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Can we leave road pricing to the regions?
-the role of institutional constraints -

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Abstract

Many countries still use federal fuel taxes as the main instrument to charge for road use. Recently, urban road pricing and regional distance charging have gained momentum, increasing opportunities for future decentralized decision-making. However, whether leaving road pricing decisions to regional authorities is a good idea is not a priori clear. Previous political economy models have suggested that in the large majority of cases decentralization yields higher welfare than federal pricing decisions. In this paper, we extend a political economy model of a two-region federation to show that this conclusion does not hold once we allow for commonly observed institutional constraints on federal decision making. We show that requiring user prices to be uniform across regions greatly improves the efficiency of centralized decision making. The same holds when federal decisions are the result of a legislative bargaining process among elected regional representatives. Under these institutional constraints, federal decisions may easily outperform decentralization, even when the opposite would hold in the absence of the constraints. The model also explains under what conditions such constraints will automatically be embedded in the federal constitution. Specifically, if regions are symmetric and drivers have a majority in both regions, they will voluntarily transfer power to the federal level, provided the relevant policy restrictions (uniform pricing or legislative bargaining) are constitutionally imposed. However, if drivers have a majority in one region only, the region where non-users have a majority will never agree to transfer decision power to the federal level.

Keywords: road pricing, fiscal federalism, political economy
JEL-codes: D62, H23, R41, R48

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1. Introduction

In most countries, road use is still mainly charged via federal gasoline and diesel taxes[1]. Recently, however, there has been a tendency to partially move from fuel taxes towards other pricing instruments. For example, a few cities (London, Stockholm, Milan) have implemented congestion pricing. Moreover, in Europe, distance-based charging for trucks has been introduced in Germany, and implementation in other countries is planned in the near future (e.g., Belgium in 2016). With further technological progress, one can expect more diffusion of congestion pricing and kilometer charges, implying a larger potential for regional decision-making in the future. The reason is that, whereas regional variation of gasoline and diesel taxes is difficult because of tax competition between regions and countries, this is less the case for congestion charging or kilometer taxes. Indeed, fuel taxes can be avoided by buying fuel outside the region; local congestion or distance-based taxes can only be avoided by not using the regional infrastructure at all.

The expected developments described above raise the question under what conditions the pricing of road use is best left to the regions, and under what conditions it is better to keep it under federal control[2]. In a previous paper (De Borger and Proost (2016)), we made a first attempt to answer this question in a political economy model of a two-region federation in the tradition of the second-generation literature on fiscal federalism (see, for example, Lockwood (2002), Besley and Coate (2003), and Oates (2005))[3]. In each region, we distinguished between users and non-users of the local road infrastructure; drivers in each region were assumed to use the road infrastructure in both regions, generating spill-overs between regions (drivers from outside the region that use the local infrastructure). Assuming standard voting procedures and lump sum redistribution of toll revenues, two forces drive policy decisions: within each region, there is revenue sharing between users and non-users; between regions, spillovers imply the potential for tax exporting, implying high prices for road use if there are many users from outside the region. It was shown that in most relevant cases decentralized decisions result in higher overall welfare than centralized, federal decisions. The only exception occurs when two conditions jointly hold: drivers in each region have a very large political majority, and in each region the share of local residents in the use of the local infrastructure is approximately fifty

[1] In the US, individual states can add their own gas and diesel tax to federal fuel taxes. Such regional differentiation is limited by tax competition, especially when regions or states are small, see below.

[2] Note that the model does not only apply to states that have an explicitly federal structure (Belgium Germany, Spain, etc.); it applies to all political structures with multi-layered governments. For example, the model can also be used to study decision making of a regional government versus local urban governments.

[3] This literature is mainly interested in comparing centralized versus decentralized provision of local public goods. Our model focuses on pricing decisions.

percent (the remaining fifty percent coming from outsiders). The intuition for this finding is easy: large driver majorities imply that revenue sharing with non-users is hardly an issue, and approximately equal shares of locals and outsiders in total road use in a region implies that at the central level incentives for decisions that favor the own region disappear. The model also showed that in many cases driver majorities will prefer small or zero tolls.

Our earlier analysis left some important questions unanswered, however, and it raised a number of further issues. First, if decentralized pricing decisions are in almost all relevant cases welfare-superior to centralized decisions, why do we observe so many instances of centralized transport decision-making? Congestion, accidents, and some types of pollution are local problems that seem to require local solutions. Now that decentralized pricing decisions are feasible, one would have expected more widespread implementation of pricing of road infrastructure that spatially differentiate according to local conditions. Second, although most decisions on road user pricing are still taken at the central level, these pricing policies are often implemented under specific institutional constraints. For example, in most countries federal fuel taxes are restricted to be uniform across the country. Similarly, the kilometer charges introduced for trucks in Germany are uniform; they do not differentiate according to local conditions. In other federal countries, there is no uniformity constraint, but pricing for road use is the result of intensive bargaining between regions; the introduction of kilometer charges in Belgium – to be implemented in 2016 – is a clear example. Are these institutional restrictions on the decision-making process only driven by political motivations, or are they also welfare-increasing in the sense that they improve the outcomes of the political process? Could it be that particular institutional constraints strongly enhance the welfare performance of centralized decisions, so that stimulating decentralized regional decision making might not be good idea after all? Third, if indeed centralization yields higher welfare under specific institutional constraints, under what conditions will regions be willing to give up regional authority and agree on transferring political decision power to the central level?

In this paper, we extend the analysis of De Borger and Proost (2016) to explore the implications of imposing institutional constraints on federal decision making, focusing on the role of uniform pricing constraints and legislative bargaining. We then reconsider the relative welfare performance of centralized versus decentralized decisions. The analysis not only contributes to explaining some of the questions raised above, it also identifies under what conditions the pricing of road use should be centralized or, on the contrary, under what conditions it is best left to the regions.

A brief description of the main results follows. First, requiring user prices to be uniform across regions greatly improves the efficiency of centralized decision making. The same holds when decision making is organized by a bargaining process between elected regional representatives. Second, provided these constitutional constraints are imposed, centralized decisions may easily outperform decentralization. We find that this is especially the case when drivers have the political majority and there are large spill-overs across regions. Third, we show that if regions are symmetric and drivers have a majority, both regions will agree to transfer decision power to the central level, provided a uniform pricing constraint across regions is imposed on the decision-making process. The same holds if the constitution prescribes that centralized decisions should be the result of negotiation between elected regional representatives. However, if people that do not drive are a majority in a given region we find that they will never agree to transfer decision power to the central level. We argue below that these findings are not inconsistent with empirical observations.

The paper relates to several strands of literature. First, it builds upon the 'second generation' literature on fiscal federalism (Persson and Tabellini (2000), Lockwood (2002) and Besley and Coate (2003), Oates (2005)) that has focused on both cooperative (for example, legislative bargaining) and non-cooperative (for example, decisions according to a minimum winning coalition) decision-making procedures. Second, our paper complements a number of recent studies that have emphasized the role of constitutional constraints. For example, Lörz and Willmann (2005) add a constitutional bargaining stage where regions negotiate the degree of centralization (in essence, what goods will be supplied centrally) as well as the associated regional cost shares (modeled by introducing side-payments between regions), showing that the level of centralization will be inefficiently low. Hickey (2013) shows that uniform taxation and federal bicameralism are institutions that facilitate federation formation. Most recently, Kessler (2014) studies the role of communication in federal political structures, showing that uniform provision of local public goods may be the result of the difficulties of credible transmission of information from the regional to the federal level. Finally, our model is related to the small but growing literature on the political economy of pricing of transport services. Although these studies typically focus on pricing in a setting with a single government (Borck and Wrede (2005), Brueckner and Selod (2006), De Borger and Proost (2012)), there are exceptions. For example, Knight (2004) uses a legislative bargaining framework to explain the allocation of highway funds in the US, showing that elected representatives may use their political power at the federal level to favor their own region, and the empirical results support his prediction. More recent studies analyze the political economy of various types of urban road pricing in a multi-government setting (see, e.g., Brueckner (2015) and Russo (2013)).

Structure of the paper is the following. In Section 2 we provide a summary of the model developed in our earlier paper and review its main findings. In Section 3, we use the model to study in detail the role of two commonly observed institutional restrictions on federal decision-making: a uniform pricing constraint, and legislative bargaining whereby centralized decisions are the result of negotiations between elected representatives of the regions. In Section 4, we analyze under what conditions such institutional constraints will automatically develop. A final section provides a summary and reviews the potential policy implications of our findings.

2. Centralized versus decentralized transport decisions: a simple model

In this section, we describe the model used for the analysis. As we start with the same basic model as De Borger and Proost (2016), we summarize their model description and some of the results that we need for purposes of comparison later in this paper.

2.1. Model setting

We use a setting with two regions, indexed $i=1,2$. We assume regions have the same population R, and that demand and cost functions are the same in both regions. In each region, there are two groups: a group of road users D_i, which we will call drivers in what follows, and a group N_i of 'non-drivers'; these are inhabitants that do not use any road infrastructure (for example, they may not own a car). Drivers make two types of trips: trips in the home region and trips in the other region. To simplify the exposition without affecting the qualitative insights to be derived from the model, we assume that the demand for both types of trips is independent.[4]

Total demand for miles on the local road system in a given region i is described by the linear inverse demand function

$$P(V_i) = a - bV_i \tag{1}$$

It consists of local traffic by inhabitants of the region, denoted L_i, plus demand for traffic in the region by inhabitants of the other region; the latter is denoted T_i. We have $V_i = L_i + T_i$. To simplify the exposition we assume that, conditional on a given generalized price, demands of

[4] These are, admittedly, strong assumptions. They are discussed in more detail in De Borger and Proost (2016). The binary set-up with drivers and non-drivers facilitates both the derivation of clear-cut results and the presentation of the results in a transparent way, without affecting the qualitative results.

local users and users from the other region are proportional. The advantage of doing this is that it allows us to define a 'spill-over' parameter, in analogy with the literature on local public goods referred to in the introduction. Specifically, the demand for use of the infrastructure of region i by locals and by people from the other region are specified as $L_i = \theta_i V_i$ and $T_i = (1-\theta_i) V_i$, respectively. The parameter θ_i $(0 \le \theta_i \le 1)$ is the share of trips or kilometers in region i made by local inhabitants of that region. The fraction $(1-\theta_i)$ can be interpreted as an indicator of 'spill-overs'. There are no spill-overs if $\theta_i = 1$.

In our model, regions differ in two dimensions. First, the degree of spillovers can differ between regions; the infrastructure of one region may be intensively used by outsiders, whereas this is not the case in the other region. Second, the composition of the population between drivers and non-drivers can differ. For example, drivers might form the majority in one region but not in the other. We do have $D_1 + N_1 = R = D_2 + N_2$. The fraction of the population that is a driver will play a crucial role in the analysis that follows. It is defined as

$$\eta_i = \frac{D_i}{D_i + N_i} = \frac{D_i}{R}; \quad i = 1,2 .$$

The generalized user cost function for road users is assumed to be linearly rising in the volume-capacity ratio. Inclusive of a potential user charge (for example, a road toll) τ on road use, we have the gross user cost $g(V)$

$$g(V_i) = C(V_i) + \tau_i = \alpha + \beta \frac{V_i}{K^0} + \tau_i \tag{2}$$

This paper focuses on pricing existing capacity, hence capacity K^0 will be assumed given throughout. It is assumed that toll revenues ($\tau_i V_i$) are redistributed lump-sum to all residents in the region, drivers and non-drivers alike.

We assume regional social welfare consists of net consumer surplus (gross consumer surplus minus total generalized costs) plus government revenues:

$$\{\int_0^{V_i} P(V_i)dV_i - V_i.g(V_i)\} + \tau_i V_i \tag{3}$$

Maximizing social welfare, it immediately follows that the optimal user price rule gives social marginal cost pricing; the tax equals the marginal external cost of congestion:

$$\tau_i = \frac{\beta V_i}{K^0}. \tag{4}$$

2.2. Centralized versus regional political decisions

The political process is kept simple. For decision making at the regional level, we assume simple majority voting so that, given the standard single crossing conditions, the median voter is decisive. For centralized decision-making, our basic model setting follows Besley and Coate (2003). They suggest that a legislature of locally elected representatives makes the decisions by forming a minimum winning coalition.[5]

Consider regional decisions. First, suppose drivers have a majority in an arbitrary region so that the decisive policy maker is a member of this group. We assume that he will choose the price level that maximizes the following objective function:

$$\underset{\tau}{Max}\ \frac{\theta}{D}\{\int_0^V P(V)dV - V.g(V)\} + \frac{\tau V}{R} \tag{5}$$

As there is no potential confusion, to save on notation we have deleted the regional index. The welfare of an individual member of the group of drivers D consists of her consumer surplus as a user (expressed per person, this is a fraction $\frac{\theta}{D}$ of total surplus) plus the net revenues from user pricing that she will receive. The optimal pricing rule under decentralization that follows from (5) can be written as:

$$\tau^d = \frac{\beta V}{K^0} + \{1 - \frac{\theta}{\eta}\}\left(\frac{V}{-\frac{\partial V}{\partial \tau}}\right) \tag{6}$$

where the superscript '*d*' stands for 'decentralized', and where we have previously defined $\eta = \frac{D}{R}$. This parameter captures the fraction of the population that are drivers; if drivers have a majority, $0.5 < \eta \le 1$. The rule (6) implies a higher price when there are more tax exporting possibilities (when θ is small); moreover, it reflects the unwillingness of drivers to share toll revenues with non-drivers. This is less important if the majority of users, η, is large.[6]

If non-drivers have a majority (so that $0 \le \eta < 0.5$) they will opt for the revenue maximizing user price: they do not pay but do share in the excess revenues. The resulting user charge is shown to equal the marginal external cost plus the monopoly margin:

[5] For a defense of these assumptions, see De Borger and Proost (2016).

[6] Note that the tax rule boils down to the first-best outcome if the share of local demand in total traffic in the region (θ) equals the share of users in the number of local voters (η). In this case, the incentives for tax exporting compensate exactly the incentives to limit redistribution to non-drivers.

$$\tau^d = \frac{\beta V}{K^0} - \frac{V}{\frac{\partial V}{\partial \tau}} \tag{7}$$

Now consider centralized decision-making by a minimum winning coalition. This is implemented by assuming that each region decides by majority voting whether to send a driver or a non-driver as representative to the central level; once elected, each of the regional representatives has a 50% probability of being decisive at the central level.[7] Assume, for example, that the representative from region 1 is a driver and that he has to decide on user prices on the existing capacity in both regions. His problem is to solve

$$\underset{\tau_1,\tau_2}{\text{Max}} \ \frac{\theta_1}{D_1}\{\int_0^{V_1} P(V_1)dV_1 - V_1.g(V_1)\} + \frac{1-\theta_2}{D_1}\{\int_0^{V_2} P(V_2)dV_2 - V_2.g(V_2)\} + \frac{\tau_1 V_1 + \tau_2 V_2}{2R}$$

where V_i is transport demand in region *i*. To understand this, the first term is the net consumer surplus from driving in his own region, the second term is his net surplus when driving in region 2 (remember that $(1-\theta_2)$ is the fraction of drivers in region 2 that are resident of region 1). The third component in the objective function is his share in total toll revenues of both regions. The problem of a driver from region 2 is analogous.

We find that this leads to the following desired user price levels for a driver from region 1 (similar for region 2):

$$\tau_1^c(1) = \frac{\beta V_1}{K_1^0} + \{1 - \frac{2\theta_1}{\eta_1}\}\left(\frac{V_1}{-\frac{\partial V_1}{\partial \tau_1}}\right) \tag{8}$$

$$\tau_2^c(1) = \frac{\beta V_2}{K_2^0} + \{1 - \frac{2(1-\theta_2)}{\eta_1}\}\left(\frac{V_2}{-\frac{\partial V_2}{\partial \tau_2}}\right) \tag{9}$$

The notation $\tau_i^c(j)$ stands for the toll in region *i* that is preferred by a representative from region *j* under 'centralized' decisions.

If the representative of region 1 (similar for region 2) who is chosen as agenda setter is not a car user at all, he will select revenue maximizing user prices for both regions:

[7] A slightly different approach would be to assume that each region delegates both users and non-users to a federal parliament, and then let one member randomly be elected as agenda setter. This person can then form a minimum winning coalition with other members of the legislature. As this approach implies many more possible coalition formations, we followed the setup of Besley and Coate (2003) in which each region sends one representative (elected by majority voting) to the federal parliament.

$$\tau_1^c(1) = \frac{\beta V_1}{K_1^0} - \frac{V_1}{\frac{\partial V_1}{\partial \tau_1}} \tag{10}$$

$$\tau_2^c(1) = \frac{\beta V_2}{K_2^0} - \frac{V_2}{\frac{\partial V_2}{\partial \tau_2}} \tag{11}$$

Careful inspection of the above pricing rules point at two types of potential exploitation. First, there is possible exploitation of one region by the other. For example, if spill-overs are limited (θ_i close to 1), drivers from a region that become decisive at the central level have incentives to impose low charges in the own region (where they drive) and high charges in the other region (where they don't drive but do share in the revenues), see (8)-(9). Second, there is potential exploitation of drivers by non-drivers. Indeed, if the agenda setter is not a car user at all, he will select revenue maximizing user prices for both regions[8].

To evaluate the relative welfare performance of decentralized and centralized decision-making -- assuming a risk-neutral definition of welfare under centralization -- we check whether

$$(W_1^d + W_2^d) > or < \left\{0.5\left[W_1^c(1) + W_1^c(2)\right] + 0.5\left[W_2^c(1) + W_2^c(2)\right]\right\}.$$

Here W_i^d is welfare in region *i* under decentralization, and $W_i^c(j)$ is welfare in region *i* under centralized decisions when the representative from region *j* is decisive at the central level. The right-hand side is expected welfare under centralized decisions, noting that each representative has equal probability of being decisive.

In the case of zero spill-overs, decentralization is found to be better than centralized decision making, provided drivers have a majority in at least one region (for details, see De Borger and Proost (2016). The intuition is that, first, whenever non-drivers decide on user prices they will be inefficiently high and, second, when drivers decide on prices, they will choose too low prices to avoid too much redistribution to non-drivers. If non-drivers have a majority in both regions, the political system does not matter but, importantly, both systems yield the same poor result: user prices will be too high and large welfare losses occur compared to the social optimum. Allowing for spillovers, decentralization generally outperforms centralized decisions, except when driver majorities are large and, in any given region, use of the infrastructure comes about equally from local users and from people from outside the region. Intuitively, the former condition means that revenue sharing is not an issue, the latter condition implies that the

[8] Note that this second type of exploitation exists both under centralized and decentralized decisions (see (7)), but it is more severe in the former case, as it applies to both regions.

incentives for decisive representatives at the central level to favor their own region disappear. Outside this ‘neighborhood’, decentralization will always do better.

3. Institutional restrictions and the relative performance of centralized pricing decisions

The finding of our previous analysis was that, when drivers form the majority in at least one of the two regions and unless very specific conditions hold, there are good reasons to prefer decentralized decision making: it avoids the potential exploitation of regions by other regions. However, in the introduction we pointed out that the superior performance of regional decisions seems in contradiction with the observation that many federal countries have centralized decision-making on transport pricing. We also noticed that in many cases of federal decision-making, transport prices are restricted to be uniform across regions; in other instances, they are the result of a legislative bargaining process between regions or member states.

In this section, we study the role of such institutional restrictions for the welfare performance of the decision-making process. The development of institutional constraints has been studied in the literature before, although in a quite different setting. Hickey (2013) shows how regions naturally require a bicameral federal system before they are ready to leave decisions to the federal level. Kessler (2014)) studies the problem where regional projects are funded by the federal level, but where regions have an informational advantage. This asymmetric information explains why federal politics are inefficient, and often lead to overspending.

In what follows, we analyze the two specific constraints mentioned before: requiring to charge uniform prices in both regions, and forcing regions to reach a solution on prices through bargaining. Both constraints can be either the result of a constitutional agreement when a federation is formed, or they can be the result of a game in trigger strategies where deviations by a regional representative are severely punished[9].

3.1. Centralized decisions under a uniformity constraint

The first constraint we consider is that the regional representatives in the central legislature are restricted to select user price levels that are equal in both regions. As before, decisions are

[9] Proost and Zaporozhets (2012) also consider centralized public good provision, but foresee that a regional representative that becomes agenda setter at the central level will observe certain regional shares for the allocation. The cost shares can then be an equilibrium in trigger strategies, in the sense that the other regional representatives can punish deviations in the future.

taken according to the principle of a minimum winning coalition. However, regional representatives that are in charge at the central level face the restriction $\tau_1 = \tau_2 = \tau$.

Consider first the case where drivers have a majority in both regions. What is the uniform toll chosen when the representative from region 1 is in charge at the central level? If in power, he determines the uniform user price so as to

$$\underset{\tau}{\text{Max}} \ \frac{\theta_1}{D_1}\{\int_0^{V_1} P(V_1)dV_1 - V_1.g(V_1)\} + \frac{1-\theta_2}{D_1}\{\int_0^{V_2} P(V_2)dV_2 - V_2.g(V_2)\} + \frac{\tau(V_1+V_2)}{2R}$$

In Appendix 1 we show that the uniform toll rule that follows from this problem can be written as

$$\tau^u(1) = \frac{\beta V^u(1)}{K^0} + \left[1 - \frac{(1+\theta_1-\theta_2)}{\eta_1}\right]\left(\frac{V^u(1)}{-\frac{\partial V^u(1)}{\partial \tau}}\right) \tag{12}$$

In this expression, $\tau^u(1), V^u(1)$ are the tolls and transport volumes under the uniformity constraint, assuming the representative from region 1 is decisive at the central level. Similarly, when the representative driver from region 2 is decisive we find (notation is interpreted analogously):

$$\tau^u(2) = \frac{\beta V^u(2)}{K^0} + \left[1 - \frac{(1-\theta_1+\theta_2)}{\eta_2}\right]\left(\frac{V^u(2)}{-\frac{\partial V^u(2)}{\partial \tau}}\right) \tag{13}$$

Interpretation of (12)-(13) is facilitated by comparison with the pricing rules given before. Two preliminary conclusions immediately follow. First, note that under symmetry, zero spill-overs (remember that this implies $\theta_1 = 1$) imply that tolls – and, hence, welfare levels -- are equal to what they are in the decentralized case (compare with (6)). This makes sense: when there are no spill-overs, the regional representatives at the central level have no incentive to deviate from what they would like for their own region. Second, comparison of (12)-(13) with centralized pricing rules in the absence of the uniformity restriction (see (8)-(9) above) clearly shows how the uniformity constraint 'averages out' the price difference between the regions.

We use the toll expressions (12)-(13) to show – assuming linear demand to facilitate the proofs -- two policy-relevant results. The formal proofs are in Appendix 1; here we focus on the intuition. First, imposing a uniform price restriction necessarily improves the welfare of centralized decision-making. The intuition is most easily explained when there are no spill-overs (so $\theta_i = 1$). The uniform price a representative driver from region *i* (*i=1,2*) wants is then

$$\tau^u(i) = \frac{\beta V^u(i)}{K^0} + \left[1 - \frac{1}{\eta_i}\right]\left(\frac{V^u(i)}{-\frac{\partial V^u(i)}{\partial \tau}}\right).$$

To see the implications of uniform pricing, compare this pricing rule with the user prices the representative wanted for his own region and for the other region in the absence of the uniformity constraint. Imposing $\theta_i = 1$ on (8)-(9) these are given by, respectively:

$$\tau_i^c(i) = \frac{\beta V_i^c(i)}{K^0} + \left[1 - \frac{2}{\eta_i}\right]\left(\frac{V_i^c(i)}{-\frac{\partial V_i^c(i)}{\partial \tau}}\right); \qquad \tau_j^c(i) = \frac{\beta V_j^c(i)}{K^0} + \left(\frac{V_j^c(i)}{-\frac{\partial V_j^c(i)}{\partial \tau}}\right)$$

The former is well below marginal external cost (remember that $\eta_i < 1$), the latter is the revenue maximizing price and exceeds marginal external cost. Using these insights, it is clear that imposing uniform prices raises the user price in the representative's own region; as this brings the user price closer to marginal external cost, it raises welfare. At the same time, the uniform user price is below the preferred price of the elected representative for the other region. This user price was too high from a welfare perspective, so that welfare rises in the other region as well. Hence, uniform user prices necessarily outperform differentiated user prices.

In Appendix 1 it is shown that this conclusion still holds when there are arbitrary levels of spill-overs. Intuitively, uniform prices smooth out unrestricted pricing under centralized decisions and, given the concavity of the welfare function in user charges, the uniformity constraint raises welfare.

A second result shown in Appendix 1 concerns the relative welfare performance of centralized decisions under a uniformity constraint and decentralized decision-making. It is shown that a sufficient condition for decentralization to yield higher welfare than centralized decisions under a uniform pricing constraint is that $\theta_i > \eta_i$ in both regions. A sufficient condition for uniform pricing to be better is that drivers have a large majority (large η_i) and spill-over levels are large ($\theta_i < \eta_i$) but not very different between regions. To see the intuition most clearly, assume symmetric regions as an example. Given that $\theta_i < \eta_i$, we saw before that decentralized tolls will exceed marginal external cost (see (6)). Uniform tolling internalizes the spillover and, as a consequence, it yields tolls that are below marginal external cost (see (12)-

(13)). Both deviate from the first-best; however, if spillovers are sufficiently large, it is intuitively clear that decentralization will yield tolls so far above marginal external cost that uniform tolls yield higher welfare.

We assumed so far drivers have a majority in both regions. If drivers have a majority in just one region, one also finds that imposing uniformity raises welfare. And, as before, if non-drivers are dominating both regions, the two political systems yield the same – and equally undesirable -- effects: prices will be the revenue maximizing ones, yielding too high prices from a social viewpoint.

We summarize findings in the following proposition.

PROPOSITION 1. Centralized decisions under a uniform pricing constraint

a. **In the case of centralized decision-making, if users have a majority in at least one region, a uniform user price restriction across regions is welfare improving.**
b. **A sufficient condition for decentralization to yield higher welfare than centralization under a uniformity constraint is that the share of local users is higher than the share of drivers in the population: $\theta_i \geq \eta_i$.**
c. **Centralization with a uniformity restriction yields higher welfare than decentralization if users have a large majority and there are large spill-overs in both regions: $\theta_i < \eta_i$**
d. **Imposing uniform tolls on decision makers does not improve the outcomes when non-users have a majority in both regions.**

3.2. Centralized decisions by legislative bargaining

One obvious alternative for the minimum winning coalition setup we used so far is legislative bargaining, whereby decisions are the result of negotiations between the elected representatives from the different regions. In this section, we focus on a bargaining game without threat points[10]. It can be justified in different ways. First, it can be based on Weingast's (1979, 2009) idea of 'universalism'. There are no explicit threat points because there is a consensus ex ante (based on trigger strategies that punish the deviant) to maximize the joint surplus of the two regions. Second, it can also be justified by observing that many federal countries have bicameral federal decision structures. Hickey (2013) shows how, in a country with only two regions, alternating proposals lead to a Rubinstein (1982) bargaining game,

[10] An alternative would be to consider a bargaining game with explicit threat points, allowing for side payments between regions (by differentiating the federal head tax over regions). The threat point is the allocation preferred by the regional representative that is the federal agenda setter. In this type of bargaining game, the agenda setter will only reduce the user price for the other region if he is compensated with lower federal head taxes.

where the solution corresponds to the outcome of a Nash bargaining solution. Finally, it could be argued that uncertainty with respect to who will be in charge at the central level leads regions to move towards a bargained solution; in expected value terms this may yield higher welfare. In what follows, we formally study bargaining assuming equal bargaining power between regions.

First, assume drivers have a majority in both regions. Then the objective function under legislative bargaining can be written as the sum of their individual objective functions. Outcomes therefore solve the following problem

$$\underset{\tau_1,\tau_2}{\text{Max}} \ \frac{\theta_1}{D_1}\{\int_0^{V_1} P(V_1)dV_1 - V_1.g(V_1)\} + \frac{1-\theta_2}{D_1}\{\int_0^{V_2} P(V_2)dV_2 - V_2.g(V_2)\} + \frac{\tau_1 V_1 + \tau_2 V_2}{2R}$$
$$+\frac{\theta_2}{D_2}\{\int_0^{V_2} P(V_2)dV_2 - V_2.g(V_2)\} + \frac{1-\theta_1}{D_2}\{\int_0^{V_1} P(V_1)dV_1 - V_1.g(V_1)\} + \frac{\tau_1 V_1 + \tau_2 V_2}{2R}$$

We denote the optimal tolls and volumes under bargaining in the two regions as τ_i^b, V_i^b, respectively. Following the same logic as before, we easily derive the tax rules:

$$\tau_1^b = \frac{\beta V_1^b}{K_1^0} + \{1 - \frac{\theta_1}{\eta_1} - \frac{(1-\theta_1)}{\eta_2}\}\left(-\frac{V_1^b}{\frac{\partial V_1}{\partial \tau_1}}\right) \tag{14}$$

$$\tau_2^b = \frac{\beta V_2^b}{K_2^0} + \{1 - \frac{\theta_2}{\eta_2} - \frac{(1-\theta_2)}{\eta_1}\}\left(-\frac{V_2^b}{\frac{\partial V_1}{\partial \tau_1}}\right) \tag{15}$$

To interpret (14)-(15) first note that, if the two regions only consist of drivers (hence, $\eta_1 = \eta_2 = 1$), then bargaining yields the first-best outcome, even when there are large spill-overs. The reason is that under those conditions there is no problem of revenue sharing with non-users, and each negotiating party takes into account traffic conditions in both regions. Second, when drivers only use the local infrastructure so that there are zero spill-overs, legislative bargaining and decentralized decisions yield the same outcome; this follows from comparing (14)-(15) with (6). In both cases, user charges will be below marginal external congestion cost (unless users make up 100% of the voters in both regions). The same result was found under a uniformity constraint.

In Appendix 2 we show that, provided drivers from both regions are elected in the federal legislature, bargaining also necessarily improves the welfare performance of centralized decisions.

Bargaining improves centralized decisions, but does it do better than decentralized regional decisions? Consider the general case with spill-overs. As mentioned above, when there are no spill-overs both yield the same outcomes. The effect of spill-overs on the tolls that result under the different regimes are easily obtained by differentiating (6) and (14)-(15) with respect to the spill-over parameter. Take the toll rules for region 1 as example. We find under decentralization and centralized legislative bargaining, respectively[11]:

$$\frac{\partial \tau_1^d}{\partial \theta_1} = \left(-\frac{1}{\eta_1}\right)\left(\frac{V_1^d}{-\dfrac{\partial V_1^d}{\partial \tau_1^d}}\right) < 0\,; \quad \frac{\partial \tau_1^b}{\partial \theta_1} = \left(-\frac{1}{\eta_1} + \frac{1}{\eta_2}\right)\left(\frac{V_1^b}{-\dfrac{\partial V_1^b}{\partial \tau_1^b}}\right) > or < 0 \qquad (16)$$

Noting that a higher θ_1 is equivalent to lower spill-overs (less traffic by 'foreigners' in the own regions), this suggests the following. First, when spill-overs are small and driver majorities are less than one, decentralization will yield higher welfare than negotiated central decisions. The reason is that, starting from zero spill-overs, a small increase in spill-overs raises user charges under decentralization so that prices come closer to their first-best levels; welfare improves. This is not the case under bargaining: more 'foreign' traffic in a region will lead the representative of this region to argue in favor of a higher toll, but the representative driver from the other region (who causes this increase in spill-overs) will plea for lower tolls. As can be seen from (16), if user majorities are equal in the two regions, the toll negotiated between the representatives from the two regions will not change at all, and neither does welfare. Hence, small spill-overs improve welfare of decentralized decisions relative to negotiated decisions.

Second, however, when spill-overs are so large that decentralization leads to user charges that are far above marginal external cost (see (6)), then the opposite may hold. A further increase in foreign traffic in the region yields even higher prices, but this now reduces welfare. Decentralization may not yield higher welfare than bargaining under these conditions. In general, we show in Appendix 2 that bargaining will perform better than decentralization when drivers have large majorities and spill overs are substantial. We will further illustrate this statement using numerical analysis below.

[11] Note that under the assumptions of our model the derivatives of demand with respect to the toll are independent of the spillover parameter. In principle, in a more general setting, this may not be the case.

Can we say anything about the relative welfare effects of imposing uniform prices and bargaining? Note that when regions are symmetric, (12)-(13) and (14)-(15) imply that uniform price restrictions and bargaining over prices yield the same outcomes, hence welfare is equal in both cases: $W^b = W^u$. In that case, Proposition 1 applies also to bargaining. The equivalence under symmetry implies that the extreme pricing decisions potentially taken by representatives from different regions can be smoothed out in two equivalent ways: impose a uniform pricing constraint on the centralized decisions taken by the representative in power, or decide over pricing by a bargaining process between representatives from different regions. When regions are asymmetric, we show in Appendix 2 that decisions by legislative bargaining will lead to higher welfare than imposing a uniform pricing constraint, unless driver majorities and spill-overs differ a lot between regions. Bargaining is better at smoothing out very different regional conditions.

For completeness sake, consider bargaining when drivers have a majority in one region only. In Appendix 2 we derive the relevant tax rules. The region where non-drivers have the majority now wants the revenue-maximizing toll in both regions. However, it is again easily shown that bargaining improves welfare of centralized decisions and that small spill-overs imply that decentralization outperforms centralized decisions, whereas for high spill-overs the opposite may hold (see Appendix 2).

Finally, of course, bargaining between two regions where non-drivers have a majority gives revenue maximizing charges everywhere, as it does under decentralization.

We summarize our results on bargaining in the following proposition.

PROPOSITION 2. Centralized decisions through legislative bargaining

a. **Bargaining between regions leads to the first-best outcome when all voters in both regions are drivers.**
b. **Bargaining may perform better than decentralization if drivers have large majorities and spill-overs are substantial.**
c. **Bargaining does not improve the outcomes if non-drivers have a majority in both regions.**
d. **If regions are symmetric, bargaining leads to the same outcomes as centralized decisions under a uniformity constraint.**

Whereas uniform pricing avoids extremes by requiring charges to be the same in both regions, bargaining allows different user prices in the two regions but requires representatives from both regions to jointly agree on the decision. The bargaining process therefore also smoothens out the extremes implicit in unrestricted centralized decisions of a minimum winning coalition: each negotiator realizes that pushing for very high tolls in a region is counterproductive, because he is a driver in that region and will be subject to this very high toll as well.

Of course, we could combine the two institutional constraints considered in Sections 3.1 and 3.2, and study bargaining under a uniformity constraint on user prices. That is, representatives would have to agree on one uniform toll level that applies universally in all regions. One easily shows that imposing uniformity (which was a good idea with a non-cooperative legislature) on the bargaining process is not necessarily a good idea. The intuition is easy: imposing a uniform toll level destroys opportunities for differentiating tolls according to different local conditions. If spill-overs and voting shares differ, transport volumes and congestion will differ across regions, requiring non-uniform toll levels. As under bargaining extreme toll differences have been smoothed out, forcing tolls to be uniform may be welfare-reducing.

3.3. Comparing alternative institutions for pricing existing capacity

We reviewed the results on pricing transport infrastructure under decentralization and centralization in Section 2; in Section 3 we analyzed the rules resulting from imposing a uniformity constraint, and we considered negotiated solutions between regions. It will be instructive to illustrate comparative findings using a simple numerical example. For the symmetric case, the results are easy to summarize in a simple figure (see below). The case of asymmetric regions does not lead to extra intuition; the numerical results for this case are discussed in the working paper version of this paper. Here we concentrate on the symmetric case.[12]

The example assumes that demand, cost and capacity parameters are the same in both regions, and the demand function is assumed to be linear. All relevant expressions for tolls, transport volumes and welfare levels under the various political systems are given in Appendix 1. The numerical exercise reported here is based on the following inverse demand function in each region *i (i=1,2)*:

$$P_i = 1.2 - 0.0001 * V_i .$$

The cost function parameters are $\alpha_i = 0.5, \beta_i = 0.75$. Capacity is assumed to be $K_i^0 = 3000$; capacity unit cost is $\rho = 0.1$.

[12] The formulas for toll and welfare levels for the different cases are provided in Appendices 1 and 2 below.

Using this example, we calculate the relative welfare performance of different systems for the symmetric ($\theta_1 = \theta_2, \eta_1 = \eta_2$) case. We summarize the results in Figure 1. On the horizontal axis, we show the share of drivers in the region, on the vertical axis the degree of spill-overs. As a starting point, consider for which parameter combinations decentralization outperforms centralization in the absence of institutional constraints. If drivers do not have a majority ($\eta_i < 0.5$), centralized and decentralized decisions yield the same (equally poor, because far from first-best) outcome. With a majority of drivers ($\eta_i > 0.5$), decentralization is better than centralization for a very wide range of parameter values. As argued before, only when drivers have a large majority and spillovers are close to $\theta_i = 0.5$ does centralization yield the highest welfare.

INSERT FIGURE 1 HERE

Now consider the role of the institutional constraints. First note that under symmetry uniform pricing and bargaining yield the same welfare outcome. This being said, we can distinguish three parameter zones in Figure 1. In zone 1, decentralization outperforms uniform and bargained solutions, which in turn are better than pure centralization. This holds true when some voters are non-drivers and, conditional on the fraction of non-drivers, when spill-overs are not too important. Of the four political systems considered, decentralization is therefore more likely to be the best option when spill-overs are very small or, when they are not, when many voters in the region are non-drivers. In zones 2 and 3, uniform and bargained solutions welfare-dominate the other systems. These centralized decision-making systems are more likely to be optimal when there are high spill-overs and users have large majorities. Note that in zone 2 pure centralized decisions are the worst possible political system. In zone 3, decentralization performs worst.

4. Federal constitutional rules

In the previous section, we considered the ranking of different institutional settings in welfare terms, and we found that in many cases imposing institutional restrictions on federal decisions implies that centralization yields higher welfare for the federation as a whole than decentralized decisions by individual regions. A logical follow-up question is whether such constraints can be embedded in a federal constitution? We view the constitution as setting the stage for the long term game between regions, or between groups of citizens within a region (for example, users versus non-users, different language groups, different ethnicities, etc.). Both dimensions are highly relevant in our setting: under some political systems, we showed that regions could be exploited by others; moreover, we found that -- within regions -- one group of voters might be subject to exploitation by another group (for example, users by non-users). The main question we ask in this section is, therefore, under what conditions regions -- or groups of citizens within regions – will be willing to transfer decision making power to the central level, provided that the relevant institutional constraints are formally embedded in the federal decision making process? For example, if uniform pricing improves the performance of centralized decision making and leads to higher welfare than decentralized decisions, does this imply that individual regions will be willing to give up their authority and transfer decision power to the central level?

A complete analysis of constitutional design is outside the scope of this paper. In the remainder of this subsection we therefore proceed in two steps. First, we study the institutional restrictions considered in Section 3 above, and we analyze under what conditions they will automatically arise. Second, we briefly discuss the imposition of other constitutional constraints to protect minorities within regions, or to protect users from other regions.

4.1. Imposing institutional restrictions: uniform pricing and legislative bargaining

We focus in this subsection on a uniform pricing restriction imposed on federal decision making. The analysis for legislative bargaining as a constitutional constraint is analogous. To avoid repetition, it is briefly discussed towards the end of this subsection.

We first consider the role of a uniform pricing restriction when drivers have a majority in both regions, next we look at what happens in a region where non-drivers have a majority.

Drivers have a majority in both regions

We assume that regions are symmetric; we briefly discuss the implications of asymmetry below. We are interested in the conditions under which drivers (who have, by assumption, a sufficiently large majority so as to be able to decide on transferring power to the central level) will agree to delegate decision making power to the central level. The proposal is that central decisions are taken by a minimum winning coalition subject to a uniformity restriction.

If there are spill-overs, we show in what follows that drivers in both regions will be better off with centralized decisions and uniform tolls than with decentralized decisions (similar analysis can be used for bargaining). If there are no spill-overs, of course, drivers are indifferent between centralized and decentralized decisions. Therefore, under the stated conditions drivers in the two regions will agree on a centralized decision-making process subject to uniform pricing constraints. The same result also holds when considering a transition from decentralization to legislative bargaining at the federal level because, under symmetry, uniformity and bargaining yield the same outcomes (see above).

To show the statement made, let us start by defining the welfare of a driver of region 1 when decentral political decisions are made. Given spill-overs, the driver enjoys a benefit of driving in region 2 as well as in his own region 1; moreover, he shares in the toll revenues collected in region 1, but gets nothing from the revenues in region 2. His total welfare is therefore

$$W^d(\textit{driver region } 1) =$$
$$\frac{\theta_1}{D_1}\{\int_0^{V_1^d} P(V_1)dV_1 - V_1.g(V_1)\} + \frac{1-\theta_2}{D_1}\{\int_0^{V_2^d} P(V_2)dV_2 - V_2.g(V_2)\} + \frac{\tau_1^d V_1}{R}$$

In this expression, the toll is in both regions the decentralized toll; the volumes are those consistent with these tolls. Using linear demands (see (1)), straightforward analysis allows us then to rewrite this expression as

$$W^d(\textit{driver region } 1) = \frac{\theta_1}{D_1}\frac{b}{2}\left(V_1^d\right)^2 + \frac{1-\theta_2}{D_1}\frac{b}{2}\left(V_2^d\right)^2 + \frac{\tau_1^d V_1^d}{R}$$

Imposing symmetry we obtain

$$W^d(\textit{driver region } 1) = \frac{1}{D}\frac{b}{2}\left(V^d\right)^2 + \frac{\tau^d V^d}{R} \tag{17}$$

This expression can be written as a function of demand and cost parameters only. Using equality of the generalized cost ($g(V^d) = \alpha + \frac{\beta V^d}{K^0} + \tau^d$) and the generalized price ($P(V^d) = a - bV^d$), it is straightforward to obtain the equilibrium volume and toll as, respectively:

$$V^d = \frac{a-\alpha}{2A - \frac{b\theta}{\eta}}; \qquad \tau^d = \left[\frac{a-\alpha}{2A - \frac{b\theta}{\eta}}\right]\left[A - \frac{b\theta}{\eta}\right],$$

where

$$A = b + \frac{\beta}{K}.$$

Substituting these expressions in (17), multiplying both sides by *R* and working out, we find:

$$R * W^d(\textit{driver region } 1) = \left(\frac{a-\alpha}{2A - \frac{b\theta}{\eta}} \right)^2 \left[A + \frac{b}{\eta}\left(\frac{1}{2} - \theta \right) \right] \tag{18}$$

Now turn to the total (expected) welfare of this same driver when uniform pricing decisions are taken at the central level. He benefits from driving in regions 1 as well as 2. Moreover, he now receives his share of the joint toll revenues in both regions. However, the uniform toll levels will depend on who is in charge at the central level. If he is in charge then his welfare is

$$\frac{\theta_1}{D_1}\{\int_0^{V_1^u(1)} P(V_1)dV_1 - V_1.g(V_1)\} + \frac{1-\theta_2}{D_1}\{\int_0^{V_2^u(1)} P(V_2)dV_2 - V_2.g(V_2)\} + \frac{\left(\tau^u(1)\right)\left(V_1^u(1) + V_2^u(1)\right)}{2R}$$

If his driving colleague from region 2 is decisive at the central level his welfare is

$$\frac{\theta_1}{D_1}\{\int_0^{V_1^u(2)} P(V_1)dV_1 - V_1.g(V_1)\} + \frac{1-\theta_2}{D_1}\{\int_0^{V_2^u(2)} P(V_2)dV_2 - V_2.g(V_2)\} + \frac{\left(\tau^u(2)\right)\left(V_1^u(2) + V_2^u(2)\right)}{2R}$$

Uniformity implies $V_1^u(1) = V_2^u(1) = V^u(1); V_1^u(2) = V_2^u(2) = V^u(2)$. Imposing symmetry and noting that there is a 50% probability that the driver from each region is decisive at the central level, we can show that expected welfare of the driver in region 1 can be written, analogous to (17), as follows:

$$E\left(W^u(\textit{driver region } 1)\right) = \frac{1}{D}\frac{b}{2}\left(V^u\right)^2 + \frac{\tau^u V^u}{R} \tag{19}$$

Finally, multiplying both sides by *R*, and using the toll and volume expressions – derived in a similar way as under decentralization, see expressions (A1.4) and (A1.7) in Appendix 1 --

we find $$R * E\left(W^u(\textit{driver region } 1)\right) = \left(\frac{a-\alpha}{2A - \frac{b}{\eta}} \right)^2 \left[A - \frac{1}{2}\frac{b}{\eta} \right] \tag{20}$$

Comparison of the two welfare levels (18) and (20) leads to some remarkable insights. First, if there are no spill-overs, welfare of a driver is identical under decentralized decisions and centralized decisions under a uniform pricing constraint. To see this, it suffices to substitute

$\theta = 1$ in (18). Second, when spill-overs do exist it easily follows that a driver will always prefer the centralized (uniform pricing) outcome. This is shown by noting that the right hand sides of (18) and (20) have the same structure, and differentiating the right hand side of (18) with respect to the spill-over parameter. We find

$$\frac{\partial\left[R*W^{d}(driver\ region\ 1)\right]}{\partial\theta}=\left(\frac{a-\alpha}{2A-\dfrac{b\theta}{\eta}}\right)^{2}\left(\frac{2b}{\eta}\right)\left[A-\frac{\theta b}{\eta}\right]>0 \qquad (21)$$

This derivative is positive: the first two terms are positive, and the last term is also positive (assuming positive decentralized tolls, see above). As driver welfare is the same under decentralized and uniform centralized tolls when there are zero spill-overs, and noting that an increase in spill-overs (a reduction in θ) reduces his welfare under decentralization, he will prefer uniform tolls for all levels of spill-overs.

The implication is simple but powerful. It means that a driver will be willing to transfer decision making power to the central level if tolls are constitutionally restricted to be uniform. Since by assumption drivers have a majority in both regions, one therefore expects regions to agree on central decision making subject to a uniformity constraint.

Importantly, note that this strong conclusion was derived under the assumption that regions were symmetric. Of course, if regions are quite asymmetric, the result is unlikely to hold. Suppose the infrastructure of one of the two regions is frequently used by drivers from 'abroad' (i.e., from the other region); the other region only has local traffic. The representative from the first region will then prefer decentralized decisions, because this allows the region to collect high toll revenues on drivers from abroad. He will then obviously not agree on transferring decision power to the central level.

Non-drivers have a majority in a given region.

Alternatively, assume there is one region with drivers in the majority and one region with non-drivers in the majority. Note that this is just another example of strong asymmetry between regions. Not surprisingly, we can show that the region where non-users have a majority will not be willing to agree on centralizing decisions. To fix ideas, let in region 1 drivers have a majority but let in region 2 the median voter be a non-driver. We focus on the total welfare of this non-user from region 2 to make our point.

When decisions are made in a decentral way, the non-user gets no benefit at all from the decisions in region 1: he does not drive and does not share in the toll revenues there. In region

2 his benefit is given by his share of the collected toll revenues. We can write his total (expected) welfare simply as

$$W^{d}(non-driver\ region\ 2)=\frac{\tau_2^d V_2^d}{R}$$

where the toll in region 2 is the revenue maximizing toll; the volume is the volume at this toll level. Multiplying by *R* and using the expressions for the toll and volume given before, we have

$$R*W^{d}(non-driver\ region\ 2)=\frac{(a-\alpha)^2}{4A} \tag{22}$$

Now let decisions be taken at the central level subject to a uniformity constraint. If the driver from region 1 becomes decisive at the central level, the non-driver from region 2 gets his revenue share equal to

$$\frac{\tau^u(1)\left[V^u(1)\right]}{R}$$

Here the toll is the one set by the representative from region 1 (who is a driver). Using the relevant toll and volume formulas this can be written as

$$\frac{1}{R}\left(\frac{a-\alpha}{2A-X^u(1)}\right)^2\left(A-X^u(1)\right)$$

where $X^u(1)=\dfrac{1+\theta_1-\theta_2}{\eta_1}b$. Similarly, if the representative from region 2 is himself decisive at the federal level, he will charge the revenue maximizing toll. It easily follows that his benefit is then

$$\frac{\tau^u(2)\left[V^u(2)\right]}{R}=\frac{1}{R}\frac{(a-\alpha)^2}{4A}$$

Multiplying by *R* and noting that both regions have an equal probability of being decisive at the central level, we obtain

$$R*W^{u}(non-driver\ region\ 2)=\frac{1}{2}\left(\frac{a-\alpha}{2A-X^u(1)}\right)^2\left(A-X^u(1)\right)+\frac{1}{2}\frac{(a-\alpha)^2}{4A} \tag{23}$$

Finally, compare (22) and (23). Both expressions are equal for $X^u(1)=0$. Noting that

$$\frac{\partial\left[\left(\dfrac{a-\alpha}{2A-X^u(1)}\right)^2\left(A-X^u(1)\right)\right]}{\partial\left(X^u(1)\right)}=\frac{(a-\alpha)^2}{\left[2A-X^u(1)\right]^3}\left(-X^u(1)\right)<0$$

for any positive X, the right hand side of (23) is smaller than that of (22). Hence, the non-driver of region 2 is always better off under decentralization. Again, the implication is powerful. A non-driver will never be willing to transfer decision power to the central level.

Summary of findings.

The above discussion leads to the following Proposition[13]:

PROPOSITION 3: Transferring decision power to the central level

a. **If regions are symmetric and drivers have a majority in both regions, both regions will agree to centralize decisions under a uniform pricing constraint.**
b. **If regions are symmetric and drivers have a majority in both regions, both regions will agree to centralize decisions if the constitution guarantees decision making by bargaining.**
c. **If drivers have a majority in one region only, the region where non-users have a majority will never agree to transfer decision power to the central level.**

A final remark is in order. We focused on uniform pricing in this section, but it is clear that similar results hold for legislative bargaining. First, under symmetry uniform pricing and bargaining yielded the same result, so that parts a. and b. of Proposition 3 directly apply to bargaining as well. Second, if regions are very asymmetric, representatives from regions with much foreign traffic will not be able to negotiate the very high tolls in their own region they could charge under decentralized decisions. They will then prefer decentralization and not agree to transferring power to the central level. Third, a non-user majority will under decentralization set a high price in the own region; he will be worse off under legislative bargaining, so that Proposition 3.c also applies here.

4.2. Other constitutional constraints

Implicit in the previous discussion was the concern of potential exploitation *between* regions. Importantly, note that one also may have to build in additional federal guarantees to prevent exploitation of minority groups *within* regions[14]. For example, when the user price is the only public policy instrument available (and redistribution is via head taxes) and non-drivers have a majority, to protect drivers a maximum fee may have to be imposed that is smaller than or equal to the marginal external congestion cost. This type of constraint exists in the EU, where

[13] Of course, if non-drivers have a majority in both regions, the choice of constitution does not matter. Prices will always be too high.
[14] This is done in some federal states; for example, certain federal restrictions in Belgium serve to protect language groups.

it was issued mainly to prevent exploitation of transit traffic in some member states. The constraint takes the form of a maximum fee in function of road capacity costs. These capacity costs are a very crude approximation of the marginal congestion costs. In theory, the mechanism can produce optimal pricing and capacity, even if the federal government does not know congestion costs (Van der Loo and Proost (2013)).

Lastly, of course, one could also imagine institutional constraints that improve decentralized solutions. In our model, one obvious constraint has already been built in: non-local users are charged the same price as local ones. The use of the non-discrimination principle in pricing policies is widespread in practice, and we will not discuss its efficiency effects here (see De Borger, Proost and Van Dender (2005) for such an analysis). Other possibilities would be to add caps on user fees, or to impose constraints on toll revenues.

5. Conclusions and policy implications

This paper studied a political economy model of pricing decisions for road use in a federal state. Starting from the observation that under a wide range of settings decentralized decisions yield higher welfare than centralization, its main purpose was to see whether various institutional constraints (requiring uniformity, requiring negotiated decisions, price restrictions) might improve the performance of centralized decisions. We found that this is indeed the case. It was shown that both bargaining between elected regional representatives and requiring user prices to be uniform across regions greatly improve the efficiency of centralized decision making. If regions are symmetric, both bargaining and uniform pricing in fact yield higher welfare than decentralized outcomes in cases where drivers have large majorities in the regions and there are large spill-overs. We further showed that such appropriate institutional restrictions may – but not always will -- naturally arise. For example, we found that, if regions are symmetric and drivers have a majority in both regions, both regions will agree to centralize decisions provided a uniform pricing clause is included in the agreement. However, if drivers have a majority in one region only, the region where non-users have a majority will never agree to transfer decision power to the central level. Finally, to avoid exploitation of users by non-users under decentralized decision making, restrictions may have to be introduced that reduce tolls below marginal external cost.

The results of this paper have relevance for understanding actual policy making in countries with a multi-layered government structure, emphasizing the interaction between the conflicting objectives of users and non-users of the infrastructure and the biases introduced by the political process.

First, our results may partly explain the choice for centralization in some, but not all, federal states. Moreover, it may help understanding why centralized decision-making procedures are often accompanied by institutional restrictions, such as uniform price constraints. The model suggested that, if regions are reasonably symmetric, drivers have large majorities and there are regional spill-overs, regions will be willing to transfer decision-making to the central level, provided pricing is uniform across regions. This is what may have happened in federal states such as Spain, Italy, Belgium, and Switzerland, where the main pricing instrument is still a federal gasoline tax (uniform across different regions) and where opposition to regionally differentiated pricing policies is fierce. Moreover, our model suggests that under the stated conditions uniform pricing may well be the welfare-optimal system. However, in the US, transport pricing is partially decentralized; apart from a federal gasoline tax which is uniform across states, there is also an additional fuel tax levied by the states (see, for example, Xie and Levinson (2009)). This makes sense. At the state level spill-overs – in terms of the percentage of users of state infrastructure that comes from other states -- are much more limited than in some of the European examples given before, but drivers have very large majorities in almost all states. Our model then suggests that decentralized decisions will be better than centralization. Note that in the US we also see some regional attempts at road pricing (for example, in California).

Second, when regions are very asymmetric (in terms of driver majorities and spill-overs), we found that uniform pricing is often dominated by bargained solutions. This will be the case, for example, when there are large differences in car ownership, and one region attracts a lot of commuter traffic from other regions (for example, in Belgium there is much more commuting from the Flemish region into the Brussels region than vice versa). Interestingly, very long negotiations have been taking place over the past decennium about the introduction of a kilometer charge for trucks (and later for passenger cars) in the three Belgian regions. The charges will become operational in 2016.

Of course, our results were derived under a set of restrictive assumptions that can be relaxed in future work. First, the size of the groups of users and non-users was fixed exogenously. In practice it may vary in function of the pricing decisions made: low charges are likely to increase the size of the groups of users. The major effect of this extension would be that there is an extra benefit of lower prices: it allows to increase the number of users; hence, it raises the likelihood of having a majority, or the size of an existing majority. Second, the results were derived for a federation of two regions of the same size. Differences in size brings in other possible exploitation mechanisms of the larger region that may require additional institutional restrictions on federal decision-making. Third, we could consider an arbitrary number of regions but, as long as regions are symmetric and they have equal probability of being decisive at the central level, much of the analysis continues to go through. However, when multiple regions are asymmetric, identifying the minimum winning coalition is much more difficult. Fourth, we assumed lump-sum redistribution of tax revenues. We could replace recycling of congestion tax revenues via the head tax by income tax recycling. In the presence of regional income differences, this introduce other incentives for federal decisions (for example, income distributional incentives).

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Appendix 1. Centralized decisions with a uniform user price restriction

Derivation of toll rules and transport volumes

Consider the problem

$$\underset{\tau}{\text{Max}}\ \frac{\theta_1}{D_1}\{\int_0^{V_1} P(V_1)dV_1 - V_1.g(V_1)\} + \frac{1-\theta_2}{D_1}\{\int_0^{V_2} P(V_2)dV_2 - V_2.g(V_2)\} + \frac{\tau(V_1+V_2)}{2R}$$

Using the equality of generalized price $P(V_i)$ and generalized cost $g(V_i)$ for *i=1,2*, the first-order condition can be written as

$$-\frac{\theta_1}{D_1}V_1\frac{dg_1}{d\tau} - \frac{(1-\theta_2)}{D_1}V_2\frac{dg_2}{d\tau} + \frac{1}{2R}\left[\tau\left(\frac{dV_1}{d\tau}+\frac{dV_2}{d\tau}\right)+(V_1+V_2)\right]=0 \qquad \text{(A1.1)}$$

Totally differentiating the definition of the generalized cost (2) it immediately follows that:

$$\frac{dg_i}{d\tau} = 1 + \frac{\beta}{K}\frac{dV_i}{d\tau}$$

The term $\frac{dV_i}{d\tau}$ captures the total effect of a toll increase on demand. The toll affects the generalized price, and hence demand, through two channels. First, holding congestion (i.e., the volume-capacity ratio) constant, a toll increase by one unit raises the generalized price by one unit. Second, however, the demand reduction that is the result of this increase in generalized price has a feedback effect on demand: it lowers congestion, and this in turn raises demand. The consequence is that the overall demand effect is smaller than the direct effect at constant congestion. To determine the overall effect, we write demand as a function of generalized price $V_i(P)$ and note that in equilibrium generalized price equals generalized cost. Totally differentiating demand and using the impact of the toll on the generalized price as previously derived, it is then straightforward to show that:

$$\frac{dV_i}{d\tau} = \frac{\frac{\partial V_i}{\partial \tau}}{1-\frac{\beta}{K}\frac{\partial V_i}{\partial \tau}}$$

In this expression $\frac{\partial V_i}{\partial \tau} = \frac{\partial V_i}{\partial P}$ is the direct demand effect of the toll, i.e., the effect at constant congestion.

Substituting the above expressions in the first-order condition (A1.1), multiplying by (*2R*) and rearranging, we solve for the uniform user price. We find:

$$\tau = \frac{V_1\left[\frac{2\theta_1}{\eta_1} - 1 + \frac{\beta}{K}\frac{\partial V_1}{\partial \tau}\right]\left(1 - \frac{\beta}{K}\frac{\partial V_2}{\partial \tau}\right) + V_2\left[\frac{2(1-\theta_2)}{\eta_1} - 1 + \frac{\beta}{K}\frac{\partial V_2}{\partial \tau}\right]\left(1 - \frac{\beta}{K}\frac{\partial V_1}{\partial \tau}\right)}{\frac{\partial V_1}{\partial \tau}\left(1 - \frac{\beta}{K}\frac{\partial V_2}{\partial \tau}\right) + \frac{\partial V_2}{\partial \tau}\left(1 - \frac{\beta}{K}\frac{\partial V_1}{\partial \tau}\right)}$$

Now note that, for a given representative being decisive, the volumes will be equal, as the tolls are uniform and demand parameters are the same in both regions by assumption.

A similar expression holds when the representative from the other region is decisive. Using these insights, we can rewrite the toll rules for both regions, after simple algebra, as

$$\tau^u(1) = \frac{\beta V^u(1)}{K} + \left[1 - \frac{(1+\theta_1-\theta_2)}{\eta_1}\right]\left(\frac{V^u(1)}{-\frac{\partial V^u(1)}{\partial \tau}}\right) \tag{A1.2}$$

$$\tau^u(2) = \frac{\beta V^u(2)}{K} + \left[1 - \frac{(1-\theta_1+\theta_2)}{\eta_2}\right]\left(\frac{V^u(2)}{-\frac{\partial V^u(2)}{\partial \tau}}\right) \tag{A1.3}$$

In these expressions, $\tau^u(i), V^u(i)$ are the tolls and transport volumes under the uniformity constraint when the representative from region *i* is decisive at the central level.

We assumed linear demand throughout, $P(V^u(i)) = a - bV^u(i)$. Use this information together with equality of generalized price and cost in (A1.2)-(A1.3), and solve for the volumes. We find:

$$V^u(1) = \frac{a-\alpha}{2A - X^u(1)}; V^u(2) = \frac{a-\alpha}{2A - X^u(2)} \tag{A1.4}$$

where

$$A = b + \frac{\beta}{K} \tag{A1.5}$$

$$X^u(1) = \left(\frac{1+\theta_1-\theta_2}{\eta_1}\right)b;\ X^u(2) = \left(\frac{1-\theta_1+\theta_2}{\eta_2}\right)b \tag{A1.6}$$

The toll as function of the parameters only can be obtained by substituting (A1.4) in (A1.2)-(A1.3). We find

$$\begin{aligned}\tau^u(1) &= \left[\frac{a-\alpha}{2A - X^u(1)}\right]\left[A - X^u(1)\right]\\ \tau^u(2) &= \left[\frac{a-\alpha}{2A - X^u(2)}\right]\left[A - X^u(2)\right]\end{aligned} \tag{A1.7}$$

For later reference, it is easy to show that the toll $\tau^u(i)$ is declining in $X^u(i)$ at an increasing rate,

$$\begin{aligned} \frac{\partial \tau^u(i)}{\partial X^u(i)} &= -A\left[\frac{a-\alpha}{(2A-X^u(i))^2}\right] < 0 \\ \frac{\partial^2 \tau^u(i)}{\partial \left(X^u(i)\right)^2} &= -2A\left[\frac{a-\alpha}{(2A-X^u(i))^3}\right] < 0 \end{aligned} \tag{A1.8}$$

<u>*Welfare comparison: does a uniform price restriction raise welfare?*</u>

We are interested in finding out whether imposing a uniform pricing restriction on centralized welfare is socially beneficial, i.e., does uniformity raise welfare? We therefore want to know whether

$$W^u(1)+W^u(2) < or > 0.5\left[W_1^c(1)+W_2^c(1)\right]+0.5\left[W_1^c(2)+W_2^c(2)\right] \tag{A1.9}$$

The left-hand side is total expected welfare in the two regions under uniform pricing, the right hand side is expected welfare under standard centralized decisions. In all cases the welfare function is given as

$$W=\{\int_0^V P(V)dV - V.g(V)\}+\tau V$$

Consider the left hand side of (A1.9). Given linear demand and using (A1.4)-(A1.7), welfare under the uniformity constraint can be found as, depending on who is in charge at the central level:

$$\begin{aligned} W^u(1) &= \left[\frac{a-\alpha}{2A-X^u(1)}\right]^2\left[A+\frac{1}{2}b-X^u(1)\right] \\ W^u(2) &= \left[\frac{a-\alpha}{2A-X^u(2)}\right]^2\left[A+\frac{1}{2}b-X^u(2)\right] \end{aligned} \tag{A1.10}$$

Turn to the right hand side of (A1.9). Using completely analogous methods, in De Borger and Proost (2016, Appendix 1) it is shown that welfare under a minimum winning coalition at the central level is given by (for the different regions and depending on who is decisive at the central level):

$$\begin{aligned} W_1^c(1) &= \left\{\frac{a-\alpha}{2A-X_1^c(1)}\right\}^2\left[A+\frac{1}{2}b-X_1^c(1)\right]; \quad W_1^c(2) = \left\{\frac{a-\alpha}{2A-X_1^c(2)}\right\}^2\left[A+\frac{1}{2}b-X_1^c(2)\right] \\ W_2^c(1) &= \left\{\frac{a-\alpha}{2A-X_2^c(1)}\right\}^2\left[A+\frac{1}{2}b-X_2^c(1)\right]; \quad W_2^c(2) = \left\{\frac{a-\alpha}{2A-X_2^c(2)}\right\}^2\left[A+\frac{1}{2}b-X_2^c(2)\right] \end{aligned} \tag{A1.11}$$

where

$$X_1^c(1) = 2b\frac{\theta_1}{\eta_1}; \qquad X_1^c(2) = 2b\frac{(1-\theta_1)}{\eta_2}$$
$$X_2^c(1) = 2b\frac{(1-\theta_2)}{\eta_1}; \quad X_2^c(2) = 2b\frac{\theta_2}{\eta_2} \tag{A1.12}$$

Toll levels and volumes are given by, as functions of parameters only, respectively:

$$V_1^c(1) = \frac{a-\alpha}{2A - X_i^c(1)}; \qquad V_1^c(2) = \frac{a-\alpha}{2A - X_1^c(2)}$$
$$V_2^c(1) = \frac{a-\alpha}{2A - X_2^c(1)}; \qquad V_2^c(2) = \frac{a-\alpha}{2A - X_2^c(2)} \tag{A1.13}$$

$$\tau_1^c(1) = \left[\frac{a-\alpha}{2A - X_1^c(1)}\right]\left[A - X_1^c(1)\right]; \qquad \tau_1^c(2) = \left[\frac{a-\alpha}{2A - X_1^c(2)}\right]\left[A - X_1^c(2)\right]$$
$$\tau_2^c(1) = \left[\frac{a-\alpha}{2A - X_2^c(1)}\right]\left[A - X_2^c(1)\right]; \qquad \tau_2^c(2) = \left[\frac{a-\alpha}{2A - X_2^c(2)}\right]\left[A - X_2^c(2)\right] \tag{A1.14}$$

Note that the derivatives of the tolls with respect to the *X*'s is similar to (A1.8): they decline at an increasing rate in the *X's*.

Given this information we turn to (A1.9). Note from (A1.10)-(A1.11) that regional welfare under different regimes has always the same structure; differences are due to different definitions of the *X*'s only. To show that expected welfare under uniform pricing exceeds centralized welfare with differentiated prices we exploit the properties of the relation between toll levels and the *X*'s together with the concavity of the welfare function in toll levels.

First, observe from (A1.12) that the mean of $X_i^c(1)$, denoted $\bar{X}^c(1)$, is:

$$\bar{X}^c(1) = 0.5\left[X_1^c(1) + X_2^c(1)\right] = \frac{b}{\eta_1}\left(1 + \theta_1 - \theta_2\right)$$

Comparison with (A1.6) immediately implies:

$$X^u(1) = \bar{X}^c(1).$$

An analogous argument yields

$$X^u(2) = \bar{X}^c(2).$$

The uniform toll the elected representative of region *i* (*i=1,2*) wants is equal to the average toll levels he wanted in the two regions.

Given the properties of the toll functions (A1.7) and (A1.14) – they are all declining at an increasing rate, see (A1.8) as example – this immediately implies

$$\tau^u(i) > \bar{\tau}^c(i) \tag{A1.15}$$

where

$$\bar{\tau}^c(i) = 0.5\left[\tau_1^c(i) + \tau_2^c(i)\right] \tag{A1.16}$$

is the average toll under centralization when the representative from region *i* is decisive.

Second, use (A1.6) to find:

$$\bar{X}(u) = 0.5\left[X^u(1) + X^u(2)\right] = 0.5\left[\frac{(1+\theta_1-\theta_2)}{\eta_1} + \frac{(1-\theta_1+\theta_2)}{\eta_2}\right]b \tag{A1.17}$$

It is easy to show that, given the restrictions on the parameters ($0 \le \theta_i \le 1; 0.5 \le \eta_i \le 1$), we necessarily have

$$0.5\left[\frac{(1+\theta_1-\theta_2)}{\eta_1} + \frac{(1-\theta_1+\theta_2)}{\eta_2}\right]b \ge b \tag{A1.18}$$

Importantly, note that the right hand side (b) can be interpreted as the value of X in the first-best optimal toll rule. To see this, use equality of generalized cost and generalized price in the first-best rule $\tau^{FB} = \frac{\beta V^{FB}}{K^0}$ and work out to find

$$\tau^{FB} = \left[\frac{a-\alpha}{2A-b}\right]\left[\frac{\beta}{K^0}\right]$$

Given the definition of A (see (A1.5)), this can be rewritten in the familiar form:

$$\tau^{FB} = \left[\frac{a-\alpha}{2A-X^{FB}}\right]\left[A - X^{FB}\right]$$

where

$$X^{FB} = b. \tag{A1.19}$$

Using (A1.17), (A1.18) and (A1.19) gives:

$$\bar{X}(u) = 0.5\left[X^u(1) + X^u(2)\right] > X^{FB}.$$

Given the properties of the toll rules this allows us to write

$$\bar{\tau}^u < \tau^{FB} \tag{A1.20}$$

Lastly, use (A1.15) and (A1.20) and note the concavity of the welfare function in tolls. This allows us to conclude

$$E(W^c) < E(W^u) < W^{FB}.$$

An analogous exercise shows that all the above results remain valid when drivers have a majority in one region only. The only difference is that in that case the non-driver wants a revenue maximizing toll, but this holds both under decentralized and uniform decision making.

Welfare comparison decentralization and centralization under a uniformity constraint

To conclude this appendix, note that the condition

$$\theta_i \geq \eta_i$$

is sufficient for welfare under decentralized decisions to exceed welfare under centralization with a uniformity constraint. To see this, using the various toll expressions ((6), (12)-13)), the condition $\theta_i \geq \eta_i$ immediately implies

$$\tau^u(1) < \tau_1^d < \tau_1^{FB}; \quad \tau^u(2) < \tau_2^d < \tau_2^{FB}$$

Given that the welfare function is concave in tolls this shows

$$W^u < W^d$$

Now consider the opposite, and assume

$$\theta_i < \eta_i .$$

The expressions derived before then easily show:

$$\tau_1^{FB} < \tau_i^d \ ; \quad \tau^u(i) < or > \tau_i^{FB} \ (i=1,2)$$

Whether uniform pricing or decentralization yields the highest welfare depends on parameter values. Intuitively, if uniform pricing comes close to first-best and decentralized tolls are much above first-best levels, then the former performs better than the latter. Loosely speaking, a sufficient condition is that spillovers are substantial but approximately equal in both regions and there are large driver majorities.

Appendix 2. Centralized decisions by legislative bargaining

Tolls, volumes and welfare

Remember the tax rules

$$\tau_1^b = \frac{\beta V_1^b}{K_1^0} + \{\frac{\theta_1}{\eta_1} + \frac{(1-\theta_1)}{\eta_2} - 1\} \frac{V_1^b}{\frac{\partial V_1}{\partial \tau_1}} \tag{A2.1}$$

$$\tau_2^b = \frac{\beta V_2^b}{K_2^0} + \{\frac{\theta_2}{\eta_2} + \frac{(1-\theta_2)}{\eta_1} - 1\} \frac{V_2^b}{\frac{\partial V_1}{\partial \tau_1}} \tag{A2.2}$$

Volumes, welfare and tolls can be derived easily, using analogous methods as before. We find:

$$V_1^b = \frac{a-\alpha}{2A - X_1^b}; \quad V_2^b = \frac{a-\alpha}{2A - X_2^b} \tag{A2.3}$$

$$W_1^b = \left[\frac{a-\alpha}{2A - X_1^b}\right]^2 \left[A + \frac{1}{2}b - X_1^b\right]; \quad W_2^b = \left[\frac{a-\alpha}{2A - X_2^b}\right]^2 \left[A + \frac{1}{2}b - X_2^b\right] \tag{A2.4}$$

$$\tau_1^b = \left[\frac{a-\alpha}{2A - X_1^b}\right]\left[A - X_1^b\right]; \qquad \tau_2^b = \left[\frac{a-\alpha}{2A - X_2^b}\right]\left[A - X_2^b\right] \tag{A2.5}$$

In these expressions,

$$\begin{aligned} X_1^b &= \left(\frac{\theta_1}{\eta_1} + \frac{1-\theta_1}{\eta_2}\right) b \\ X_2^b &= \left(\frac{\theta_2}{\eta_2} + \frac{1-\theta_2}{\eta_1}\right) b \end{aligned} \tag{A2.6}$$

Welfare comparisons

First, using analogous methods as in the case of uniform pricing we can show that legislative bargaining improves the welfare performance of centralized decision-making.

Define

$$\tilde{X}_1^c = 0.5\left[X_1^c(1) + X_1^c(2)\right]$$

Using the relevant expressions we have

$$\tilde{X}_1^c = b\left(\frac{\theta_1}{\eta_1} + \frac{1-\theta_1}{\eta_2}\right) = X_1^b$$

Similarly

$$\tilde{X}_2^c = X_2^b.$$

The negotiated toll in a given region equals the average toll in a region under centralized decisions. Applying completely analogous reasoning as in Appendix 1, we can show that/

$$W^b = W_1^b + W_2^b > 0.5\left[W_1^c(1) + W_2^c(1)\right] + 0.5\left[W_1^c(2) + W_2^c(2)\right]$$

Second, as in Appendix 1, again using similar techniques we can show that

$$\theta_i \geq \eta_i$$

is sufficient for decentralized welfare to exceed welfare under bargaining.

Comparing bargaining and uniform pricing

Finally, we want to compare the welfare performance of bargaining and decisions by a minimum winning coalition under a toll uniformity restriction. We know that symmetry implies that uniform pricing and bargaining lead to the same welfare.

Next turn to asymmetric regions. Note that there are two other sets of conditions such that bargaining and uniformity produce the same overall federal welfare, although regional welfare will differ across regions. If

$$\frac{\theta_1}{\eta_1} = \frac{\theta_2}{\eta_2}$$

then (A1.5)-(A1.7) and (A2.5)-(A2.6) imply

$$\tau^u(1) = \tau_2^b$$
$$\tau^u(2) = \tau_1^b$$

Moreover, if

$$\frac{1-\theta_1}{\eta_2} = \frac{1-\theta_2}{\eta_1}$$

the same expressions yield

$$\tau^u(1) = \tau_1^b$$
$$\tau^u(2) = \tau_1^b$$

In both cases, we have

$$W^u(1) + W^u(2) = W_1^b + W_2^b$$

To study the relative welfare performance of the two systems under asymmetry, note that we have, again using (A1.6) and (A2.6):

$$X^u(1) + X^u(2) = X_1^b + X_2^b \tag{A2.7}$$

We can now show that the following two sets of joint conditions are sufficient for bargaining to yield higher welfare than imposing a uniformity constraint on centralized MWC-decision making:

$$\begin{aligned} &\frac{\theta_1}{\eta_1} > \frac{\theta_2}{\eta_2} \quad \textit{and} \quad \frac{1-\theta_1}{\eta_2} < \frac{1-\theta_2}{\eta_1} \\ &\frac{\theta_1}{\eta_1} < \frac{\theta_2}{\eta_2} \quad \textit{and} \quad \frac{1-\theta_1}{\eta_2} > \frac{1-\theta_2}{\eta_1} \end{aligned} \tag{A2.8}$$

To see this, take the first set of inequality conditions as an example. They imply (using (A1.6) and (A2.6)):

$$X_1^b > X^u(2)$$
$$X^u(1) > X_2^b$$
$$X_2^b > X^u(2)$$

Together with (A2.7) this implies that the bargained tolls are 'in between' the two bargained tolls. Given concavity on the welfare function this implies

$$W^u(1) + W^u(2) < W_1^b + W_2^b \ .$$

It will be instructive to illustrate an example of this case graphically, see Figure A2. The relative position of the *X*'s on the lower panel (together with constraint (A2.7)) produces the relative toll levels on the horizontal axis of the upper panel. It then immediately follows from the concavity of the welfare function that bargaining yields higher total welfare than a minimum winning coalition under uniformity restrictions.

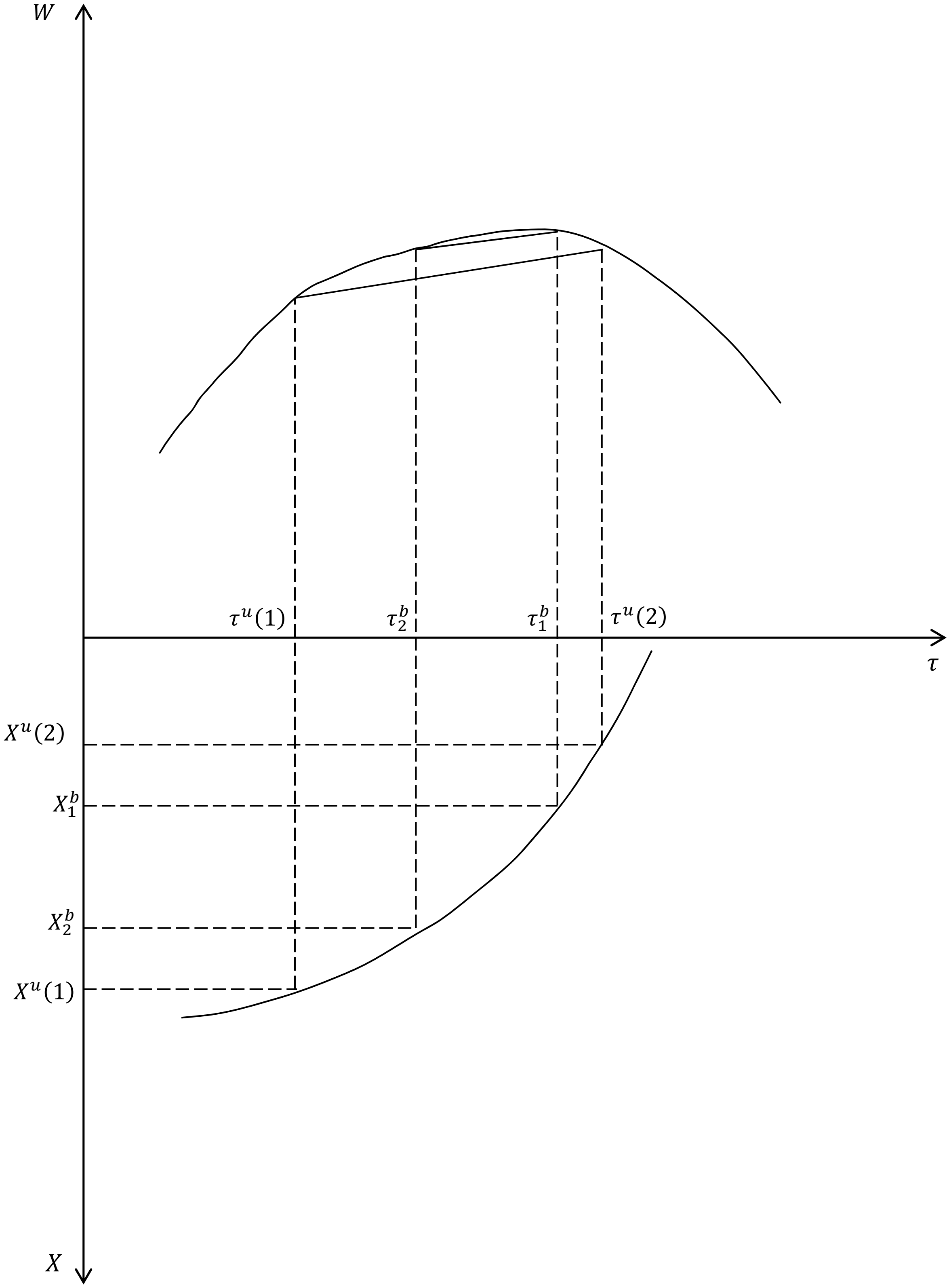

Figure A2: Bargaining versus a minimum winning coalition under uniformity

A similar result holds for the second set of inequality restrictions. If, however, one of the following sets of conditions hold

$$\begin{aligned} &\frac{\theta_1}{\eta_1} < \frac{\theta_2}{\eta_2} \quad \textit{and} \quad \frac{1-\theta_1}{\eta_2} < \frac{1-\theta_2}{\eta_1} \\ &\frac{\theta_1}{\eta_1} > \frac{\theta_2}{\eta_2} \quad \textit{and} \quad \frac{1-\theta_1}{\eta_2} > \frac{1-\theta_2}{\eta_1} \end{aligned} \tag{A2.9}$$

then uniformity is necessarily better than bargaining. The first set of conditions imply

$$\begin{aligned} &X_1^b < X^u(1) \\ &X^u(2) < X_2^b \\ &X_1^b < X_2^b \end{aligned}$$

Together with (A2.7) we now have that the two uniform tolls will now in between the negotiated tolls. We find

$$W^u(1) + W^u(2) > W_1^b + W_2^b$$

Uniformity is better than bargaining. A similar story applies to the second set of inequalities.

Loosely speaking, bargaining will certainly be better if the driver majorities are close to being equal; in that case, (A2.8) automatically holds so that bargaining is better. If there are large differences in user majorities and differences in spill-overs are of the opposite sign, then uniform prices may be better. Numerical analysis suggests, see the main body of the paper, that for most plausible parameter configurations, bargaining is better.

Second, if there is bargaining between one region where drivers have a majority (say, region 1) and a region where a non-driver is elected as representative (say, region 2) then the objective function is

$$\begin{aligned} \underset{\tau_1,\tau_2}{\text{Max}} \ & \frac{\theta_1}{D_1}\{\int_0^{V_1} P(V_1)dV_1 - V_1.g(V_1)\} + \frac{1-\theta_2}{D_1}\{\int_0^{V_2} P(V_2)dV_2 - V_2.g(V_2)\} + \frac{\tau_1 V_1 + \tau_2 V_2}{2R} \\ & + \frac{\tau_1 V_1 + \tau_2 V_2}{2R} \end{aligned}$$

We find the tax rules

$$\tau_1 = \frac{\beta V_1}{K_1^0} + \{\frac{\theta_1}{\eta_1} - 1\}\frac{V_1}{\frac{\partial V_1}{\partial \tau_1}}$$

$$\tau_2 = \frac{\beta V_2}{K_2^0} + \{\frac{1-\theta_2}{\eta_2} - 1\}\frac{V_2}{\frac{\partial V_2}{\partial \tau_2}}$$

where it should be noted that now $\eta_2 < 0.5$.

Under standard centralized decisions, the driver from region 1 wants the very low toll (if spill overs are limited) in his own region and a high toll in the other region, but the non-driver of region 2 wants the revenue maximizing toll everywhere. Bargaining leads to a mixture of these wishes. The outcome depends. For example, if there are no spillovers, the outcome is a high toll in region 2, because both representatives now want the revenue maximizing toll for this region. However, if there are large spillovers, the elected representative from region 1 wants a low toll in region 2, whereas the person from region 2 still wants a high toll. The outcome then depends on the relative strength of these two tendencies. Small spill-overs imply that decentralization outperforms centralized decisions, but for high spill-overs the opposite may hold.

Third, bargaining between two regions where non-drivers have a majority gives revenue maximizing charges everywhere, as it does under a uniformity restriction.

Figures

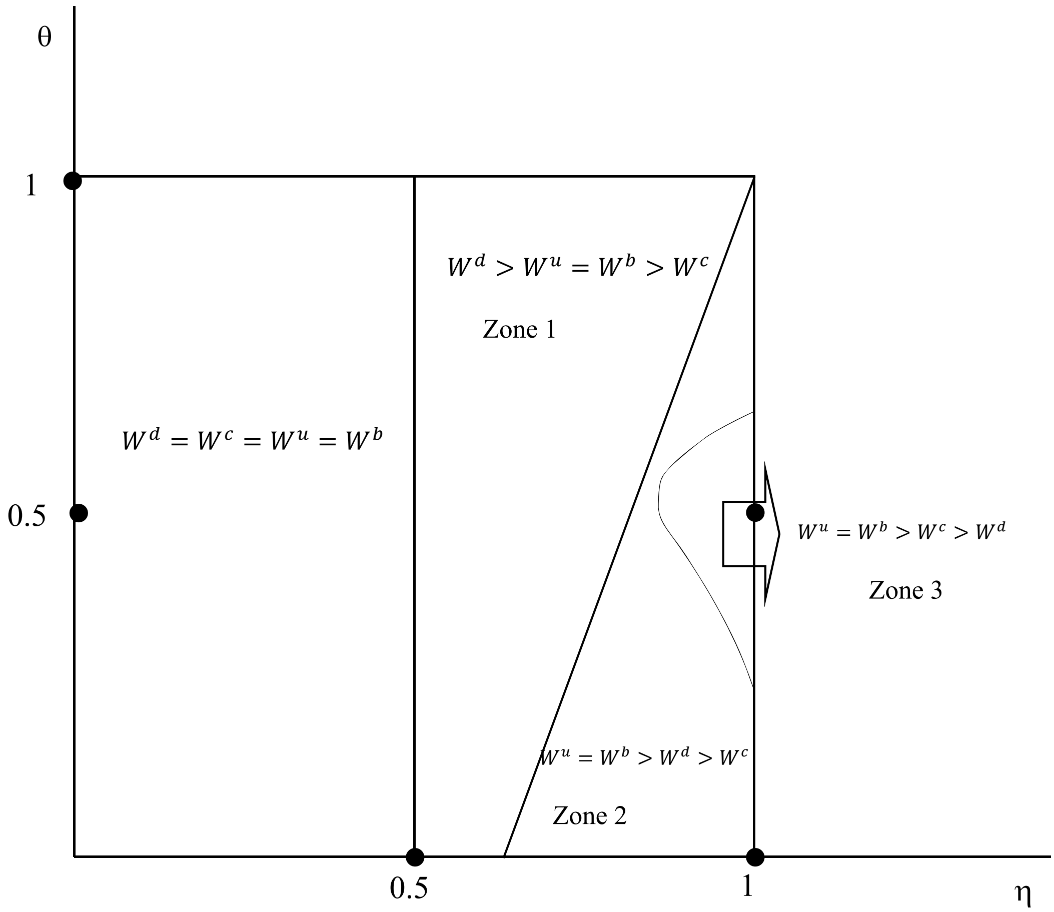

Figure 1: Welfare comparison between the four political systems for symmetric regions (d: decentralization, c: centralized decisions, u: centralized with a uniform pricing constraint, b: centralized with legislative bargaining between regions)