FUTURE OF GASOLINE TAXES – A VERTICAL TAX COMPETITION APPROACH[1]

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ABSTRACT

This paper sets up a simple model to study a tax reform where federal gasoline taxes are gradually replaced by a combination of tolls that are decided by local authorities. When the federal and local governments maximize the welfare of their own citizens, there are no spillovers, capacity is given and all tax revenues are returned to the different regions, the reform can increase welfare if the implementation costs of the local tolls remain limited. This result holds for governments that behave non-cooperatively or when the federal government is a Stackelberg leader. One of the major barriers in the reform is the allocation of the revenues: when the federal government wants to keep the initial gasoline tax revenue constant, there is a vertical tax conflict that reduces the efficiency gains of the new instruments. The reallocation of tax revenues via changes in the intergovernmental transfer system is therefore an important component of this tax reform.

Keywords: tax reform, gasoline taxes, road tolls, parking charges, decentralization

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1. INTRODUCTION

Gasoline taxes have been the dominant instrument to raise taxes from car users and to correct different externalities such as congestion, air pollution, noise, climate change and accident costs. They are the right instrument to address climate change but an imperfect instrument to address congestion as they do not vary by time of day and by location. In fact, while the gasoline tax level in the UK is more than double the marginal external cost, the level of gasoline tax in the US cannot even account for non-congestion externalities while in the Netherlands the level of gasoline tax can only account for a very small amount of congestion cost.

Over time, technological progress has made the implementation of smarter charges such as congestion charges as well as parking charges much easier and urban road tolls are already introduced in places such as Singapore, London, Stockholm and Milan. It is expected that further progress in pricing technology as well as public acceptability will lead to a generalized use of parking and congestion pricing by local governments.

This raises several research questions - what results can be expected from the generalized introduction of parking charges and congestion taxes by local governments on top of the federal fuel taxes? Will the overall tax level be excessive? Under what conditions will the correct charge and tax levels be generated at the different government levels?

In this paper we study the transition problem of moving towards better pricing systems using a stylized model of a country where there are regions with and without traffic congestion. We study the efficiency and acceptability of the different equilibria that can be generated.

We have the following findings. As expected, in the federal government optimum, conditional on the implementation costs, a more complete combination of tax instruments increases welfare because it allows lower gasoline taxes in rural areas and better targeted congestion taxes in urban areas. In the non-cooperative equilibrium where tax instruments are decided by different levels of government, the same tax equilibrium will be reached when a certain list of conditions are satisfied. Important conditions are the absence of spillovers, governments maximizing the welfare of their voters, tax revenues that are returned to the region that is paying them. The last condition implies an important restructuring of intergovernmental transfers.

2. LITERATURE REVIEW

The optimal pricing of road transport externalities and the relation with road capacity are well covered in textbooks like (Small & Verhoef, 2007). For our transition problem we will make use of two strands in the literature. The first is on the optimal level of a gasoline tax given that it is the only instrument that can be used. The second is on the specific issues that arise when tax authority is shared by different levels of government.

(Parry & Small, 2005) looked into the optimal levels of gasoline taxes for the UK and the US. The optimal tax is defined as the tax that internalizes the main externalities associated to the use of fuel: climate damage, other air pollution, energy market issues and externalities specific to the use of a car: accidents and congestion. In addition, the derivation of the optimal tax also takes into account the revenue raising objective.

Although many effects enter the optimal gas tax, the marginal external congestion cost is the main driver of the results. The main conclusion for the UK is that the optimal gas price is high but not as high as it is now. For the US, the current gasoline tax is too low and the optimal gasoline tax is about half of the optimal UK gasoline price.

There are four main differences with our approach. First, they consider only a gas tax or a VMT tax. Second, the tax is applied uniformly for the whole country although the most important externality (congestion) is not uniform. Third, there is only one government that is deciding while in most cases, authority over the different tax instruments is divided over different levels of governments. Finally, no implementation or reform costs are discussed.

(DeBorger & Proost, 2012) survey the policy interactions between different government levels. Gasoline taxes are federal while parking and road pricing are often local. This creates vertical tax competition where both government levels may end up taxing too much the same tax base.

3. A STYLISED MODEL

In the stylized model a country consists of an urban region and a rural region and there is no interaction between the two regions and the rest of the world is ignored. We further limit the scope of our analysis to gasoline car use as diesel is mostly used for trucks and the road pricing of trucks has more international scope[2].

Typically, gasoline taxes are set by federal governments at the country level for two reasons. First because local differences in gasoline taxes would induce horizontal tax competition which probably can result in a race to the bottom. Second, there are political economy reasons why regions do not approve federal taxes that are differentiated by region (De Borger, Proost, 2013). While gasoline taxes are uniform, road pricing and parking charges are typically set by the local governments because traffic conditions vary strongly among regions. A gasoline tax acts as a distance-based charge. It has low implementation and transaction costs as it suffices to impose excise taxes at the refinery gate or at the import point. We analyze two stylized additional tax instruments. The first instrument is a parking charge or non-time differentiated road toll which decreases congestion levels but does not affect departure times. The second instrument is road pricing of the fine toll type (see (Arnott, et al., 1990)). It is strongly efficiency enhancing as it also affects departure times but it is more costly to implement.

More simplifying assumptions are introduced - First, agents are immobile and homogeneous in the sense that they all have the same utility function but their local traffic conditions can differ: either urban or rural. Agents do not move to other regions and within a region they all make the same trips in terms of length. Second, all governments maximize the welfare of their own residents. Third, congestion is of the bottleneck type and all trips have the same desired arrival time. There is congestion in the urban region but not in the rural region. Fourth, fuel efficiency of cars is fixed; it could be determined by internationally binding efficiency standards. Fifth, public transport is either not considered or assumed to be priced at marginal social cost and financed with lump sum taxes. Last but not least, road capacities are assumed to be fixed.

The inverse demand functions and user cost functions of trips in urban and rural region are:

$$\text{Rural Demand: } P_R(X_R) = a - b_R X_R \tag{1}$$

$$\text{Rural Cost: } C_R = \alpha + t_g \tag{2}$$

$$\text{Urban Peak Demand: } P_U^P(X_U^P) = a - b_U X_U^P \tag{3}$$

$$\text{Urban Peak Cost: } C_U^P(X_U^P) = \alpha + \beta X_U^P + t_g + t_p + t_f \tag{4}$$

[2] The taxation of gasoline and diesel for passenger cars is a topic on itself. See (Mayeres & Proost, 2013).

Urban Off-peak Demand (lower willingness to pay): $P_U^O(X_U^O) = a - b_U X_U^O - OP$ (5)

Urban Off-peak Cost: $C_U^O = \alpha + t_g + t_p$ (6)

where X is the number of trips made, t_g, t_p and t_f denote the level of gasoline tax, parking charge and fine toll respectively. The subscript R represents the rural region and U represents the urban region. The superscripts P and O represent the peak period and the off-peak period respectively. We assume all individuals have the same demand function for trips. Also the number of individuals in the federation is fixed. But we can vary the proportion θ of individuals that live in the urban and rural regions. In our model formulation, this is translated in the parameterization of b: $b_U = \frac{1}{\theta}$, $b_R = \frac{1}{1-\theta}$ as b_U is inversely proportional to the importance of urban traffic. This reduces the two parameters (b_R and b_U) of the demand functions to only one (θ). The user cost of travel during the peak period depends positively on the flow X_U^P. The parameter β represents the degree of congestion. The proportion of peak hours in the urban region is represented by γ. There is also an external cost e per trip that is proportional to the use of gasoline. This can stand for climate damage etc.

In the next section, we start with the case where the federal government decides on all tax levels.

4. ONE LEVEL OF GOVERNMENT

4.1 Gasoline tax as the only instrument

With the gasoline tax available as the only instrument to reduce congestion in the urban region, the federal government decides on the tax level, which is uniform in both urban and rural regions, by maximizing welfare of both the urban and the rural regions:

$$\begin{aligned} W = &\int_0^{X_R} P_R(X)dX - C_R X_R + t_g X_R - eX_R + \gamma[\int_0^{X_U^P} P_U^P(X)dX - C_U^P(X_U^P)X_U^P + t_g X_U^P - eX_U^P] \\ &+(1-\gamma)[\int_0^{X_U^O} P_U^O(X)dX - C_U^O X_U^O + t_g X_U^O - eX_U^O] \end{aligned} \quad (7)$$

By assumption, all tax revenue collected is returned to the region which bears the tax burden.

By differentiating welfare with respect to the uniform gas tax level, we obtain the first order conditions and the optimal level of country-wide gasoline tax is:

$$t_g = e + X_U \beta\left(\frac{\gamma\theta}{1+\beta\theta(1-\gamma\theta)}\right) = \frac{(a-\alpha-e)\beta\gamma\theta^2}{1+\beta\theta[2+\beta\theta(1-\gamma\theta)]} + e$$

$$e < t_g < e + X_U^P \beta\left(\frac{\gamma}{1+\beta\theta(1-\gamma)}\right) \quad (8)$$

This level of gasoline tax is too high for the rural region but too low for the urban region. As it is efficient to charge the marginal external cost (MEC), the first best optimal gasoline tax in the rural region is e, the environmental externality (remember there is no congestion in the rural region) while the optimal tax in

the urban region is $X_U^P \beta \left(\frac{\gamma}{1+\beta\theta(1-\gamma)} \right)$ on top of e, which is the "averaged" urban marginal external congestion cost. The uniform t_g is placed in between these two levels, as it is an attempt to internalize different levels of externality using one instrument. A uniform gasoline tax fails to achieve optimality.

The drawback of this instrument is that it discourages insufficiently trips in the urban area during peak hours, but discourages too much trips in the rural area and in the urban area during off-peak hours where there is no need to curb congestion.

4.2 Parking charge as an additional instrument

With the parking charge (equivalent to a flat toll) and the gasoline tax as the available instruments, the optimal level of gasoline tax can be reduced to the level of the environmental externalities e. As a result, the rural region faces a tax on traffic that is efficient. For the urban region, a parking charge which acts as a congestion tax is charged at rate $X_U^P \beta$ on top of the gasoline tax e.

$$t_g = e \tag{9}$$

$$t_p = X_U^P \beta \left(\frac{\gamma}{1+\beta\theta(1-\gamma)} \right) = \frac{(a-\alpha-e)\beta\theta\gamma}{1+\beta\theta[2+\beta\theta(1-\gamma)]} \tag{10}$$

4.3 Fine toll as an additional instrument

When the fine toll and the gasoline tax are the available instruments, the optimal level of gasoline tax is also equal to the environmental externalities e. At the same time, a fine toll is imposed on the urban traffic during the peak period and it transforms the queuing costs into toll revenue (Arnott, et al., 1990). The fine toll is different for every person making the trip because it changes the departure times, so that the travelers do not have to queue but still face different schedule delay costs because they have to arrive before or after their desired time of arrival. Therefore, the average fine toll during the peak period is $\frac{X_U^P \beta}{2}$ but the number of trips is not affected by the introduction of the fine toll and the number of trips is the same as when the total tax levied on urban trips is e.

$$t_g = e \tag{11}$$

$$t_f = \frac{X_U^P \beta}{2} = \frac{(a-\alpha-e)\theta\beta}{2(1+\beta\theta)} \tag{12}$$

An interesting difference between the parking charge and the fine toll is that while imposing a parking charge increases the user cost and lowers the number of trips, imposing a fine toll has no impact on the number of trips. As a result, the gasoline tax revenue decreases when the parking charge is introduced but it remains unchanged in the case of fine toll. This distinction will be crucial to the analysis with two levels of government in the next section.

4.4 Some comparisons

Disregarding implementation costs, the magnitudes of welfare are as follows: $W(t_g) < W(t_g + t_p) < W(t_g + t_f)$. So it is welfare improving for both the rural and urban regions to have a regional-specific tax instrument, on top of the uniform gasoline tax.

Proposition 1 *Disregarding implementation costs, introducing more complex tax instruments on top of a uniform gasoline tax, the welfare (of both regions) increases under the conditions that: a) the federal*

government has full information about the local situations in the regions and b) the federal government has the correct objective functions c) the gasoline tax can be lowered.

The analysis in the next section involves two levels of government, with the federal government deciding on the level of the gasoline tax and the local governments deciding on additional instruments.

5. TWO LEVELS OF GOVERNMENT

This section looks into the strategic behavior of the federal government and the regional governments under vertical tax competition. Now the regional governments have the option to implement a parking charge or a fine toll. In the remaining of the analysis only the urban and federal governments are active players, while the rural government is inactive as it has no influence on the gasoline tax level (except via its federal representatives) and has no reason to impose the parking charge or fine toll as long as the level of gasoline tax is larger than the environmental externalities.

The following assumptions are used in this section:
A1: Every government maximizes the welfare of its inhabitants. A2: There are no spillovers between regions. A3: All tax revenue is returned to the citizens who pay it. A4: No tax revenue concern or there are possibilities to use a head tax to finance any expenditures they need. A5: There are no implementation costs.

Proposition 2 *Under A1, A2, A3, A4, A5, the non-cooperative equilibrium where the federal government sets the uniform gas tax and the regional governments set parking and fine tolls, produces correct transport taxes.*

We prove the proposition in this section.

5.1 Right level of taxes with two levels of government

5.1.1 Parking charge as an additional instrument

In this non-cooperative game, the urban government maximizes its own welfare with respect to the level of parking charge, taking the gasoline tax level as given:

$$\begin{aligned} W_U &= \gamma[\int_0^{X_U^P} P_U^P(X)dX - C_U^P(X_U^P)X_U^P + (t_g + t_P)X_U^P - eX_U^P] \\ &+(1-\gamma)[\int_0^{X_U^O} P_U^O(X)dX - C_U^O X_U^O + (t_g + t_P)X_U^O - eX_U^O] \end{aligned} \tag{13}$$

The federal government maximizes the welfare of the whole country with respect to the level of gasoline tax, taking the level of parking charge as given:

$$W = \int_0^{X_R} P_R(X)dX + C_R X_R - eX_R + t_g X_R + W_U \tag{14}$$

The reaction functions are:

$$\begin{aligned} t_g(t_p) &= (a-\alpha)\left[\frac{\beta\theta^2\gamma}{1+\beta\theta[(2+\beta\theta(1-\gamma\theta)]}\right] + e\left[\frac{(1+\beta\theta)[1+\beta\theta(1-\gamma\theta)]}{1+\beta\theta[2+\beta\theta(1-\gamma\theta)]}\right] \\ &-t_p\left[\frac{\theta+\beta\theta^2[2+\beta\theta(1-\gamma)]}{1+\beta\theta[2+\beta\theta(1-\gamma\theta)]}\right] \end{aligned} \tag{15}$$

$$t_p(t_g) = (a-\alpha)\frac{\beta\theta\gamma}{1+\beta\theta[2+\beta\theta(1-\gamma)]} + (e)\frac{1+\beta\theta[2+\beta\theta(1-\gamma)]-\beta\theta\gamma}{1+\beta\theta[2+\beta\theta(1-\gamma)]} - t_g \quad (16)$$

Solving these two equations simultaneously gives the mutual best response (Nash equilibrium):

$$t_g^{NE} = e \quad (17)$$

$$t_p^{NE} = \frac{(a-\alpha-e)\beta\theta\gamma}{1+\beta\theta[2+\beta\theta(1-\gamma)]} \quad (18)$$

which are the same as the optimal levels of parking charge and gasoline tax derived in the previous section when the federal government was the only decision maker (10).

If the federal government is the Stackelberg leader, the best response function of t_p is the same as above. But as the federal government chooses the gasoline tax level, it takes the urban government's response into account. We replace t_p with $t_p(t_g)$ in the objective function of the federal government. The resulting tax levels with the federal government as the Stackelberg leader are again the same as the optimal levels of parking charge and gasoline tax derived previously.

5.1.2 Fine toll as an additional instrument

Under this setting, road pricing does not affect the total volume of traffic in the urban region because, with our assumptions, the toll merely transforms the queuing cost into toll revenue. Moreover, the implementation of a fine toll reduces the congestion cost during the peak period of the urban region by half on average as the queuing cost is transformed into fine toll payments.

Initially, the gasoline tax is the only available instrument and the implementation of a fine toll triggers a move from the initial equilibrium to a more efficient equilibrium where the combination of taxes is the same as the equilibrium with the federal government in command of all instruments. This result remains valid when the federal government is the Stackelberg leader in the game.

5.2 Violation of the assumptions

Having A1 to A5 eliminates the problem of double marginalization where both the regional governments and the federal government charge the same tax base, disregarding the effects on the other government's tax base. This is an ideal case and we look into four problems. First, if the governments are Leviathans (violation of A1), which maximize its total revenues instead of the welfare of its inhabitants, the tax levels will be higher and too many trips are discouraged. Second, if transit traffic is present, the governments have incentives to charge higher taxes on transit traffic so the right level of taxes cannot be attained. Third, if the tax revenue is not returned to the regions, the welfare of the regional government decreases when the federal government charges a higher gasoline tax and the regional government also increases the parking charge. The sum of taxes may be higher. Fourth, correct tax levels cannot be reached with the presence of revenue constraints or the absence of lump sum taxes. We will look into the case where the federal government has to keep the gasoline tax revenue constant.

5.2.1 Parking charge as an additional instrument with federal tax revenue constraints

Take the case where the initial federal gasoline tax revenue $\bar{R} = t_g[X_R + (\gamma)X_U^P + (1-\gamma)X_U^O]$ is kept constant in the tax reform. This means we add a revenue constraint to the maximization problem of the federal government; the federal government maximizes:

$$W = \int_0^{X_R} P_R(X)dX - C_R X_R - eX_R + t_g X_R + \gamma[\int_0^{X_U^P} P_U^P(X)dX - C_U^P(X_U^P)X_U^P + (t_g + t_P)X_U^P - eX_U^P] \\ +(1-\gamma)[\int_0^{X_U^O} P_U^O(X)dX - C_U^O X_U^O + (t_g + t_P)X_U^O - eX_U^O] - \lambda[\bar{R} - t_g(X_R + (\gamma)X_U^P + (1-\gamma)X_U^O)] \quad (19)$$

Suppose the federal government starts at the gasoline tax level t_g. When the regional governments can implement a parking charge, the urban government decides to have a parking charge t_P, the volume of traffic in the urban area decreases due to the higher tax level on urban traffic. In response, the federal government has to raise the gasoline tax to keep the revenue constant. The resulting gasoline tax level is higher than the original levels t_g.

Whether the federal government acts as the Stackelberg leader who intends to keep the gasoline tax revenue constant or both governments make the decision simultaneously, the equilibrium levels of the gasoline tax and the parking charge are the same in both cases.

This equilibrium level of gasoline tax is higher than that without the revenue constraint, as the revenue constraint acts as a barrier for the lowering of the gasoline tax when the parking charge is introduced. This implies that the tax levied on the rural traffic is now higher when the federal government keeps the gasoline tax revenue constant. On the other hand, the tax levied on the urban traffic, which is the sum of the gasoline tax level and the parking charge, is identical, with or without the revenue constraint.

The end result is inefficient and somewhat contradictory. Instead of lowering the tax level in rural areas and increasing the tax level in urban areas, the tax level in the rural region increases and that in the urban region remains unchanged.

5.2.2 Fine toll as an additional instrument

Now the gasoline tax revenue has to remain constant when the fine toll is introduced. Suppose the federal government starts at the gasoline tax level t_g to keep the revenue constant. When the fine toll is available to the regional governments and the urban government decides to charge a fine toll t_f, the volume of traffic in the urban area is unaffected. So in contrast to the response of the federal government with the parking charge as an additional instrument, the federal government does not have to raise the gasoline tax to keep the revenue constant as there is no decrease in traffic flow due to the new instrument. The resulting tax levels remain at the original levels t_g and t_f, regardless of whether both the federal government and the urban government make the decision simultaneously or the federal government acts as the Stackelberg leader in this tax setting game.

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