
Kansas (KS)	20	0.184	0.240	13.788	0.117	0.043	0.160
Kentucky (KY)	21	0.184	0.260	14.428	0.117	0.045	0.162
Louisiana (LA)	22	0.184	0.200	12.482	0.118	0.026	0.144
Maine (ME)	23	0.184	0.300	15.732	0.120	0.061	0.181
Maryland (MD)	24	0.184	0.367	17.905	0.135	0.047	0.181
Massachusetts (MA)	25	0.184	0.265	14.604	0.132	0.050	0.182
Michigan (MI)	26	0.184	0.259	14.396	0.120	0.043	0.163
Minnesota (MN)	27	0.184	0.286	15.273	0.126	0.059	0.185
Mississippi (MS)	28	0.184	0.188	12.085	0.115	0.044	0.159
Missouri (MO)	29	0.184	0.174	11.640	0.12	0.054	0.174
Montana (MT)	30	0.184	0.328	16.622	0.113	0.049	0.162
Nebraska (NE)	31	0.184	0.306	15.923	0.119	0.042	0.161
Nevada (NV)	32	0.184	0.338	16.956	0.124	0	0.124
New Hampshire (NH)	33	0.184	0.238	13.723	0.121	0	0.121
New Jersey (NJ)	34	0.184	0.414	19.433	0.129	0.026	0.155
New Mexico (NM)	35	0.184	0.189	12.115	0.117	0.041	0.157
New York (NY)	36	0.184	0.460	20.914	0.127	0.051	0.178
North Carolina (NC)	37	0.184	0.365	17.824	0.116	0.05	0.166
North Dakota (ND)	38	0.184	0.230	13.453	0.120	0.012	0.132
Ohio (OH)	39	0.184	0.385	18.493	0.118	0.028	0.147
Oklahoma (OK)	40	0.184	0.200	12.478	0.119	0.051	0.171
Oregon (OR)	41	0.184	0.368	17.944	0.120	0.08	0.200
Pennsylvania (PA)	42	0.184	0.587	25.054	0.12	0.031	0.151
Rhode Island (RI)	44	0.184	0.350	17.353	0.12	0.038	0.158
South Carolina (SC)	45	0.184	0.228	13.372	0.117	0.057	0.173
South Dakota (SD)	46	0.184	0.300	15.728	0.118	0	0.118
Tennessee (TN)	47	0.184	0.274	14.883	0.118	0	0.118
Texas (TX)	48	0.184	0.200	12.478	0.117	0	0.117
Utah (UT)	49	0.184	0.300	15.731	0.12	0.049	0.169
Vermont (VT)	50	0.184	0.310	16.056	0.127	0.039	0.166
Virginia (VA)	51	0.184	0.220	13.112	0.125	0.053	0.178
Washington (WA)	53	0.184	0.494	22.032	0.124	0	0.124
West Virginia (WV)	54	0.184	0.357	17.580	0.118	0.044	0.162
Wisconsin (WI)	55	0.184	0.329	16.670	0.119	0.046	0.165
Wyoming (WY)	56	0.184	0.240	13.778	0.122	0	0.122

Notes: t_C^{fed} *and* t_C^{state} *are federal and state specific taxes in $ per gallon;* t_C *is the total tax paid by someone in 2017 $ commuting 24 hours;* t_w^{fed}*,* t_w^{state} *and* t_w *are the % federal, state and total marginal income tax rates. Source: Bureau of Transportation Statistics, IRS, NBER and the Tax Foundation.*

The household's budget constraint is

$$x^h + p_1^h C_1^h + p_2^h C_2^h \leq w_1^h H_1^h + w_2^h H_2^h + T^h.$$

After substituting (C.3), (C.5), (C.4) and (C.6), the budget constraint can be written as

$$\begin{aligned} x^h &+ \left[w_1^h - c_1^h(E)\left[w_1^h + p_1^h\right]\right] L_1^h + \left[w_2^h - c_2^h(E)\left[w_2^h + p_2^h\right]\right] L_2^h \\ &= w_1^h - c_1^h(E)\left[w_1^h + p_1^h\right] + w_2^h - c_2^h(E)\left[w_2^h + p_2^h\right] + T^h. \end{aligned} \tag{C.11}$$

Define the price of leisure for earners 1 and 2 as

$$p_{R1}^h = w_1^h - c_1^h(E)\left[w_1^h + p_1^h\right], \tag{C.12}$$

$$p_{R2}^h = w_2^h - c_2^h(E)\left[w_2^h + p_2^h\right], \tag{C.13}$$

the wage rates corrected for the fact that work requires commuting, and commuting is both time consuming ($c_i^h(E)w_i^h$) and gasoline consuming ($c_i^h(E)p_i^h$). Hence $c_i^h(E)$ decreases the relative price of leisure. The budget constraint can be written as

$$x^h = p_{R1}^h\left[1 - L_1^h\right] + p_{R2}^h\left[1 - L_2^h\right] + T^h. \tag{C.14}$$

Maximizing $v^h(x^h, L_1^h, L_2^h)$ with respect to x^h, L_1^h and L_2^h subject to budget constraint (C.14), yields the following first order conditions:

$$\frac{\frac{\partial v^h}{\partial x^h}}{\lambda^h} = 1, \tag{C.15}$$

$$\frac{\frac{\partial v^h}{\partial L_1^h}}{\lambda^h} = p_{R1}^h, \tag{C.16}$$

$$\frac{\frac{\partial v^h}{\partial L_2^h}}{\lambda^h} = p_{R2}^h, \tag{C.17}$$

with λ^h the Lagrangian multiplier associated with the budget constraint; λ^h equals household h's marginal utility of income. The left hand side of expressions (C.15), (C.16) and (C.17) measures household h's marginal willingness to pay (in monetary terms) for consumption and leisure of both earners. From the first order conditions above, in the optimum, the marginal rate of substitution between consumption and earners' leisure is equal to the relative price of consumption and leisure:

$$\frac{\frac{\partial v^h}{\partial L_1^h}}{\frac{\partial v^h}{\partial x^h}} = p_{R1}^h, \tag{C.18}$$

$$\frac{\frac{\partial v^h}{\partial L_2^h}}{\frac{\partial v^h}{\partial x^h}} = p_{R2}^h. \tag{C.19}$$

The solution to the optimization problem yields the Marshallian demands for x^h, L_1^h and L_2^h and can be written as:

$$x^h = x^h\left(p_{R1}^h, p_{R2}^h, T^h\right), \tag{C.20}$$

$$L_1^h = L_1^h\left(p_{R1}^h, p_{R2}^h, T^h\right), \tag{C.21}$$

$$L_2^h = L_2^h\left(p_{R1}^h, p_{R2}^h, T^h\right), \tag{C.22}$$

while commuting times C_1^h and C_2^h and working times H_1^h and H_2^h follow from (C.3), C.4), (C.5), (C.6), (C.21) and (C.22).

C.2 The planner's evaluation of commuting time

Instead of (C.7) the planner uses the following utility function to evaluate household h's well-being.

$$V^h(x^h, L_1^h, l_2^h) = v^h\left(x^h, L_1^h, L_2^h\right) - d^h\left(\bar{C}^h\right), \tag{C.23}$$

with $\bar{C}^h = C_1^h + C_1^h = c_1^h(E)\left[1 - L_1^h\right] + c_2^h(E)\left[1 - L_2^h\right]$, the household's total commuting time. The increasing function $d^h\left(\bar{C}^h\right)$ gives the demerit effect of commuting on well-being. The derivatives of $V^h(x^h, L_1^h, L_2^h)$ with respect to its arguments are

$$\begin{aligned}
\frac{\partial V^h\left(x^h, L_1^h, L_2^h\right)}{\partial x^h} &= \frac{\partial v^h\left(x^h, L_1^h, L_2^h\right)}{\partial x^h}, \\
\frac{\partial V^h\left(x^h, L_1^h, L_2^h\right)}{\partial L_1^h} &= \frac{\partial v^h\left(x^h, L_1^h, L_2^h\right)}{\partial L_1^h} + \frac{\partial d^h\left(\bar{C}^h\right)}{\partial \bar{C}^h} c_1^h(E), \\
\frac{\partial V^h\left(x^h, L_1^h, L_2^h\right)}{\partial L_2^h} &= \frac{\partial v^h\left(x^h, L_1^h, L_2^h\right)}{\partial L_2^h} + \frac{\partial d^h\left(\bar{C}^h\right)}{\partial \bar{C}^h} c_2^h(E).
\end{aligned}$$

Consequently, the planner's marginal rate of substitution between consumption and leisures of the earners of household h is

$$\frac{\frac{\partial V^h}{\partial L_1^h}}{\frac{\partial V^h}{\partial x^h}} = \frac{\frac{\partial v^h}{\partial L_1^h}}{\frac{\partial v^h}{\partial x^h}} + \frac{\frac{\partial d^h\left(\bar{C}^h\right)}{\partial \bar{C}^h}}{\frac{\partial v^h}{\partial x^h}} c_1^h(E), \tag{C.24}$$

$$\frac{\frac{\partial V^h}{\partial L_2^h}}{\frac{\partial V^h}{\partial x^h}} = \frac{\frac{\partial v^h}{\partial L_2^h}}{\frac{\partial v^h}{\partial x^h}} + \frac{\frac{\partial d^h\left(\bar{C}^h\right)}{\partial \bar{C}^h}}{\frac{\partial v^h}{\partial x^h}} c_2^h(E). \tag{C.25}$$

Define

$$S^P_{x^h,\bar{C}^h} = \frac{\frac{\partial d^h\left(\bar{C}^h\right)}{\partial \bar{C}^h}}{\frac{\partial v^h}{\partial x^h}}, \tag{C.26}$$

the (planner's) marginal rate of substitution between the demerit effect of commuting and consumption of household h. It measures how many units of consumption of household h the planner is willing to give up to reduce the demerit caused by household h's total commuting with one unit such that the household's welfare as measured by the planner remains constant. Use of (C.26) and (C.18) in (C.24) and (18) and (C.19) in (C.25)yields

$$\frac{\frac{\partial V^h}{\partial L_1^h}}{\frac{\partial V^h}{\partial x^h}} = p_{R1}^h + c_1^h(E) \cdot S^P_{x^h,\bar{C}^h} > p_{R1}^h, \tag{C.27}$$

$$\frac{\frac{\partial V^h}{\partial L_2^h}}{\frac{\partial V^h}{\partial x^h}} = p_{R2}^h + c_2^h(E) \cdot S^P_{x^h,\bar{C}^h} > p_{R2}^h, \tag{C.28}$$

such that in the household's chosen optimum, the indifference curve used by the planner is steeper than the slope of the household's indifference curve which equals the slope of the budget constraint, implying that the planner would like the earners of the household to have more leisure.

C.3 From private utility to social utility

The Utilitarian social welfare function W is given by

$$W = \sum_{h=1}^{N} V^h\left(x^h, L_1^h, L_2^h\right).$$

Substitution of (C.23) and (C.7) into this expression yields

$$W = \sum_{h=1}^{N} u^h\left(x^h, L_1^h, L_2^h, c_1^h(E)\left[1 - L_1^h\right], c_2^h(E)\left[1 - L_2^h\right]\right) - d^h(\bar{C}^h). \tag{C.29}$$

The derivative of expression (C.29) with respect to x^h is, using (C.8) and (C.15),

$$\frac{\partial W}{\partial x^h} = \frac{\partial u^h}{\partial x^h} = \lambda^h. \tag{C.30}$$

The derivative of expression (C.29) with respect to L_1^h is

$$\begin{aligned}
\frac{\partial W}{\partial L_1^h} &= \left[\frac{\partial u^h}{\partial L_1^h} - c_1^h(E)\left[\frac{\partial u^h}{\partial C_1^h} - \frac{\partial d^h}{\partial \bar{C}^h}\right]\right] \\
&+ \sum_{k=1}^{N}\left[\left[\frac{\partial u^k}{\partial C_1^k} - \frac{\partial d^k}{\partial \bar{C}^k}\right]\left[1 - L_1^k\right]\frac{\partial c_1^k(E)}{\partial E} + \left[\frac{\partial u^k}{\partial C_2^k} - \frac{\partial d^k}{\partial \bar{C}^k}\right]\left[1 - L_2^k\right]\frac{\partial c_2^k(E)}{\partial E}\right]\frac{\partial E}{\partial C_1^h}\left[-c_1^h(E)\right] \\
&+ \sum_{k=1}^{N}\left[\frac{\partial u^k}{\partial x^k}\frac{\partial x^k}{\partial p_{R1}^k} + \left[\frac{\partial u^k}{\partial L_1^k} - \left[\frac{\partial u^k}{\partial C_1^k} - \frac{\partial d^k}{\partial \bar{C}^k}\right]c_1^k(E)\right]\frac{\partial L_1^k}{\partial p_{R1}^k}\right. \\
&\qquad \left. + \left[\frac{\partial u^k}{\partial L_2^k} - \left[\frac{\partial u^k}{\partial C_2^k} - \frac{\partial d^k}{\partial \bar{C}^k}\right]c_2^k(E)\right]\frac{\partial L_2^k}{\partial p_{R1}^k}\right]\frac{\partial p_{R1}^k}{\partial L_1^h} \\
&+ \sum_{k=1}^{N}\left[\frac{\partial u^k}{\partial x^k}\frac{\partial x^k}{\partial p_{R2}^k} + \left[\frac{\partial u^k}{\partial L_1^k} - \left[\frac{\partial u^k}{\partial C_1^k} - \frac{\partial d^k}{\partial \bar{C}^k}\right]c_1^k(E)\right]\frac{\partial L_1^k}{\partial p_{R2}^k}\right. \\
&\qquad \left. + \left[\frac{\partial u^k}{\partial L_2^k} - \left[\frac{\partial u^k}{\partial C_2^k} - \frac{\partial d^k}{\partial \bar{C}^k}\right]c_2^k(E)\right]\frac{\partial L_2^k}{\partial p_{R2}^k}\right]\frac{\partial p_{R2}^k}{\partial L_1^h}.
\end{aligned} \tag{C.31}$$

Using (C.8), (C.9) and (C.10) in the first and third line of (C.31), we get

$$\begin{aligned}
\frac{\partial W}{\partial L_1^h} &= \left[\frac{\partial v^h}{\partial L_1^h} + c_1^h(E)\frac{\partial d^h}{\partial \bar{C}^h}\right] \\
&+ \sum_{k=1}^{N}\left[\left[\frac{\partial u^k}{\partial C_1^k} - \frac{\partial d^k}{\partial \bar{C}^k}\right]\left[1 - L_1^k\right]\frac{\partial c_1^k(E)}{\partial E} + \left[\frac{\partial u^k}{\partial C_2^k} - \frac{\partial d^k}{\partial \bar{C}^k}\right]\left[1 - L_2^k\right]\frac{\partial c_2^k(E)}{\partial E}\right]\frac{\partial E}{\partial C_1^h}\left[-c_1^h(E)\right] \\
&+ \sum_{k=1}^{N}\left[\frac{\partial v^k}{\partial x^k}\frac{\partial x^k}{\partial p_{R1}^k} + \left[\frac{\partial v^k}{\partial L_1^k} + \frac{\partial d^k}{\partial \bar{C}^k}c_1^k(E)\right]\frac{\partial L_1^k}{\partial p_{R1}^k} + \left[\frac{\partial v^k}{\partial L_2^k} + \frac{\partial d^k}{\partial \bar{C}^k}c_2^k(E)\right]\frac{\partial L_2^k}{\partial p_{R1}^k}\right]\frac{\partial p_{R1}^k}{\partial L_1^h} \\
&+ \sum_{k=1}^{N}\left[\frac{\partial v^k}{\partial x^k}\frac{\partial x^k}{\partial p_{R2}^k} + \left[\frac{\partial v^k}{\partial L_1^k} + \frac{\partial d^k}{\partial \bar{C}^k}c_1^k(E)\right]\frac{\partial L_1^k}{\partial p_{R2}^k} + \left[\frac{\partial v^k}{\partial L_2^k} + \frac{\partial d^k}{\partial \bar{C}^k}c_2^k(E)\right]\frac{\partial L_2^k}{\partial p_{R2}^k}\right]\frac{\partial p_{R2}^k}{\partial L_1^h}.
\end{aligned}$$

The first order conditions (C.15), (C.16) and (C.17) allow us to rewrite this as

$$\begin{aligned}
\frac{\partial W}{\partial L_1^h} &= \lambda^h\left[p_{R1}^h + \frac{c_1^h(E)}{\lambda^h}\frac{\partial d^h}{\partial \bar{C}^h}\right] \\
&+ \sum_{k=1}^{N}\left[\left[\frac{\partial u^k}{\partial C_1^k} - \frac{\partial d^k}{\partial \bar{C}^k}\right]\left[1 - L_1^k\right]\frac{\partial c_1^k(E)}{\partial E} + \left[\frac{\partial u^k}{\partial C_2^k} - \frac{\partial d^k}{\partial \bar{C}^k}\right]\left[1 - L_2^k\right]\frac{\partial c_2^k(E)}{\partial E}\right]\frac{\partial E}{\partial C_1^h}\left[-c_1^h(E)\right] \\
&+ \sum_{k=1}^{N}\lambda^k\left[\frac{\partial x^k}{\partial p_{R1}^k} + \left[p_{R1}^k + \frac{\partial d^k}{\partial \bar{C}^k}\frac{c_1^k(E)}{\lambda^k}\right]\frac{\partial L_1^k}{\partial p_{R1}^k} + \left[p_{R2}^k + \frac{\partial d^k}{\partial \bar{C}^k}\frac{c_2^k(E)}{\lambda^k}\right]\frac{\partial L_2^k}{\partial p_{R1}^k}\right]\frac{\partial p_{R1}^k}{\partial L_1^h} \\
&+ \sum_{k=1}^{N}\lambda^k\left[\frac{\partial x^k}{\partial p_{R2}^k} + \left[p_{R1}^k + \frac{\partial d^k}{\partial \bar{C}^k}\frac{c_1^k(E)}{\lambda^k}\right]\frac{\partial L_1^k}{\partial p_{R2}^k} + \left[p_{R2}^k + \frac{\partial d^k}{\partial \bar{C}^k}\frac{c_2^k(E)}{\lambda^k}\right]\frac{\partial L_2^k}{\partial p_{R2}^k}\right]\frac{\partial p_{R2}^k}{\partial L_1^h}.
\end{aligned} \tag{C.32}$$

The budget constraint for household k can be written as

$$x^k + p^k_{R1} L^k_1 + p^k_{R2} L^k_2 = p^k_{R1} + p^k_{R2} + T^k,$$

such that

$$\begin{aligned}
\frac{\partial x^k}{\partial p^k_{R1}} + p^k_{R1} \frac{\partial L^k_1}{\partial p^k_{R1}} + p^k_{R2} \frac{\partial L^k_2}{\partial p^k_{R1}} &= 1 - L^k_1, \\
\frac{\partial x^k}{\partial p^k_{R2}} + p^k_{R1} \frac{\partial L^k_1}{\partial p^k_{R2}} + p^k_{R2} \frac{\partial L^k_2}{\partial p^k_{R2}} &= 1 - L^k_2.
\end{aligned}$$

Using these expressions in (C.32) gives

$$\begin{aligned}
\frac{\partial W}{\partial L^h_1} &= \lambda^h \left[p^h_{R1} + c^h_1(E) \frac{\frac{\partial d^h}{\partial \bar{C}^h}}{\lambda^h} \right] \\
&+ \sum_{k=1}^{N} \lambda^k \left[\left[-\frac{\frac{\partial u^k}{\partial C^k_1}}{\lambda^k} + \frac{\frac{\partial d^k}{\partial \bar{C}^k}}{\lambda^k} \right] \left[1 - L^k_1\right] \frac{\partial c^k_1(E)}{\partial E} + \left[-\frac{\frac{\partial u^k}{\partial C^k_2}}{\lambda^k} + \frac{\frac{\partial d^k}{\partial \bar{C}^k}}{\lambda^k} \right] \left[1 - L^k_2\right] \frac{\partial c^k_2(E)}{\partial E} \right] \frac{\partial E}{\partial C^h_1} c^h_1(E) \\
&+ \sum_{k=1}^{N} \lambda^k \left[1 - L^k_1 + \frac{\frac{\partial d^k}{\partial \bar{C}^k}}{\lambda^k} c^k_1(E) \frac{\partial L^k_1}{\partial p^k_{R1}} + \frac{\frac{\partial d^k}{\partial \bar{C}^k}}{\lambda^k} c^k_2(E) \frac{\partial L^k_2}{\partial p^k_{R1}} \right] \frac{\partial p^k_{R1}}{\partial L^h_1} \\
&+ \sum_{k=1}^{N} \lambda^k \left[1 - L^k_2 + \frac{\frac{\partial d^k}{\partial \bar{C}^k}}{\lambda^k} c^k_1(E) \frac{\partial L^k_1}{\partial p^k_{R2}} + \frac{\frac{\partial d^k}{\partial \bar{C}^k}}{\lambda^k} c^k_2(E) \frac{\partial L^k_2}{\partial p^k_{R2}} \right] \frac{\partial p^k_{R2}}{\partial L^h_1}. \qquad \text{(C.33)}
\end{aligned}$$

Household k's marginal rate of substitution between commuting and consumption is given by

$$S^k_{x^k,\bar{C}^k} = -\frac{\frac{\partial u^k}{\partial \bar{C}^k}}{\lambda^k}, \qquad \text{(C.34)}$$

and measures the consumption household k is willing to give up to decrease commuting by one unit. Using (C.26) and (C.34), (C.33) becomes

$$\begin{aligned}
\frac{\partial W}{\partial L^h_1} &= \lambda^h \left[p^h_{R1} + c^h_1(E) \cdot S^P_{x^h,\bar{C}^h} \right] \\
&+ \sum_{k=1}^{N} \lambda^k \left[\left[S^k_{x^k,\bar{C}^k} + S^P_{x^k,\bar{C}^k} \right] \left[1 - L^k_1\right] \frac{\partial c^k_1(E)}{\partial E} + \left[S^k_{x^k,\bar{C}^k} + S^P_{x^k,\bar{C}^k} \right] \left[1 - L^k_2\right] \frac{\partial c^k_2(E)}{\partial E} \right] \frac{\partial E}{\partial C^h_1} c^h_1(E) \\
&+ \sum_{k=1}^{N} \lambda^k \left[1 - L^k_1 + S^P_{x^k,\bar{C}^k} \cdot c^k_1(E) \frac{\partial L^k_1}{\partial p^k_{R1}} + S^P_{x^k,\bar{C}^k} \cdot c^k_2(E) \frac{\partial L^k_2}{\partial p^k_{R1}} \right] \frac{\partial p^k_{R1}}{\partial L^h_1} \\
&+ \sum_{k=1}^{N} \lambda^k \left[1 - L^k_2 + S^P_{x^k,\bar{C}^k} \cdot c^k_1(E) \frac{\partial L^k_1}{\partial p^k_{R2}} + S^P_{x^k,\bar{C}^k} \cdot c^k_2(E) \frac{\partial L^k_2}{\partial p^k_{R2}} \right] \frac{\partial p^k_{R2}}{\partial L^h_1}. \qquad \text{(C.35)}
\end{aligned}$$

This reduces to

$$\begin{aligned}
\frac{\partial W}{\partial L^h_1} &= \lambda^h \left[p^h_{R1} + c^h_1(E) \cdot S^P_{x^h,\bar{C}^h} \right] \\
&+ \sum_{k=1}^{N} \lambda^k \left[S^k_{x^k,\bar{C}^k} + S^P_{x^k,\bar{C}^k} \right] \left[\left[1 - L^k_1\right] \frac{\partial c^k_1(E)}{\partial E} + \left[1 - L^k_2\right] \frac{\partial c^k_2(E)}{\partial E} \right] \frac{\partial E}{\partial C^h_1} c^h_1(E) \\
&+ \sum_{k=1}^{N} \lambda^k \left[1 - L^k_1 + S^P_{x^k,\bar{C}^k} \cdot \left[c^k_1(E) \frac{\partial L^k_1}{\partial p^k_{R1}} + c^k_2(E) \frac{\partial L^k_2}{\partial p^k_{R1}} \right] \right] \frac{\partial p^k_{R1}}{\partial L^h_1} \\
&+ \sum_{k=1}^{N} \lambda^k \left[1 - L^k_2 + S^P_{x^k,\bar{C}^k} \cdot \left[c^k_1(E) \frac{\partial L^k_1}{\partial p^k_{R2}} + c^k_2(E) \frac{\partial L^k_2}{\partial p^k_{R2}} \right] \right] \frac{\partial p^k_{R2}}{\partial L^h_1}. \qquad \text{(C.36)}
\end{aligned}$$

Observe that, from (C.12) and (C.13), the effects of L_1^h on p_{R1}^k and p_{R2}^k are given by

$$\begin{aligned}\frac{\partial p_{R1}^k}{\partial L_1^h} &= \left[w_1^k + p_1^k\right] \frac{\partial c_1^k(E)}{\partial E} \frac{\partial E}{\partial C_1^h} c_1^h(E) > 0, \\ \frac{\partial p_{R2}^k}{\partial L_1^h} &= \left[w_2^k + p_2^k\right] \frac{\partial c_2^k(E)}{\partial E} \frac{\partial E}{\partial C_1^h} c_1^h(E) > 0.\end{aligned}$$

Finally, the effect of L_2^h on W can be found similarly:

$$\begin{aligned}\frac{\partial W}{\partial L_2^h} &= \lambda^h \left[p_{R2}^h + c_2^h(E) \cdot S_{x^h,\bar{C}^h}^P\right] \\ &+ \sum_{k=1}^N \lambda^k \left[S_{x^k,\bar{C}^k}^k + S_{x^k,\bar{C}^k}^P\right] \left[\left[1 - L_1^k\right] \frac{\partial c_1^k(E)}{\partial E} + \left[1 - L_2^k\right] \frac{\partial c_2^k(E)}{\partial E}\right] \frac{\partial E}{\partial C_2^h} c_2^h(E) \\ &+ \sum_{k=1}^N \lambda^k \left[1 - L_1^k + S_{x^k,\bar{C}^k}^P \cdot \left[c_1^k(E) \frac{\partial L_1^k}{\partial p_{R1}^k} + c_2^k(E) \frac{\partial L_2^k}{\partial p_{R1}^k}\right]\right] \frac{\partial p_{R1}^k}{\partial L_2^h} \\ &+ \sum_{k=1}^N \lambda^k \left[1 - L_2^k + S_{x^k,\bar{C}^k}^P \cdot \left[c_1^k(E) \frac{\partial L_1^k}{\partial p_{R2}^k} + c_2^k(E) \frac{\partial L_2^k}{\partial p_{R2}^k}\right]\right] \frac{\partial p_{R2}^k}{\partial L_2^h}.\end{aligned} \tag{C.37}$$

From (C.12) and (C.13), the effects of L_2^h on p_{R1}^k and p_{R2}^k are given by

$$\begin{aligned}\frac{\partial p_{R1}^k}{\partial L_2^h} &= \left[w_1^k + p_1^k\right] \frac{\partial c_1^k(E)}{\partial E} \frac{\partial E}{\partial C_2^h} c_2^h(E) > 0, \\ \frac{\partial p_{R2}^k}{\partial L_2^h} &= \left[w_2^k + p_2^k\right] \frac{\partial c_2^k(E)}{\partial E} \frac{\partial E}{\partial C_2^h} c_2^h(E) > 0.\end{aligned}$$

The terms on the different lines of the welfare effects of L_i^h can be easily interpreted. Take (C.37). The first line gives the effect of L_2^h on the planner's evaluation of well being of household h and thereby on W. The second line gives the effect of L_2^h on the externality, thereby on every household's cummuting and welfare, and on W. The third line gives the effect of L_2^h on the relative price of leisure for the first member of every household k, p_{R1}^k and on W. Similarly, the fourth line gives the effect of L_2^h on the relative price of leisure for the second member of every household k, p_{R2}^k and on W.

C.4 Marginal Costs of Funds

Marginal cost of funds can be calculated for a number of policy measures, as in Ahmad and Stern (1984); Brendemoen and Vennemo (1996); Schöb (1996); Mayeres and Proost (2001); Dahlby and Ferede (2012). They measure the cost, in terms of social welfare, of a change of a number of tax rates yielding one dollar of tax revenue:

$$MCF_i = -\frac{\frac{\partial W}{\partial t_i}}{\frac{\partial R}{\partial t_i}}. \tag{C.38}$$

We calculate MCF_i for three taxes: t_C, a tax on commuting time, t_w, the income tax rate t_w, and T, a poll transfer which is given to each household, and is a component of the household's non-labour income T^h. If the MCF_i differ, a budget neutral welfare increasing tax reform can be proposed by increasing the tax which has the lowest marginal cost of funds and decreasing the tax with the highest marginal cost of funds. In the present framework the marginal costs of funds will be influenced by the demerit corrections, given by the function $d^h(\bar{C}^h)$.

C.4.1 Preliminaries

Before calculating the marginal costs of funds, we pay attention to its building blocks. From the above it is clear that there are two prices in the model: the relative price of leisure of both earners, p^h_{R1} and p^h_{R2}. The effects of the taxes on these relative prices play an important role in the calculations. We include the tax rates into the relative prices:

$$p^h_{R1}(t_w, t_C) = w^h_1(1-t_w) - c^h_1(E)\left[w^h_1(1-t_w) + p^h_1 + t_C\right]. \tag{C.39}$$

$$p^h_{R2}(t_w, t_C) = w^h_2(1-t_w) - c^h_2(E)\left[w^h_2(1-t_w) + p^h_2 + t_C\right]. \tag{C.40}$$

For simplicity, we use a linearised budget constraint, as in Kleven and Kreiner (2006) who use average tax rates at the household's observed earnings level, see also Mayeres and Proost (2001). The derivatives of p^h_R with respect to t_C and t_w gives two systems of N equations in N unknowns: for every $h \in \{1, \ldots, N\}$:[12] For p^h_{R1} we obtain the following.

$$\begin{aligned}
\frac{\partial p^h_{R1}}{\partial t_C} &= -c^h_1(E) - \frac{\partial c^h_1}{\partial E}\sum_{k=1}^{N}\left[\frac{\partial E}{\partial C^k_1}\frac{\partial C^k_1}{\partial L^k_1}\frac{\partial L^k_1}{\partial p^k_{R1}} + \frac{\partial E}{\partial C^k_2}\frac{\partial C^k_2}{\partial L^k_2}\frac{\partial L^k_2}{\partial p^k_{R1}}\right]\frac{\partial p^k_{R1}}{\partial t_C} \\
\frac{\partial p^h_{R1}}{\partial t_w} &= -w^h_1\left(1 - c^h_1(E)\right) - \left[w^h_1(1-t_w) + p^h_1 + t_C\right]\frac{\partial c^h_1}{\partial E} \\
&\quad \sum_{k=1}^{N}\left[\frac{\partial E}{\partial C^k_1}\frac{\partial C^k_1}{\partial L^k_1}\frac{\partial L^k_1}{\partial p^k_{R1}} + \frac{\partial E}{\partial C^k_2}\frac{\partial C^k_2}{\partial L^k_2}\frac{\partial L^k_2}{\partial p^k_{R1}}\right]\frac{\partial p^k_{R1}}{\partial t_w}
\end{aligned}$$

From (C.3) and (C.4), $\frac{\partial C^k_i}{\partial L^k_i} = -c^k_i(E)$, such that the typical equations of the systems of equations can be written as

$$\frac{\partial p^h_{R1}}{\partial t_C} = -c^h_1(E) + \frac{\partial c^h_1}{\partial E}\sum_{k=1}^{N}\left[\frac{\partial E}{\partial C^k_1}c^k_1(E)\frac{\partial L^k_1}{\partial p^k_{R1}} + \frac{\partial E}{\partial C^k_2}c^k_2(E)\frac{\partial L^k_2}{\partial p^k_{R1}}\right]\frac{\partial p^k_{R1}}{\partial t_C} \tag{C.41}$$

$$\begin{aligned}
\frac{\partial p^h_{R1}}{\partial t_w} &= -w^h_1\left(1 - c^h_1(E)\right) + \left[w^h_1(1-t_w) + p^h_1 + t_C\right]\frac{\partial c^h_1}{\partial E} \\
&\quad \sum_{k=1}^{N}\left[\frac{\partial E}{\partial C^k_1}c^k_1(E)\frac{\partial L^k_1}{\partial p^k_{R1}} + \frac{\partial E}{\partial C^k_2}c^k_2(E)\frac{\partial L^k_2}{\partial p^k_{R1}}\right]\frac{\partial p^k_{R1}}{\partial t_w}
\end{aligned} \tag{C.42}$$

A similar result can be obtained for p^h_{R2}:

$$\frac{\partial p^h_{R2}}{\partial t_C} = -c^h_2(E) + \frac{\partial c^h_2}{\partial E}\sum_{k=1}^{N}\left[\frac{\partial E}{\partial C^k_1}c^k_1(E)\frac{\partial L^k_1}{\partial p^k_{R2}} + \frac{\partial E}{\partial C^k_2}c^k_2(E)\frac{\partial L^k_2}{\partial p^k_{R2}}\right]\frac{\partial p^k_{R2}}{\partial t_C} \tag{C.43}$$

$$\begin{aligned}
\frac{\partial p^h_{R2}}{\partial t_w} &= -w^h_2\left(1 - c^h_2(E)\right) + \left[w^h_2(1-t_w) + p^h_2 + t_C\right]\frac{\partial c^h_2}{\partial E} \\
&\quad \sum_{k=1}^{N}\left[\frac{\partial E}{\partial C^k_1}c^k_1(E)\frac{\partial L^k_1}{\partial p^k_{R2}} + \frac{\partial E}{\partial C^k_2}c^k_2(E)\frac{\partial L^k_2}{\partial p^k_{R2}}\right]\frac{\partial p^k_{R2}}{\partial t_w}
\end{aligned} \tag{C.44}$$

The prices of leisure, together with the household's non labour income influence each earner's choice of leisure time

$$L^h_1 = L^h_i\left(p^h_{R1}(t_w, t_C), p^h_{R2}(t_w, t_C), T^h\right)$$

The derivatives of L^h_i with respect to t_C and t_w are

$$\frac{\partial L^h_i}{\partial t_C} = \frac{\partial L^h_i}{\partial p^h_{R1}}\frac{\partial p^h_{R1}}{\partial t_C} + \frac{\partial L^h_i}{\partial p^h_{R1}}\frac{\partial p^h_{R2}}{\partial t_C}, \tag{C.45}$$

$$\frac{\partial L^h_i}{\partial t_w} = \frac{\partial L^h_i}{\partial p^h_{R1}}\frac{\partial p^h_{R1}}{\partial t_w} + \frac{\partial L^h_i}{\partial p^h_{R2}}\frac{\partial p^h_{R2}}{\partial t_w}. \tag{C.46}$$

[12] By accounting for the endogeneity of E, we take into account the externality feedback loop through E, as proposed by Mayeres and Proost (2001).

From the budget constraint (C.14),

$$\begin{aligned} x^h &= p_{R1}^h(t_w,t_C)\left(1-L_1^h\left(p_{R1}^h(t_w,t_C),p_{R2}^h(t_w,t_C),T^h\right)\right) \\ &\quad +p_{R2}^h(t_w,t_C)\left(1-L_2^h\left(p_{R1}^h(t_w,t_C),p_{R2}^h(t_w,t_C),T^h\right)\right)+T^h \end{aligned}$$

The derivatives of x^h with respect to t_C, t_w and T^h are

$$\begin{aligned} \frac{\partial x^h}{\partial t_C} &= \frac{\partial p_{R1}^h}{\partial t_C}\left[\left(1-L_1^h\right)-p_{R1}^h\frac{\partial L_1^h}{\partial p_{R1}^h}-p_{R2}^h\frac{\partial L_2^h}{\partial p_{R1}^h}\right] && \text{(C.47)} \\ &\quad +\frac{\partial p_{R2}^h}{\partial t_C}\left[\left(1-L_2^h\right)-p_{R1}^h\frac{\partial L_1^h}{\partial p_{R2}^h}-p_{R2}^h\frac{\partial L_2^h}{\partial p_{R2}^h}\right], && \text{(C.48)} \\ \frac{\partial x^h}{\partial t_w} &= \frac{\partial p_{R1}^h}{\partial t_w}\left[\left(1-L_1^h\right)-p_{R1}^h\frac{\partial L_1^h}{\partial p_{R1}^h}-p_{R2}^h\frac{\partial L_2^h}{\partial p_{R1}^h}\right] && \text{(C.49)} \\ &\quad +\frac{\partial p_{R2}^h}{\partial t_C}\left[\left(1-L_2^h\right)-p_{R1}^h\frac{\partial L_1^h}{\partial p_{R2}^h}-p_{R2}^h\frac{\partial L_2^h}{\partial p_{R2}^h}\right], && \text{(C.50)} \\ \frac{\partial x^h}{\partial T^h} &= 1-p_{R1}^h\frac{\partial L_1^h}{\partial T^h}+p_{R2}^h\frac{\partial L_2^h}{\partial T^h}. && \text{(C.51)} \end{aligned}$$

C.4.2 Revenue

Denote the social planner's revenue as $R(t)$:

$$\begin{aligned} R(t) &= \tilde{R}-NT+t_C\sum_{h=1}^{N}\left[c_1^h\left(1-L_1^h\right)+c_2^h\left(1-L_2^h\right)\right] \\ &\quad +\sum_{h=1}^{N}t_w\left[w_1^h\left(1-c_1^h\right)\left(1-L_1^h\right)+w_2^h\left(1-c_2^h\right)\left(1-L_2^h\right)\right] \end{aligned}$$

with $\tilde{R}$ exogenous revenue. The derivative of R with respect to the three policy instruments are

$$\begin{aligned} \frac{\partial R}{\partial t_C} &= \sum_{h=1}^{N}\left[c_1^h\left(1-L_1^h\right)+c_2^h\left(1-L_2^h\right)\right] \\ &\quad +t_C\sum_{h=1}^{N}\left[\frac{\partial c_1^h}{\partial t_C}\left(1-L_1^h\right)+\frac{\partial c_2^h}{\partial t_C}\left(1-L_2^h\right)\right]-t_C\sum_{h=1}^{N}\left[c_1^h\frac{\partial L_1^h}{\partial t_C}+c_2^h\frac{\partial L_2^h}{\partial t_C}\right] \\ &\quad -t_w\sum_{h=1}^{N}\left[w_1^h\frac{\partial c_1^h}{\partial t_C}\left(1-L_1^h\right)+w_2^h\frac{\partial c_2^h}{\partial t_C}\left(1-L_2^h\right)\right] \\ &\quad -t_w\sum_{h=1}^{N}\left[w_1^h\left(1-c_1^h\right)\frac{\partial L_1^h}{\partial t_C}+w_2^h\left(1-c_2^h\right)\frac{\partial L_2^h}{\partial t_C}\right], && \text{(C.52)} \end{aligned}$$

$$\begin{aligned} \frac{\partial R}{\partial t_w} &= \sum_{h=1}^{N}\left[w_1^h\left(1-c_1^h\right)\left(1-L_1^h\right)+w_2^h\left(1-c_2^h\right)\left(1-L_2^h\right)\right] \\ &\quad +t_C\sum_{h=1}^{N}\left[\frac{\partial c_1^h}{\partial t_w}\left(1-L_1^h\right)+\frac{\partial c_2^h}{\partial t_w}\left(1-L_2^h\right)\right]-t_C\sum_{h=1}^{N}\left[c_1^h\frac{\partial L_1^h}{\partial t_w}+c_2^h\frac{\partial L_2^h}{\partial t_w}\right] \\ &\quad -t_w\sum_{h=1}^{N}w^h\left[\frac{\partial c_1^h}{\partial t_w}\left(1-L_1^h\right)+\frac{\partial c_2^h}{\partial t_w}\left(1-L_2^h\right)\right] \\ &\quad -t_w\sum_{h=1}^{N}\left[w_1^h\left(1-c_1^h\right)\frac{\partial L_1^h}{\partial t_w}+w_2^h\left(1-c_2^h\right)\frac{\partial L_2^h}{\partial t_w}\right], && \text{(C.53)} \end{aligned}$$

$$\begin{aligned}\frac{\partial R}{\partial T} &= -N + t_C \sum_{h=1}^{N} \left[\frac{\partial c_1^h}{\partial T^h} \left(1 - L_1^h\right) + \frac{\partial c_2^h}{\partial T^h} \left(1 - L_2^h\right) \right] - t_C \sum_{h=1}^{N} \left[c_1^h \frac{\partial L_1^h}{\partial T^h} + c_1^h \frac{\partial L_1^h}{\partial T^h} \right] \\ &\quad - t_w \sum_{h=1}^{N} \left[w_1^h \frac{\partial c_1^h}{\partial T^h} \left(1 - L_1^h\right) + w_2^h \frac{\partial c_2^h}{\partial T^h} \left(1 - L_2^h\right) \right] \\ &\quad - t_w \sum_{h=1}^{N} \left[w_1^h \left(1 - c_1^h\right) \frac{\partial L_1^h}{\partial T^h} + w_2^h \left(1 - c_2^h\right) \frac{\partial L_2^h}{\partial T^h} \right]. \qquad \text{(C.54)}\end{aligned}$$

C.4.3 Welfare

Finally, we derive the impact on W of the three policy measures via their influence on x^h and L^h:

$$\frac{\partial W}{\partial t_C} = \sum_{h=1}^{N} \frac{\partial W}{\partial x^h} \frac{\partial x^h}{\partial t_C} + \sum_{h=1}^{N} \left[\frac{\partial W}{\partial L_1^h} \frac{\partial L_1^h}{\partial t_C} + \frac{\partial W}{\partial L_2^h} \frac{\partial L_2^h}{\partial t_C} \right], \qquad \text{(C.55)}$$

$$\frac{\partial W}{\partial t_w} = \sum_{h=1}^{N} \frac{\partial W}{\partial x^h} \frac{\partial x^h}{\partial t_w} + \sum_{h=1}^{N} \left[\frac{\partial W}{\partial L_1^h} \frac{\partial L_1^h}{\partial t_C} + \frac{\partial W}{\partial L_2^h} \frac{\partial L_2^h}{\partial t_C} \right], \qquad \text{(C.56)}$$

$$\frac{\partial W}{\partial T^h} = \sum_{h=1}^{N} \frac{\partial W}{\partial x^h} \frac{\partial x^h}{\partial T^h} + \sum_{h=1}^{N} \left[\frac{\partial W}{\partial L_1^h} \frac{\partial L_1^h}{\partial T^h} + \frac{\partial W}{\partial L_2^h} \frac{\partial L_2^h}{\partial T^h} \right]. \qquad \text{(C.57)}$$

D From wage and income elasticities to derivatives

In this appendix, we provide information on the calculations related to the behavioural effects.

First we focus on the derivative of leisure time L^k with respect to the price of own leisure. Obviously this is a behavioural reaction, based on the wage elasticities of labour supply.

$$\frac{\partial L^k}{\partial p_R^k} = \frac{\partial L^k}{\partial H^k}\frac{\partial H^k}{\partial w^k}\frac{\partial w^k}{\partial p_R^k}$$

We know that $L^h = 1 - \frac{H^k}{1-c^k}$ and so $\frac{\partial L^k}{\partial H^k} = -\frac{1}{1-c^k}$. Furthermore, from the definition of $p_R^k = w^k - c^k(w^k + p^k)$, (29), we have $w^k = \frac{p_R^k + c^k\left[p^k + t_C\right]}{[1-c^k][1-t_w]}$ and $\frac{\partial w^k}{\partial p_R^k} = \frac{1}{[1-c^k][1-t_w]}$. Household k's wage elasticity of labour demand is equal to $\varepsilon_H^{wk} = \frac{\partial H^k}{\partial w^k}\frac{w^k}{H^k}$. Using all these results we find

$$\frac{\partial L^k}{\partial p_R^k} = -\left(\frac{1}{1-c^k}\right)^2 \frac{1}{1-t_w}\varepsilon_H^{wk}\frac{H^k}{w^k}$$

For the second household member (spouse), with $\varepsilon_{H2}^{wk1} = \frac{w_1^k}{H_2^k}\frac{\partial H_2^k}{\partial w_1^k}$ and $\frac{\partial w_2^k}{\partial p_{R2}^k} = \frac{1}{\left[1-c_2^k\right][1-t_w]}$, such that

$$\frac{\partial L_2^k}{\partial p_{R1}^k} = -\left(\frac{1}{1-c_2^k}\right)^2 \frac{1}{1-t_w}\varepsilon_{H2}^{wk1}\frac{H_2^k}{w_1^k}$$

From budget constraint (28) we can derive

$$\frac{\partial x^k}{\partial p_R^k} = \left(1 - L^k\right) - p_R^k\frac{\partial L^k}{\partial p_R^k}$$

and so

$$\frac{\partial x^k}{\partial p_R^k} = \left(1 - L^k\right) + p_R^k\left(\frac{1}{1-c^k}\right)^2 \frac{1}{1-t_w}\varepsilon_H^{wk}\frac{H^k}{w^k}$$

Household k's elasticity of labour supply with respect to the lump sum grant is $\varepsilon_H^{Tk} = \frac{\partial H^k}{\partial T^k}\frac{T^k}{H^k}$.

$$\frac{\partial L^k}{\partial T^k} = \frac{\partial L^k}{\partial H^k}\frac{\partial H^k}{\partial T^k},$$

from which follows that

$$\frac{\partial L^k}{\partial T^k} = -\frac{1}{1-c^k}\frac{H^k}{T^k}\varepsilon_H^{Tk}.$$

and as

$$\frac{\partial x^k}{\partial T^k} = 1 - p_R^k\frac{\partial L^k}{\partial T^k},$$

we can derive that

$$\frac{\partial x^k}{\partial T^k} = 1 + p_R^k\frac{1}{1-c^k}\frac{H^k}{T^k}\varepsilon_H^{Tk},$$

The impact of household h's leisure time on household k's price of leisure can be written as follows

$$\frac{\partial p_R^k}{\partial L^h} = \left[w^k\left[1-t_w\right] + p^k + t_C\right]\frac{\partial c^k}{\partial \bar{C^h}}\frac{\partial \bar{C^h}}{\partial C^h}c^h$$

E Externality feedback

In this appendix we derive the externality feedback effect, such as in Mayeres and Proost (2001).

First of all, note that $\frac{\partial E}{\partial t_C}$ and $\frac{\partial E}{\partial t_w}$ can be written as

$$\begin{aligned}
\frac{\partial E}{\partial t_C} &= \sum_{k=1}^{N} \frac{\partial E}{\partial C^k} \frac{\partial C^k}{\partial L^k} \frac{\partial L^k}{\partial p_R^k} \frac{\partial p_R^k}{\partial t_C}\Big|_{\bar{E}} + \sum_{k=1}^{N} \frac{\partial E}{\partial C^k} \frac{\partial C^k}{\partial L^k} \frac{\partial L^k}{\partial p_R^k} \frac{\partial p_R^k}{\partial c^k} \frac{\partial c^k}{\partial E} \frac{\partial E}{\partial t_C} \\
\frac{\partial E}{\partial t_w} &= \sum_{k=1}^{N} \frac{\partial E}{\partial C^k} \frac{\partial C^k}{\partial L^k} \frac{\partial L^k}{\partial p_R^k} \frac{\partial p_R^k}{\partial t_w}\Big|_{\bar{E}} + \sum_{k=1}^{N} \frac{\partial E}{\partial C^k} \frac{\partial C^k}{\partial L^k} \frac{\partial L^k}{\partial p_R^k} \frac{\partial p_R^k}{\partial c^k} \frac{\partial c^k}{\partial E} \frac{\partial E}{\partial t_w} \\
\frac{\partial E}{\partial T} &= \sum_{k=1}^{N} \frac{\partial E}{\partial C^k} \frac{\partial C^k}{\partial L^k} \frac{\partial L^k}{\partial T}\Big|_{\bar{E}} + \sum_{k=1}^{N} \frac{\partial E}{\partial C^k} \frac{\partial C^k}{\partial c^k} \frac{\partial c^k}{\partial E} \frac{\partial E}{\partial T}
\end{aligned}$$

The first term in each line represents the direct effect on p_R^k holding E fixed, i.e. without feedback effects. An increase in the tax on commuting increases p_R^k and reduces E. The feedback effects only emerge in the second term on each line. The second term represents the effect due to the change in E. An increase in the tax on commuting reduces traffic and attracts new cars.

It implies that $\frac{\partial E}{\partial t_C}$ and $\frac{\partial E}{\partial t_w}$ can be written as

$$\frac{\partial E}{\partial t_C} = \frac{\sum_{k=1}^{N} \frac{\partial E}{\partial C^k} \frac{\partial C^k}{\partial L^k} \frac{\partial L^k}{\partial p_R^k} \frac{\partial p_R^k}{\partial t_C}\Big|_{\bar{E}}}{1 - \sum_{k=1}^{N} \frac{\partial E}{\partial C^k} \frac{\partial C^k}{\partial L^k} \frac{\partial L^k}{\partial p_R^k} \frac{\partial p_R^k}{\partial c^k} \frac{\partial c^k}{\partial E}} \tag{E.1}$$

$$\frac{\partial E}{\partial t_w} = \frac{\sum_{k=1}^{N} \frac{\partial E}{\partial C^k} \frac{\partial C^k}{\partial L^k} \frac{\partial L^k}{\partial p_R^k} \frac{\partial p_R^k}{\partial t_w}\Big|_{\bar{E}}}{1 - \sum_{k=1}^{N} \frac{\partial E}{\partial C^k} \frac{\partial C^k}{\partial L^k} \frac{\partial L^k}{\partial p_R^k} \frac{\partial p_R^k}{\partial c^k} \frac{\partial c^k}{\partial E}} \tag{E.2}$$

$$\frac{\partial E}{\partial T} = \frac{\sum_{k=1}^{N} \frac{\partial E}{\partial C^k} \frac{\partial C^k}{\partial L^k} \frac{\partial L^k}{\partial T}\Big|_{\bar{E}}}{\sum_{k=1}^{N} \frac{\partial E}{\partial C^k} \frac{\partial C^k}{\partial c^k} \frac{\partial c^k}{\partial E}} \tag{E.3}$$

The numerators contains the direct effects, which is presumably negative as the three last terms are negative. The denominator contains the feedback loop. Note that if there is no feedback loop, the denominator equals 1. If there is feedback, the denominator increases. Note that the expression behind the summation sign is negative as $\frac{\partial C^k}{\partial L^k} < 0$, $\frac{\partial L^k}{\partial p_R^k} < 0$ (if the labour supply curve is not backwards bending), and $\frac{\partial p_R^k}{\partial c^k} < 0$.

F Estimation of behavioural effects

Table D.1 contains the OLS estimates

In table D.2 the OLS estimates are provided for calculating the spouses' wages and commuting information, w_2^h and c_2^h. Some limited information is available for the spouses, e.g. education level and race. Based on that information, spouse information is calculated in order to be able to calculate the marginal costs of funds.

Table D.1: Estimated coefficients of the determinants of $\ln(c^h)$

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$ln\bar{C}$	0.742***	0.777***	0.845***	0.591***	0.772***	0.797***	0.839***	0.746***
D single+kids	-0.054***							
D 1 earner	0.087***							
D 1 earner+kids	0.105***							
D 2 earner	0.058***							
D 2 earner+kids	0.000							
D Low educ	0.042**							
D High educ	0.125***							
Age /1000	0.001							
D male	0.096***							
Intercept	-0.216	0.001	0.185	-0.630*	0.730	0.172	0.228	-0.101
R squared	0.028	0.014	0.017	0.007	0.014	0.016	0.018	0.013
N	19 999	19 999	5 675	3 192	1 062	1 610	3 049	5 411

Note: The dependent variable in the estimations is $ln(c^h)$*. Significance at 1, 5 or 10 percent is indicated by ***, ** and *, respectively. D stands for Dummy variable. Columns (3) until (8) reflect estimations with the different types of household: (3) one member, (4) one member with children, (5) one earner, (6) one earner with children, (7) couple, and (8) couple with children*

Table D.2: Estimated coefficients of the determinants of $\ln(c^h)$ and w^h

dependent variable	$\ln(c^h)$	w^h
family size	-0.016**	0.537***
D male	0.122***	3.853***
D Low educ	-0.019	-2.923***
D High educ	0.115***	6.953***
age (/1000)	-0.200***	100.420***
D white	-0.039	-0.452
D hispanic	0.111*	-3.246***
D other	0.022	0.289
D spouse Low educ	-0.003	-1.905***
D spouse High educ	0.058**	2.060***
Spouse age (/1000)	3.000**	7.447
D spouse white	-0.010	-1.169
D spouse hispanic	0.020	-1.617
D spouse other	0.041	-2.697***
D low commuting state (<0.05)	-0.145***	-1.560***
D high commuting state (>0.06)	0.091***	1.726***
Intercept	-2.371***	11.732***
R squared	0.028	0.183
N	8 191	8 191

Note: The dependent variable in the estimations is $ln(c^h)$*. Significance at 1, 5 or 10 percent is indicated by ***, ** and *, respectively. D stands for Dummy variable.*

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