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

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Abstract

In most federal countries, the pricing of road use is still largely decided at the federal level, and often takes the form of fuel taxes. Recently, however, (urban) road pricing and (regional) distance charging have gained momentum, increasing opportunities for decentralized decision-making. In this paper we use a political economy model to analyze under what conditions the pricing of roads can better be left to the regions. We use a two-region model that allows for spill-overs between regions, it takes into account congestion, and it captures demand heterogeneity both between and within regions. At the regional level, decisions are taken by majority voting; at the federal level, elected regional representatives decide on charges for road use. We start from the observation, shown in earlier literature, that decentralized political decisions will under most plausible conditions yield higher welfare than federal decisions. We then show the following results. First, there are two institutional settings that necessarily improve the performance of federal decisions: (i) requiring uniform prices across regions, and (ii) legislative bargaining, whereby federal decisions are the result of negotiations between regional representatives. Second, under these constraints, federal decisions may easily outperform decentralization; this will be the case when users of the congestible good have large political majorities and there are substantial spill-overs across regions. Third, the model explains why in some, but not all, circumstances such institutions may automatically develop. Specifically, if regions are symmetric and drivers have a majority in both regions, we show that they will voluntarily transfer power to the federal level if a uniform pricing constraint is 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. We argue that these results are consistent with empirical observations.

Keywords: congestible local public goods, pricing, fiscal federalism
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1. Introduction

In most countries, road use is still mainly charged via federal gasoline and diesel taxes¹. 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. 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 just described raises 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. The answer is not obvious for two reasons. First, although strong regional variations in congestion levels favor the use of regional pricing instruments, full pricing autonomy for the regions carries the risk of overcharging ‘foreign’ users (users from outside the region). This potential exploitation of regions by other regions may be a reason for uniform federal charges, or for federal constraints on regional charges. Second, if not all inhabitants of a region are users of the infrastructure, there is also possible exploitation of one group by another. For example, whenever road users have a majority, they may opt for charges that are too low from a social perspective; on the contrary, when non-users are the majority, they may prefer monopoly charges that are too high from a social viewpoint. This problem is present at the regional as well as the federal level, albeit to a different degree. In this paper we study the trade-off between the advantages and disadvantages of regional versus federal decision-making, and we analyze what institutions can mitigate the different types of inefficiencies.

We build on the results of an earlier paper (De Borger and Proost (2015)), where we studied the political economy of local congestible public goods (like roads) in a model of a

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.

two-region federation². In each region we distinguished between users and non-users of the local (road) infrastructure, and users (drivers) in each region were assumed to use the road infrastructure in both regions, generating spill-overs between regions. Assuming standard voting procedures and lump sum redistribution of toll revenues, the main purpose was to analyze under what conditions centralized or federal decisions on pricing and capacity of transport infrastructure resulted in higher welfare than decentralized or regional decisions. In the model, two forces are driving 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 decentralized decisions perform better than centralization unless drivers in each region have a large majority, and the shares in total road use of local residents and residents of other regions are approximately equal in each region. The intuition for this latter 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 a number of important questions unanswered, however. First, if decentralization is in most relevant cases welfare-superior to centralized decisions, why do we observe so many instances of centralized transport decision-making? Why do we see so few cases of pricing of road infrastructure that spatially differentiate according to local conditions? After all, congestion, accidents, and some types of pollution are local problems that seem to require local solutions. Second, relatedly, why are centralized decisions often implemented under what we might call institutional constraints; these include the requirement of uniform pricing across regions or decision-making by legislative bargaining between regions. Are these institutional arrangements driven by political motivations, or are they also welfare-increasing in the sense that they improve the outcomes of the political process? Third, why are regions voluntarily willing to give up regional authority and agree on transferring political decision power to the central level? Under what conditions will they do so? Is this facilitated by the constitutional arrangements mentioned before? In this paper, we try to answer some of these questions.

² The explicit reference to ‘federal’ states is made for convenience. In principle, the model applies to all political structures with multi-layered governments. For example, it applies equally well to decision making processes of a regional government versus local urban governments.

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 road users have large political majorities and there are 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 non-users 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 fits in with the ‘second generation’ literature on fiscal federalism (Persson and Tabellini (2000), Lockwood (2002) and Besley and Coate (2003)), focusing on both cooperative (for example, legislative bargaining) and non-cooperative (for example, decisions according to a minimum winning coalition) decision-making procedures. Recent contributions include, among many others, Redoano and Scharf (2004), Oates (2005), and Hatfield and Padro i Miquel (2012).

Second, a number of papers have endogenized the division of authority over different layers of government, and 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.

Third, 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), Russo (2013) and De Borger and Proost (2015)).

Structure of the paper is the following. In the next section, we describe the model used for the analysis. In Section 2 we provide a summary of the model developed in our earlier paper. 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. Potential policy implications of our findings are summarized in Section 5. A final section concludes.

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 (2015), we summarize their model description.

2.1. Model setting

We use a setting with two regions, indexed $i=1,2$. In each region, there are two groups: a group of users D_i , and a group of inhabitants N_i that does not use any road infrastructure (for example, they may not own a car). Users 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.³

We assume regions have the same population R , and that demand and cost functions are the same in both regions. However, regions differ in two dimensions. First, the composition of the population between users and non-users can differ. For example, car users might form the majority in one region but not in the other. We do have $D_1 + N_1 = R = D_2 + N_2$

³ These are, admittedly, strong assumptions. They are discussed in more detail in De Borger and Proost (2015). The binary set-up with users and non-users facilitates both the derivation of clear-cut results and the presentation of the results in a transparent way, without affecting the qualitative results.

Second, for the group of users, the proportion of trips made at home and in the other region can be different. Specifically, denoting local trips as L_i ($i = 1, 2$), total demand for trips in each region is given by $L_1 + T_1, L_2 + T_2$, respectively. Here T_1 is the number of trips in region 1 made by inhabitants of region 2, and an analogous definition applies to T_2 . In other words, the index refers to where the transport takes place.

Total demand V for miles on the local road system is described by the linear inverse demand function

$$P(V) = a - bV \quad (1)$$

Total demand V consists of local traffic by local inhabitants of the region plus traffic in the region by inhabitants of the other region, $V = V_L + V_T$. We finally assume that, conditional on a given generalized price, demands of local users and users that live in the other region are proportional. This allows us to define a ‘spill-over’ parameter, in analogy with the literature on local public goods referred to in the introduction. Demands for local and transit demand by people from the other region are specified as $V_L = \theta V$ and $V_T = (1 - \theta)V$, respectively. The parameter θ ($0 \leq \theta \leq 1$) is the share of trips or kilometers that users from a given region make in their own region. The fraction $(1 - \theta)$ can be interpreted as an indicator of ‘spill-overs’.

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 $g(V)$

$$g(V) = C(V) + \tau = \alpha + \beta \frac{V}{K^0} + \tau \quad (2)$$

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

Assuming fixed capacity, regional social welfare simply consists of net consumer surplus (gross consumer surplus minus total generalized costs) plus government revenues:

$$\left\{ \int_0^V P(V) dV - V \cdot g(V) \right\} + \tau V \quad (3)$$

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:

$$\tau = \frac{\beta V}{K^0}. \quad (4)$$

2.2. Decentralized versus centralized 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.⁴

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

$$\text{Max}_{\tau} \frac{\theta}{D} \left\{ \int_0^V P(V) dV - V \cdot g(V) \right\} + \frac{\tau V}{R} \quad (5)$$

The policy-maker, as representative of a large group of homogenous individuals, understands the problem like a social planner, except that he adapts the objective function to his own interests. The welfare of an individual member of the group of users 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:

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

where the superscript ‘ d ’ stands for ‘decentralized’, and where we have defined $\eta = \frac{D}{R}$. This parameter captures the fraction of voters that are users; if users have a majority, $0.5 < \eta \leq 1$. The rule (6) implies a higher price when there are more tax exporting possibilities (when θ is small); moreover, it reflects the unwillingness of road users to share toll revenues with non-users. This is less important if the voting majority of users, η , is large.⁵

If voters that do not use the regional infrastructure have a majority (so that $0 \leq \eta < 0.5$) they will then opt for the revenue maximizing user price: they do not pay but do

⁴ For a defense of these assumptions, see De Borger and Proost (2015).

⁵ 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-users.

share in the excess revenues. The resulting user charge is shown to equal the marginal external cost plus the monopoly margin:

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

Now consider centralized decision-making by a minimum winning coalition. This is implemented by assuming that in each region a member of each of the two groups (users and non-users) can be elected – by majority voting -- as representative and, once elected, has a 50% probability of being decisive at the central level.⁶ Assume, for example, that the representative from region 1 is a user and that he has to decide on user prices on the existing capacity in both regions. His problem is to solve

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

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 (note 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 user from region 1 (similar for region 2):

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

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

⁶ Alternatively, one could assume that each region delegates both users and non-users to the federal parliament (for example, proportional representation), and let one representative from the federal parliament randomly be elected as agenda setter. He/she then forms a minimum winning coalition with other members of the legislature. This approach would have required to analyze many more possible coalition formations. We therefore followed Besley and Coate (2003) and opted for a setup in which each region delegates one representative (elected by majority voting) to the federal parliament. Also note that we implicitly assume the central decision maker has perfect information on preferences and costs in both regions. This can be justified in our model, as the use of the local public good is observable (road use) and it can be priced.

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, it is easy to show that he will select revenue maximizing user prices for both regions:

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

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

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), users 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 share in the revenues), see (8)-(9). Second, there is potential exploitation of users by non-users. Indeed, if the representative who is chosen as agenda setter is not a car user at all, he will select revenue maximizing user prices for both regions (see (10)-(11)). Note that this second type of exploitation exists both under centralized and decentralized decisions (see (7)) but is more severe in the former case, as it applies to both regions.

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

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

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.

The analysis leads to the main results of De Borger and Proost (2015) that will serve as benchmark for the institutional analysis in the next sections. They are easily summarized as follows.

In the case of zero spill-overs, it was shown that decentralization is better than centralized decision making, provided users have a majority in at least one region. The intuition is that, first, whenever non-users decide on user prices they will be inefficiently high and, second, when users decide on prices, they will choose too low prices to avoid too much redistribution to non-users. If non-users 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 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 users 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, the superior performance of regional decisions seems in contradiction with the observation, noted in the introduction, that many federal countries have centralized decision-making on transport pricing. At the same time, we noticed that in some cases of federal decision-making, transport prices are uniform across regions; in others, they are the result of bargaining between regions or member states.

In this section, we study the role of institutional restrictions for the welfare performance of the decision-making process. The development of such institutions 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 punished⁷.

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 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

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

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

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

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):

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

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 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

⁷ 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.

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. The uniform price a representative from region i ($i=1,2$) wants is then

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

It is easily seen that this is a weighted average of the user prices the representative wanted for his own region and for the other region in the absence of the uniformity constraint. Indeed, these prices are (see (8)-(9)) given by, respectively:

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

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; as this user price was too high from a welfare perspective, 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. All results will be numerically illustrated below.

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 points⁸. 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

⁸ 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.

country with only two regions, alternating proposals lead to a Rubinstein (1982) bargaining game, 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.

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

$$\begin{aligned} \text{Max}_{\tau_1, \tau_2} \quad & \frac{\theta_1}{D_1} \left\{ \int_0^{V_1} P(V_1) dV_1 - V_1 \cdot g(V_1) \right\} + \frac{1-\theta_2}{D_1} \left\{ \int_0^{V_2} P(V_2) dV_2 - V_2 \cdot g(V_2) \right\} + \frac{\tau_1 V_1 + \tau_2 V_2}{2R} \\ & + \frac{\theta_2}{D_2} \left\{ \int_0^{V_2} P(V_2) dV_2 - V_2 \cdot g(V_2) \right\} + \frac{1-\theta_1}{D_2} \left\{ \int_0^{V_1} P(V_1) dV_1 - V_1 \cdot g(V_1) \right\} + \frac{\tau_1 V_1 + \tau_2 V_2}{2R} \end{aligned}$$

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:

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

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

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:

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

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, 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 illustrate this statement using numerical analysis below.

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. See Appendix 2 and the numerical illustration for more details.

Finally, for completeness sake, consider bargaining when drivers have a majority in one region (say, region 1) but not in the other (say, region 2). We find the tax rules (see Appendix 2):

$$\tau_1^b = \frac{\beta V_1}{K_1^0} + \left\{1 - \frac{\theta_1}{\eta_1}\right\} \left(- \frac{V_1}{\frac{\partial V_1}{\partial \tau_1}} \right) \quad (17)$$

$$\tau_2^b = \frac{\beta V_2}{K_2^0} + \left\{1 - \frac{1 - \theta_2}{\eta_2}\right\} \left(- \frac{V_2}{\frac{\partial V_2}{\partial \tau_2}} \right) \quad (18)$$

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, as expressed by (17)-(18). Results are similar to the case with drivers in charge in both regions. If spill-overs are absent, then the bargained outcome is again the same as under decentralization, see (6) and (7). One again shows 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.

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 negotiating party realizes that pushing for very high tolls in a region is counterproductive, because it 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. To do so, we

first consider a full comparison under symmetry, then we discuss the case of asymmetric regions⁹.

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 $\rho = 0.1$.

Using this example, we calculate the relative welfare performance of different systems. Although spill-overs and driver majorities can differ between regions, we first focus on 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 users in the region, on the vertical axis the degree of spill-overs. The figure illustrates for which parameter combinations decentralization outperforms centralization. If voters do not have a majority ($\eta_i < 0.5$), centralized and decentralized decisions yield the same (equally poor, because far from first-best) outcome. Provided voters have a majority ($\eta_i > 0.5$), decentralized decisions are first-best for all parameter combinations $\theta_i = \eta_i$; centralization gives first-best outcomes when all voters are users and users of a given region travel as much in the other as in the own region ($\eta_i = 1, \theta_i = 0.5$). With a majority of drivers, 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.

Note that under symmetry uniform pricing and bargaining yield the same welfare outcome. We can then 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-users. In zones 2

⁹ The formulas for toll and welfare levels for the different cases are provided in Appendices 1 and 2 below.

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.

INSERT FIGURE 1 HERE

We numerically illustrate the results under asymmetries between regions in Table 1, using the same example. In each row, the alternative that yields the highest welfare is indicated in bold and underlined. For purposes of comparison, note that the first best welfare in the example is 517.

INSERT TABLE 1 HERE

Several observations stand out from Table 1. First, the results confirm the theoretical results summarized in the propositions: for example, decentralization yields the highest welfare as long as spill-overs are not too important, and requiring uniform prices across regions as well as bargained solutions improve the performance of centralized decisions. Second, when driver majorities are large, asymmetries in spill-overs improve the performance of bargaining relative to decentralization. However, bargaining becomes less attractive compared to decentralization when voting majorities are asymmetric. Finally, bargaining yields substantially higher welfare than uniform pricing when spill-overs are highly asymmetric between regions.

4. Federal constitutional rules

In the previous section, we considered the ranking of different institutional settings in welfare terms. A logical follow-up question is whether and how restrictions that lead to favorable welfare outcomes can be embedded in federal constitutions? Constitutions can be seen 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.). Note that both dimensions are highly relevant in our setting: under some political systems, regions could be exploited by other regions; moreover, we found that within regions one group of voters might be subject to exploitation by another group (for example, users by non-users).

Compared to the previous section, we therefore add a constitutional formation stage to the analysis. The question we ask is under what constitutional federal decision rules will regions -- or groups of citizens within regions -- be willing to transfer decision making power to the central level? Although a complete analysis of constitutional design is outside the scope of this paper, in the remainder of this subsection we analyze this question for a few specific cases. First, we focus on the institutional restrictions studied in Section 3 above. Assuming symmetric regions, both uniform pricing constraints and legislative bargaining were shown to improve the performance of centralized decisions; under some conditions, they outperformed regional decentralized decision-making. We analyze under what conditions such constitutional constraints 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. Uniform pricing as a constitutional restriction

We first consider the situation where drivers have a majority in both regions, next we look at what happens when they have a majority in one region only.

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 users (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 (driver region 1) =

$$\frac{\theta_1}{D_1} \left\{ \int_0^{V_1^d} P(V_1) dV_1 - V_1 \cdot g(V_1) \right\} + \frac{1-\theta_2}{D_1} \left\{ \int_0^{V_2^d} P(V_2) dV_2 - V_2 \cdot g(V_2) \right\} + \frac{\tau_1^d V_1}{R}$$

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

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

Imposing symmetry we obtain

$$W^d$$
 (driver region 1) = $\frac{1}{D} \frac{b}{2} (V^d)^2 + \frac{\tau^d V^d}{R}$ (19)

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:

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

where

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

Substituting these expressions in (19), multiplying both sides by R and working out, we find:

$$R * W^d$$
 (driver region 1) = $\left(\frac{a - \alpha}{2A - \frac{b\theta}{\eta}} \right)^2 \left[A + \frac{b}{\eta} \left(\frac{1}{2} - \theta \right) \right]$ (20)

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

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

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

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

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 (19), as follows:

$$E(W^u(\text{driver region 1})) = \frac{1}{D} \frac{b}{2} (V^u)^2 + \frac{\tau^u V^u}{R} \quad (21)$$

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

$$R * E(W^u(\text{driver region 1})) = \left(\frac{a - \alpha}{2A - \frac{b}{\eta}} \right)^2 \left[A - \frac{1}{2} \frac{b}{\eta} \right] \quad (22)$$

Comparison of the two welfare levels (20) and (22) 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 (20). 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 (20) and (22) have the same structure, and differentiating the right hand side of (20) with respect to the spill-over parameter. We find

$$\frac{\partial [R^*W^d(\text{driver region 1})]}{\partial \theta} = \left(\frac{a-\alpha}{2A-\frac{b\theta}{\eta}} \right)^2 \left(\frac{2b}{\eta} \right) \left[A - \frac{\theta b}{\eta} \right] > 0 \quad (23)$$

This derivative is positive: the first two terms are positive, and the last term is also positive (assuming positive decentralized tolls, see (6)). 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.

Drivers have a majority in one region only.

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

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

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

$$R * W^d(\text{non-driver region 2}) = \frac{(a - \alpha)^2}{4A} \quad (24)$$

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

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

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

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

where $X^u(1) = \frac{1 + \theta_1 - \theta_2}{\eta_1} b$. 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

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

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

$$R * W^u(\text{non-driver region 2}) = \frac{1}{2} \left(\frac{a - \alpha}{2A - X^u(1)} \right)^2 (A - X^u(1)) + \frac{1}{2} \frac{(a - \alpha)^2}{4A} \quad (25)$$

Finally, compare (24) and (25). Both expressions are equal for $X^u(1) = 0$. Noting that

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

for any positive X , the right hand side of (25) is smaller than that of (24). 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 Proposition¹⁰:

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* regions¹¹. 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

¹⁰ Of course, if non-drivers have a majority in both regions, the choice of constitution does not matter. Prices will always be too high.

¹¹ This is done in some federal states; for example, certain federal restrictions in Belgium serve to protect language groups.

the EU, where 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. Policy implications

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 Belgium, Spain 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.

6. Conclusions and caveats

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.

These results hold 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).

References

- Besley T., Coate S. (2003), Centralized versus decentralized provision of local public goods: a political economy approach, *Journal of Public Economics*, 87, 2611-37.
- Borck, R. and M. Wrede (2005), Political economy of commuting subsidies, *Journal of Urban Economics* 57, 478-99
- Brueckner, J.K. and Selod (2006), The political economy of urban transport-system choice, *Journal of Public Economics* 90, 983, 1005.
- Brueckner, J.K. (2015), Decentralized Road Investment and Pricing in a Multi-Jurisdictional City: Efficiency with Spillovers, *National Tax Journal* 68, 839-854.
- De Borger, B. and S. Proost (2012), A political economy model of road pricing, *Journal of Urban Economics* 71, 79-92.
- De Borger, B. and S. Proost (2015), The political economy of pricing and capacity decisions for congestible local public goods in a federal state, working paper (available at <http://feb.kuleuven.be/drc/Economics/research/dps-papers/dps-13/dps1316.pdf>).
- Hatfield, J. and Padro i Miquel (2012), A Political Economy Theory of Partial Decentralization, *Journal of the European Economic Association* 10 (3), 605-633.
- Hickey, R., (2013), Bicameral bargaining and federation formation, *Public Choice* 154, 217–241.
- Kessler, A.(2014), Communication in Federal Politics: Universalism, Policy Uniformity, and the Optimal Allocation of Fiscal Authority, forthcoming *Journal of Political Economy*, 122(4), 766-805.
- Knight, B. (2004). Parochial interests and the centralized provision of local public goods: evidence from congressional voting on transportation projects. *Journal of Public Economics* 88, 845-866.
- Lockwood, B. (2002), Distributive politics and the costs of centralization, *Review of Economic Studies* 69, 313-337.
- Lockwood, B. (2006), The political economy of decentralization, in Ahmad, E. and G. Brosio, *Handbook on fiscal federalism*, Edgar Elgar.
- Lorz, O., Willmann, G., (2005). On the endogenous allocation of decision powers in federal structures, *Journal of Urban Economics*, 57(2), 242-257
- Oates, W.E. (2005), Toward a Second-Generation Theory of Fiscal Federalism, *International Tax and Public Finance*, 12(4), 349–373.
- Ogawa, H. and D. Wildasin (2009), Think locally, act locally: spill-overs, spillbacks, and efficient decentralized policymaking, *American Economic Review* 99, 1206-2017.

Persson, T. and G. Tabellini (2000), *Political Economics: Explaining Economic Policy*. MIT Press, Cambridge.

Proost, S., Zaporozets, V. (2013). The political economy of fixed regional public expenditure shares with an illustration for Belgian railway investments, *Regional Science and Urban Economics*, 43, 808-815.

Redoano, M. and K. Scharf (2004), The political economy of policy centralization: direct versus representative democracy, *Journal of Public Economics* 88, 799–817.

Rubinstein, A. (1982), Perfect equilibrium in a bargaining model, *Econometrica* 50, 97–109.

Russo, A. (2013), Voting on road congestion policy, *Regional Science and Urban Economics* 43 (5), 707-724.

Xie, F. and D. Levinson (2009), Governance choice on a serial network, *Public Choice* 141, 189–212.

Van der Loo, S. and S. Proost (2013), The European road pricing game: how to enforce optimal pricing in high-transit countries under asymmetric information, forthcoming *Journal of Transport Economics and Policy*, 47, 399-418.

Weingast, B. (1979), A rational choice perspective on congressional norms. *American Journal of Political Science* 23, 245–262.

Weingast, B. (2009), Second generation fiscal federalism: The implications of fiscal incentives, *Journal of Urban Economics* 65, 279–293.

Appendix 1. Centralized decisions with a uniform user price restriction

Derivation of toll rules and transport volumes

Consider the problem

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

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

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

Again using $g(V_i) = P(V_i)$ and expression (2) it is straightforward to show that

$$\begin{aligned} \frac{dg_i}{d\tau} &= 1 + \frac{\beta}{K} \frac{dV_i}{d\tau} \\ \frac{dV_i}{d\tau} &= \frac{\frac{\partial V_i}{\partial \tau}}{1 - \frac{\beta}{K} \frac{\partial V_i}{\partial \tau}} \end{aligned}$$

Substituting these 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

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

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

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:

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

where

$$A = b + \frac{\beta}{K} \quad (\text{A1.5})$$

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

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

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

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

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

Welfare comparison: does a uniform price restriction raise welfare?

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

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

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

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

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:

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

Turn to the right hand side of (A1.9). Using completely analogous methods, in De Borger and Proost (2015, 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):

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

where

$$\begin{aligned} X_1^c(1) &= 2b \frac{\theta_1}{\eta_1}; & X_1^c(2) &= 2b \frac{(1-\theta_1)}{\eta_2} \\ X_2^c(1) &= 2b \frac{(1-\theta_2)}{\eta_1}; & X_2^c(2) &= 2b \frac{\theta_2}{\eta_2} \end{aligned} \quad (\text{A1.12})$$

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

$$\begin{aligned} V_1^c(1) &= \frac{a-\alpha}{2A-X_1^c(1)}; & V_1^c(2) &= \frac{a-\alpha}{2A-X_1^c(2)} \\ V_2^c(1) &= \frac{a-\alpha}{2A-X_2^c(1)}; & V_2^c(2) &= \frac{a-\alpha}{2A-X_2^c(2)} \end{aligned} \quad (\text{A1.13})$$

$$\begin{aligned} \tau_1^c(1) &= \left[\frac{a-\alpha}{2A-X_1^c(1)} \right] \left[A - X_1^c(1) \right]; & \tau_1^c(2) &= \left[\frac{a-\alpha}{2A-X_1^c(2)} \right] \left[A - X_1^c(2) \right] \\ \tau_2^c(1) &= \left[\frac{a-\alpha}{2A-X_2^c(1)} \right] \left[A - X_2^c(1) \right]; & \tau_2^c(2) &= \left[\frac{a-\alpha}{2A-X_2^c(2)} \right] \left[A - X_2^c(2) \right] \end{aligned} \quad (\text{A1.14})$$

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:

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

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

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

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

Second, use (A1.6) to find:

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

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

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

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:

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

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

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

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

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

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

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

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

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

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

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/

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

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

$$\begin{aligned}\tau^u(1) &= \tau_2^b \\ \tau^u(2) &= \tau_1^b\end{aligned}$$

Moreover, if

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

the same expressions yield

$$\begin{aligned}\tau^u(1) &= \tau_1^b \\ \tau^u(2) &= \tau_1^b\end{aligned}$$

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):

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

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:

$$\begin{aligned}\frac{\theta_1}{\eta_1} > \frac{\theta_2}{\eta_2} \quad \text{and} \quad \frac{1-\theta_1}{\eta_2} < \frac{1-\theta_2}{\eta_1} \\ \frac{\theta_1}{\eta_1} < \frac{\theta_2}{\eta_2} \quad \text{and} \quad \frac{1-\theta_1}{\eta_2} > \frac{1-\theta_2}{\eta_1}\end{aligned} \quad (\text{A2.8})$$

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

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

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.

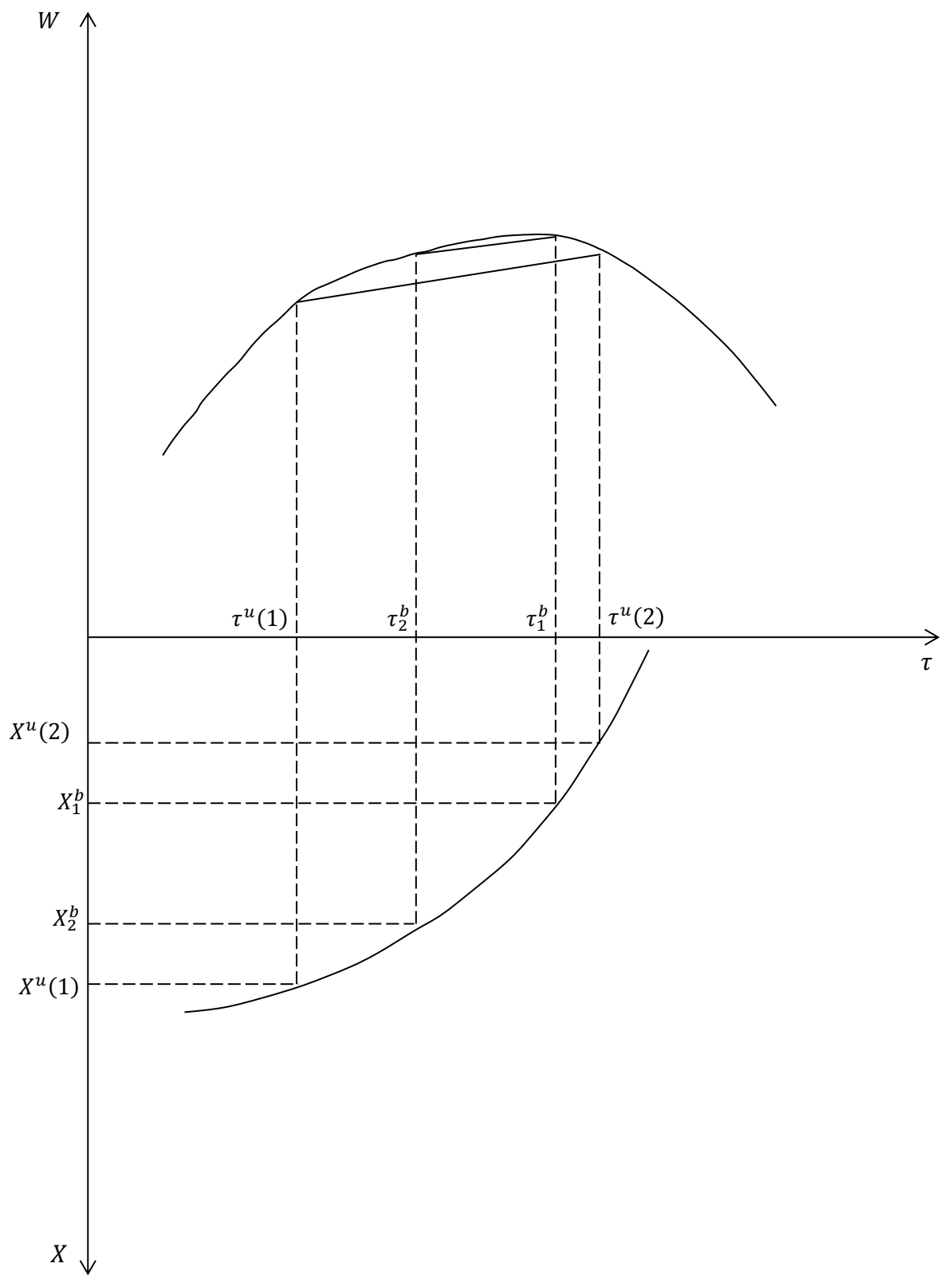


Figure A2: Bargaining versus a minimum winning coalition under uniformity

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

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

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

$$X_1^b < X^u(1)$$

$$X^u(2) < X_2^b$$

$$X_1^b < X_2^b$$

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

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

We find the tax rules

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

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

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

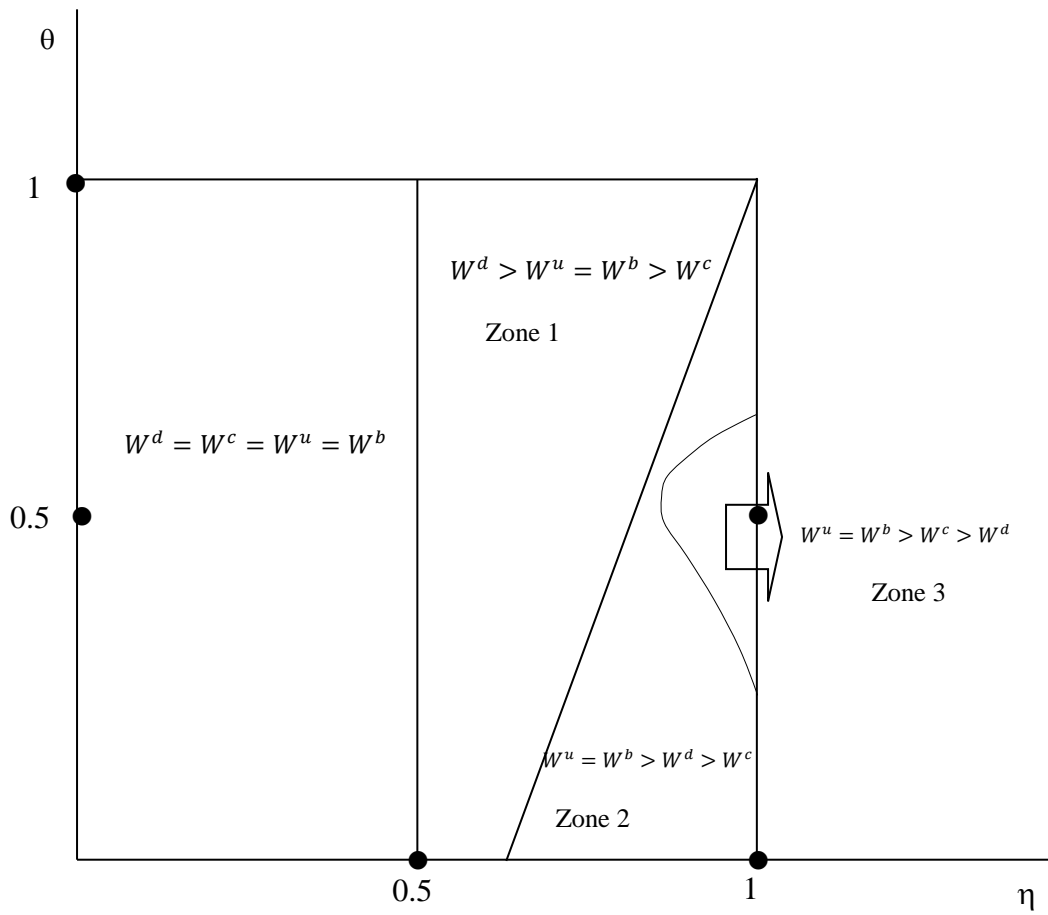


Figure 1: Welfare comparison between the four political systems (symmetric case)

Tables

θ_1	θ_2	η_1	η_2	W^d	W^c	W^u	W^b
0.9	0.9	0.9	0.9	<u>517</u>	485	516	516
0.5	0.9	0.9	0.9	515	506	511	<u>516</u>
0.1	0.9	0.9	0.9	510	495	495	<u>516</u>
0.9	0.9	0.7	0.7	<u>515</u>	461	512	512
0.5	0.9	0.7	0.7	<u>515</u>	486	500	512
0.1	0.9	0.7	0.7	509	461	461	<u>512</u>
0.9	0.9	0.5	0.5	<u>497</u>	274	484	484
0.5	0.9	0.5	0.5	<u>507</u>	379	441	484
0.1	0.9	0.5	0.5	<u>501</u>	274	274	484

0.9	0.9	0.9	0.9	<u>517</u>	485	516	516
0.9	0.9	0.9	0.7	<u>516</u>	478	514	514
0.9	0.9	0.9	0.5	<u>507</u>	384	500	503
0.5	0.5	0.9	0.9	513	<u>516</u>	<u>516</u>	<u>516</u>
0.5	0.5	0.9	0.7	514	514	514	<u>516</u>
0.5	0.5	0.9	0.5	<u>515</u>	500	500	508
0.1	0.1	0.9	0.9	503	494	<u>516</u>	<u>516</u>
0.1	0.1	0.9	0.7	504	478	514	<u>515</u>
0.1	0.1	0.9	0.5	<u>504</u>	385	500	503

0.1	0.5	0.5	1	509	502	<u>514</u>	513
0.2	0.5	0.5	1	511	506	<u>513</u>	512
0.3	0.5	0.5	1	<u>513</u>	507	511	512
0.1	0.5	0.5	1	509	502	<u>514</u>	513
0.1	0.5	0.6	0.9	509	503	512	<u>515</u>
0.1	0.5	0.7	0.8	509	498	508	<u>514</u>

Table 1: Numerical example for regions asymmetric in parameters

