How to decide on regional infrastructure to achieve intra-regional acceptability and inter-regional consensus?

Jonas Westin, Joel P. Franklin, Sofia Grahn-Voorneveld and Stef Proost

Abstract
Many regions face through-traffic that causes local negative externalities. Regions might respond by imposing user charges or investing in bypass transport infrastructure. In this paper two levels of decision making are studied: cooperation among regions and acceptability within regions. If left to a single region, it will overcharge for usage and under-invest in bypass capacity. Through interregional cooperation, an efficient outcome can be reached. Without compensation within each region, intraregional acceptability constraints protecting certain interest groups can lead to inefficient tolling. This can explain political preferences for tolling bypasses and not city centre roads.

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Key words: user charges, political economy, regional transport infrastructure, acceptability of transport pricing, regional cooperation
1 Introduction

After many decades of unpopularity, road tolls are gradually coming into wider use, partly because of their potential to reduce transport externalities such as emissions, noise, accidents, and lost time due to congestion, and partly because of technological progress in the cost of collection. A particularly common context where new tolls have been proposed is in association with transit (i.e. through) traffic in cities where a regional highway passes through the city center. The tolls are set to finance the construction of a bypass, and in some cases to discourage traffic. The problem is not confined to roads but can also be present in rail, air and inland waterways. New ring roads as well as the building of a second or third airport to alleviate noise and pollution in the center have been the subject of long debates in most metropolitan areas. This appears to be a universal problem in countries where interregional traffic is growing strongly because of increased regional integration.

We can consider this as a simple parallel network with two links, where the first link is given and the second one proposed. We look for optimality conditions for when the construction of a second link that diverts most of the through traffic increases welfare, and we analyze optimal pricing of the two links on the network. This is a standard cost-benefit problem in transport economics (see Small & Verhoef (2007), Ch. 5). Two issues make this problem more complex. First, because of informational asymmetries, the decision to build and toll is often left to the regions, and every region is mainly interested in the welfare of its own citizens. Second, with limited redistribution policies for the regional government, not all interest groups will gain when tolls and bypasses are introduced leading to a political acceptability problem within every region.

When the region where the link is located can toll all traffic, it will use this opportunity to set tolls higher than the marginal external costs and will under-invest in bypass capacity. The main reason is that they do not consider the welfare of non-resident users, only their contribution to regional tax revenue. This issue is known as tax exporting behavior (Arnott and Grieson 1981); empirical evidence for roads in the US has been provided by Levinson (2001). Levinson (1999) studied the problem of serial tolled links in a theoretical paper using game both cooperative and non-cooperative game theory, finding that without cooperation both tolls would be overpriced. De Borger, Proost, Van Dender (2005) and De Borger, Dunkerley, Proost (2007, 2008) have studied this problem for both a simple parallel and serial network where regional governments control each one of the links and compete on tolls and capacity. They found that the risks of overcharging are much more important in serial than in parallel networks. The reasons were that the serial structure gives rise to double marginalization while the parallel structure had two regions competing for the same through traffic and this tempered their tolls. In this paper we focus on the bypass problem where the initial link and the bypass to be built are both controlled by the same through-traffic region. A second difference with the De Borger et al papers is that we allow the tolling region and the region where most through traffic originates to cooperate and improve the non-cooperative equilibrium. A third difference is that we also consider the intra-region acceptability.

Even within regions, it is not easy to get political acceptance for tolls. The possible reasons for this range from a perceived loss of freedom and anonymity (Jakobsson, Fujii, and Gärling 2000), to various aspects of unfairness, especially with respect to vertical, horizontal, and
spatial equity (Raux and Souche 2004). In our case, we are especially concerned with spatial equity, in the sense of two regions that would be affected differently by a new toll, bypass, or both; and horizontal equity, in the sense of different interest groups within the same region that are affected differently, depending on their travel patterns and exposure to environmental externalities. For example, if non-residents pay tolls and contribute to the tax revenues of the region, then those residents within the region who also have to pay are likely to lose in the process. There exists a large literature on acceptability of pricing (see especially Schade and Schlag (2003)), but among political economy papers, the focus has been mainly on single political regions and how they choose to use collected revenues (Oberholzer-Gee and Weck-Hannemann 2002; K.A. Small 1992). The approach we use in this paper is to analyze how different interest groups (such as road users, environmental victims and tax payers) in each region are affected by the proposed policies. The setup is similar to the qualitative analysis in Verhoef, Nijkamp and Rietveld (1996a).

The main contribution of the paper is to create a theoretical model that explains some of the political constraints that make governments propose inefficient tolling strategies. The paper also contributes to the existing literature on political acceptability of road pricing by analyzing the conflict and potential trade-off between political acceptability and economic efficiency in a context where intraregional and interregional decision rules both affect the outcome. Through interregional cooperation an efficient outcome can be reached, the outcome does however come at the expense of lower acceptability with the regions. Without compensation within each region, intraregional acceptability constraints protecting certain interest groups can therefore lead to inefficient tolling.

In section two we give a background to the institutional setting and legal context to the problem. In section three we describe the model framework and examine how an autonomous city-region would choose to minimize transport externalities and maximize welfare, if there were no political constraints on its choices. In the analysis we compare the globally efficient solution (the solution preferred by a benevolent federal government) with the solution that the local government in the region with through traffic would unilaterally propose. In section four we analyze whether adjacent city-regions might cooperate to bring about a more efficient outcome and how the possible benefit from cooperation might be split.

In section five we study how acceptable cooperation between the two regions would be to the various interest groups in the regions. We especially study how the solution from the negotiations increases or decreases acceptability among the affected interest groups. So, first, can region A and region B agree, second, how does this solution change acceptability within each region? By comparing outcomes one can estimate the cost of political acceptability. In section six, the theoretical results are illustrated with a numerical example. Section seven discusses limitations to transferability of the results and section eight concludes.
2 Background

In Sweden, the role of local finance for major infrastructures has grown significantly in recent years. Traditionally, major transport infrastructure such as highway bypasses has been fully financed by the national government, motivated by a desire to increase economic integration between Sweden’s widely dispersed regions. More recently, and in particular in the 2010 – 2021 national infrastructure planning cycle, the government has transferred some of the responsibility for setting this balance to local governments by setting up a system for co-finance as well as increased voice in project priorities. Several high-profile infrastructure projects, such as Stockholm’s southern ring-road segment, have been financed with minority contributions from the local municipality and county. Co-financing has also entered into the picture in the form of public-private partnerships to develop some of the most ambitious projects in Sweden, especially at its borders: both the Öresund bridge to Denmark and the new Svinesund bridge to Norway are operated by private consortia.

A notable distinction in the two new cross-border bridges is that tolls are collected for the express purpose of financing construction costs. This is the first of two developments that has fundamentally changed the political context for financing roadway infrastructure with tolls. These first cases have led to preliminary discussions about financing future bypass projects in many other locations around Sweden, such as Norrköping, Sundsvall, and not least Örnsköldsvik, which forms the basis for the numerical illustration in this paper.

The second development is the well-known congestion pricing scheme in Stockholm, which is a cordon-based charging system with tolls varying on a fixed time schedule. This system is notable in that it was implemented on existing roadway infrastructure, originally with no express intent from the government to use the revenues to finance roadway infrastructure, but rather to manage congestion and, as a secondary priority, to finance increased public transport. After a change of government, the tolls are now intended to finance a major new roadway link, Stockholm’s Western Bypass.

Because the congestion charging system was placed on existing roads, it was necessary to classify it as a tax, which in turn required new national legislation. This legislation is enabling in that it provides a precedent and framework for how other cities may propose to implement congestion pricing. Yet it is also restrictive in that it specifies precisely the amounts of the toll and the control point locations. Thus, to engage in this kind of tolling requires engaging in a political process to encode the charging system in tax law. Nevertheless, Gothenburg is already following Stockholm’s lead with a plan to implement congestion pricing in its city center, though in this case the purpose is indeed to finance a new river undercrossing.

New proposals to construct and finance highway bypasses have cropped up in several of Sweden’s mid-sized cities, where congestion itself is less the problem than other externalities of traffic flowing through the city center: noise, pollution, increased risk of accidents both among cars and with pedestrians. In these cases, regions face increased demand for local contributions, and hence the attractiveness of tolling as a finance mechanism has increased, even as political acceptability remains a challenge. Moreover, if a toll is to be implemented, two approaches have emerged: first, to place tolls on the new infrastructure itself, as in the case of the cross-border bridges; or to place tolls in the city.
center to help finance a more peripheral roadway, following Gothenburg’s and, implicitly, Stockholm’s lead. Thus, it is can be useful for local decision makers to explore these two approaches in terms of their efficiency, their interregional equity, and their acceptability to different local populations.

3 Regional infrastructure and pricing without cooperation

In this section we present the model framework and the main players. We analyze the differences between the pricing and bypass investment solutions that are generated by the regional government and by the federal government. Both types of government will propose different solutions because the regional government is only concerned by the welfare of its own citizens while the higher level government also cares about the welfare of the transit traffic from adjacent regions. The difference between the two solutions will be the main driver for conflicts and cooperation among neighboring regions and federal interventions in the regional policies.

3.1 Model framework

We consider a simple transport network where a road passes through the city center of a region A (see Figure 1). The road is used both by citizens from region A and by citizens from neighboring region B. Since all local and transit traffic initially passes through the city center, this creates a negative environmental externality for the inhabitants of the city center. To solve this problem, the regional government A considers introducing road user charges on the city center road and building a tolled bypass.

In the model we make a distinction between three different traveler groups: local travelers of region A (LA) who only use the city center road, transit travelers who are inhabitants of region A (TA) and transit travelers from region B (TB). The transit travelers can choose between using the city road and the bypass if it is built. We also assume a stationary economy in which the same demand functions and cost functions hold in every sub period. In addition, there are no credit risks so that all governments can rent infrastructure by paying an annuity every period. These assumptions allow us to reduce the investment problem to a one period problem.

We further assume that neither the city road nor the bypass gets congested under any of the demand levels considered. This assumption simplifies our argumentation but is not crucial for most of our results. We return to this assumption in the end of the paper. We also assume that Wardrop’s principle holds for the transit travelers, that is, we assume that all transit travelers choose the road with the lowest generalized cost. To simplify the analysis we assume that if the generalized costs of the city road and the bypass are equal, then all transit travelers will use the bypass. Without this assumption, the split between the two alternatives would be undetermined if the generalized costs of both roads are equal. Since the purpose of the bypass is to relieve the city road, the assumption also corresponds to a situation where the policy maker, in case of a tie, decreases the bypass toll marginally to make all transit travelers use the bypass.

We assume that all travelers have identical linear demand functions and the same value of time. Let the share of local travelers (LA) be $1 - \gamma - \delta$, the share of transit travelers from A (TA) be $\gamma$ and the share of transit travelers from neighboring region B (TB) be $\delta$. The
aggregate demand for travel for each group can then be represented by the following inverse demand functions:

\[ p_{LA}(x_{LA}) = a - \frac{1}{1-\gamma-\delta} b \cdot x_{LA} \]  

(1)

\[ p_{TA}(x_{TA}) = a - \frac{1}{\gamma} b \cdot x_{TA} \]  

(2)

\[ p_{TB}(x_{TB}) = a - \frac{1}{\delta} b \cdot x_{TB} \]  

(3)

In these demand functions, \( x_{LA} \) is the demand for travel from local travelers from A (LA), \( x_{TA} \) and \( x_{TB} \) are the demand for transit trips, and \( p \) stands for the generalized price that includes all resource costs, tolls as well as time costs. Finally, \( a \) and \( b \) are constants corresponding to the intercept and slope of the aggregated inverse demand function.

By assumption, only the city inhabitants in region A are affected by the negative environmental impact from the traffic on the city road. The negative effect is assumed to be proportional to the traffic volume on the city road, hence the marginal external cost on the city road from the traffic is constant and equal to \( MEC > 0^1 \).

3.2 Initial situation

First we study the initial situation (designated by superscript 0) with neither a bypass nor any road tolls. The generalized user cost (including time and monetary costs) for travelling on the city road is \( g_c \). Since there is no congestion, the generalized cost does not depend on the traffic volume. In equilibrium the total demand for travel in the initial situation is therefore:

\[ x^0 = \frac{a-g_c}{b} \]  

(4)

where \( x^0 = x_{LA}^0 + x_{TA}^0 + x_{TB}^0 \).

When calculating aggregated welfare in each region, we assume that the regions only consider the welfare gains and losses for their own citizens. Welfare for region A is therefore equal to the consumer surplus of the local travelers and the transit travelers belonging to region A minus the negative environmental impact on the residents in the city center from the total traffic on the city road, that is:

\[ W^0_A = (1-\delta) \frac{(a-g_c)^2}{2b} - MEC \frac{a-g_c}{b} \]  

(5)

Similarly, welfare for region B is equal to the consumer surplus of the share of transit travelers that belongs to region B, which is:

\[ W^0_B = \delta \frac{(a-g_c)^2}{2b} \]  

(6)

Adding these two together, total welfare for both regions in the initial situation is:

\[ W^0 = W^0_A + W^0_B \]

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1 We also assume that \( MEC < a - g_c \), otherwise no one would use the bypass with efficient tolling.
Observe that the total welfare does not depend on the share parameters $\gamma$ and $\delta$.

### 3.3 Policy instruments and decision makers

In the model we distinguish between three different decision makers:
- The government in region A
- The government in neighboring region B
- The federal government

We assume for now that both local governments want to maximize welfare for their own citizens while the federal government wants to maximize total welfare.

The local decision makers have four policy instruments at their disposal: a road toll on the city road to decrease the flow of traffic and collect revenue, the option to build a bypass to divert transit traffic, a toll on the bypass to pay for the construction, and a monetary transfer between the two regions. We assume that there are no transaction costs in tolling and that the marginal cost of funds\(^2\) for the regional and federal governments is equal to one. In this section we only consider homogeneous regions and the assumption on the marginal cost of public funds means that each of the governments is only interested in the sum of consumer surplus, environmental damage and tax revenues minus the annuity of construction and maintenance of the bypass.

The road tolls can both be placed on the city road at a level $t_c$ and on the bypass at a level $t_B$ (given that the bypass is built). The annuity for the bypass is named $COST$. The regional governments can also make transfers $D$ among them.

To study how welfare and acceptability of road user charges depends on political coordination between different political entities we will explore several institutional arrangements. First we let the federal government chose the toll levels to maximize total welfare for both regions. Second, we compare the outcome of this policy with the situation where region A controls all policy instruments and sets the toll levels to maximize welfare for its own citizens. This analysis is done with and without the bypass. In section three we will add cooperation between regional governments and in section four we include political acceptability.

### 3.4 Without a bypass

First we study the welfare effect of introducing a toll on the city road without building a bypass. The toll increases the total generalized cost for a trip on the city road to $g_c + t_c$.

With no bypass, total welfare $W_{TOT}^{nb}$ as a function of the road toll $t_c$ is:

$$W_{TOT}^{nb}(t_c) = \frac{(a-g_c-t_c)^2}{2b} + (t_c - MEC) \frac{a-g_c-t_c}{b}$$

\(^2\) The marginal cost of funds of $1$ is the total welfare loss associated to the tax collection of $1$ extra before considering how the $1$ of tax revenues is spent (see Dahlby (2008)).
Total welfare without a bypass is maximized when the toll level is equal to the marginal external cost, i.e. $t_C^{enb} = MEC$. We call this policy $enb$ (efficient toll, no bypass).

The efficient toll level can be compared to the toll level that the government in region A would choose unilaterally. Since the regional government A only considers the welfare for its own citizens, welfare for this region as a function of $t_c$ is:

$$W^*_A(t_c) = (1 - \delta) \left( \frac{(a-g_C-t_c)^2}{2b} \right) + (t_c - MEC) \frac{a-g_C-t_c}{b}$$

As the welfare of the non-resident transit users is not part of the objective function of the regional government we obtain a toll level that is also motivated by exporting tax to the other region. The optimal toll is now the MEC plus a markup that is an increasing function of the share of transit users from the other region:

$$t_C^{anb} = \frac{MEC + \delta(a-g_C)}{1+\delta}$$

We denote this policy $anb$ (region A decides, no bypass). Since $\frac{dt_C^{anb}}{d\delta} > 0$ the transit traffic from region B makes it profitable to increase the road toll above the marginal external cost in order to increase the revenues collected from travelers from neighboring regions. When the share of transit traffic from region B is small (\(\delta\) close to zero) the preferred road toll approaches the efficient toll level.

### 3.5 With a bypass

If a bypass is built, the decision makers have two policy instruments at their disposal, a toll on the city road $t_c$ and a toll on the bypass $t_B$. Throughout the paper, we assume that the generalized user cost before the toll for the bypass $g_B$ is lower than the generalized cost for the city road before the toll, i.e. $g_B < g_C$ and that there is no congestion on either of the roads.

Since we have assumed that the transit travelers only use the bypass if the generalized cost is equal to or lower than the generalized cost on the city road, this places a restriction on the maximal toll level that can be set on the bypass:

$$g_C + t_C \geq g_B + t_B$$

Assuming that (11) holds, total welfare as a function of the toll levels is:

$$W_{TOT}^b(t_c,t_B) = (1 - \gamma - \delta) \left( \frac{(a-g_C-t_c)^2}{2b} \right) + (t_c - MEC) \cdot (1 - \gamma - \delta) \frac{a-g_C-t_c}{b} + t_B \cdot (\gamma + \delta) \frac{a-g_B-t_B}{b} - COST$$

The federal government’s welfare maximization problem can therefore be formulated as:

$$\max_{t_c,t_B} W_{TOT}^b(t_c,t_B) \quad \text{s.t.} \quad g_C + t_C \geq g_B + t_B$$

8
Taking the first order condition we find that total welfare is maximized when \( t_{C}^{eb} = MEC \) and \( t_{B}^{eb} = 0 \). This policy is referred to as \( eb \) (efficient toll levels, with bypass).

Note that the optimal toll levels do not depend on the cost of the bypass and that the optimal toll level on the bypass also is independent of the marginal external cost on the city road. The intuition for this result goes as follows. Our assumption that the marginal cost of funds equals one implies that the tolls are not necessary to finance the bypass. The regional or federal government can use any non-distortionary (lump-sum) taxes to balance the budget. There remain two functions for the toll: to charge the external cost for the users of the city road \( (t_{C}^{eb} = MEC) \) and to extract revenues from non-inhabitants. If transit uses only the bypass, this will be the main function of the tax on the bypass. But when a federal government is in command there is no point in extracting revenues from the users of the bypass and \( t_{B}^{eb} = 0 \).

This optimal tax result is counterintuitive for most politicians. They expect the tolls on the bypass to pay for the construction and maintenance of the bypass. In section 4 we will show that the political acceptability concern is at the basis of the political preference for bypass tolls paying for the bypass.

Consider now what will happen if regional government A decides unilaterally on tolls and bypass construction. Assume that region A builds the bypass and sets both toll levels to maximize welfare for its own citizens. We also assume that region A cannot price discriminate between transit travelers from region A and transit travelers from region B. In the absence of regional cooperation, the taxpayers in region A bear the full cost of the bypass but also receive all toll revenues.

With a bypass, the welfare for the citizens in region A (assuming that \( g_{C} + t_{C} \geq g_{B} + t_{B} \)) is:

\[
W_{A}^{b}(t_{C}, t_{B}) = (1 - \gamma - \delta) \frac{(a-g_{C}-t_{C})^{2}}{2b} + \gamma \frac{(a-g_{B}-t_{B})^{2}}{2b} + (t_{C} - MEC) \cdot (1 - \gamma - \delta) \frac{a-g_{C}-t_{C}}{b} + t_{B} \cdot (\gamma + \delta) \frac{a-g_{B}-t_{B}}{b} - COST
\]

(14)

When both tolls are available, the regional optimum can have two regimes. In case 1 it is optimal to charge \( MEC \) on the city road and this means that the optimal tax on the bypass is not constrained by this type of tax setting on the city road. Figure 2 illustrates this case.

In case 1 we obtain the following optimal tolls by using the first order conditions:

\[
t_{C}^{eb} = MEC \quad \quad \quad (15)
\]

\[
t_{B}^{eb} = \frac{\delta}{2\delta + \gamma} (a - g_{B}) \quad \quad \quad (16)
\]

First we note that the optimal toll on the city road is the same as the efficient toll level. This is because in case 1, generalized prices are such the city road is only used by residents in region A. On the bypass, the region will set a revenue maximizing toll mitigated by the presence of residents who also use the bypass.
The toll on the bypass is increasing in the share of travelers from region B since \( \frac{dt_{aB}^{ab}}{d\gamma} > 0 \) as long as \( \gamma > 0 \). When the bypass is only used by travelers from A (\( \delta = 0 \)) the toll level is the same as the efficient toll level. If \( \gamma = 0 \) (corresponding to only outside transit traffic), the region will set the toll to maximize the revenues from the bypass, i.e. \( t_{c}^{aB,\gamma=0} = \frac{a-g_{B}}{2} \).

In case 2, it is more beneficial for region A to charge its city inhabitants a toll above the MEC because this allows charging a higher toll on the bypass without transit users migrating to the city road. More precisely, when \( MEC + g_{C} \geq g_{B} + \frac{\delta}{2\delta + \gamma} (a - g_{B}) \) does not hold, we are in case 2. This may arise in the context of a low MEC, a small difference between the generalized cost on the two routes, or a high share of interregional transit. In such a case we have the following optimal tolls. On the city road, the toll is a weighted average of three elements: the MEC (the real cost for inhabitants using the road), the toll revenue potential on the interregional transit users and the difference in transport costs between the two routes for the local bypass users:\(^3\)

\[
t_{cB}^{aB} = \frac{MEC(1-\gamma-\delta)}{1+\delta} \frac{MEC(1-\gamma-\delta)}{1+\delta} + \frac{\delta}{1+\delta} (a + g_{B} - 2g_{C}) \frac{\delta(a+g_{B}-2g_{C})}{1+\delta} + \frac{\gamma}{1+\delta} (g_{B} - g_{C}) \frac{\gamma(g_{B}-g_{C})}{1+\delta} \tag{17}
\]

\[
t_{cB}^{aB} = g_{C} - g_{B} + t_{c}^{aB} \tag{18}
\]

3.6 When will governments build a bypass?

A welfare maximizing federal government will build the bypass if it increases total welfare given efficient toll levels, that is, if \( W_{TOT}^{eb} > W_{TOT}^{en} \). Using the optimal toll setting, this means that the annuity for the bypass has to be lower than:

\[
COST_{c} < (\delta + \gamma) \left( \frac{(a-g_{B})^2}{2b} - \frac{(a-g_{C}-MEC)^2}{2b} \right) \tag{19}
\]

The expression shows that for the bypass to increase total welfare, the annualized construction cost must be lower than the gain in transit travelers’ social surplus from the lower generalized cost on the bypass minus the social surplus they would have had on the city road with an efficient toll. What matters for welfare maximum is the intrinsic quality advantage \( a - g_{B} \) compared to the intrinsic advantage of the city center road \( a - g_{C} - MEC \). If the bypass adds no intrinsic quality, it is never built.

A local government is only interested in the gain of the local travelers’ social surplus and in the toll revenue earned on the interregional transit travelers. As one of the benefit components taken into account by the federal government is missing, the local government will always invest less easily in a bypass than the federal government with efficient toll levels.

If the regional government in city A unilaterally can set the road tolls the situation changes. The local government will invest in a bypass if \( W_{A}^{aB} > W_{A}^{an} \). If the road tolls are chosen to

\(^{3}\) The expression is derived by solving for toll that maximizes (14) with the restriction that \( g_{C} + t_{C} = g_{B} + t_{B} \).
maximize welfare for region A, the following condition needs to be true for the regional
government to invest:

\[ \text{COST}^a < (\delta + \gamma) \left( \frac{\delta + \gamma}{2\delta + \gamma} \frac{(a-g_b)^2}{2b} - \frac{\delta^2 + \delta\gamma + \gamma(a-g_C-MEC)^2}{2b} \right) \]  

(20)

Since the local government is only interested in the welfare gain for its own citizens, this
expression differs from the condition where it is rational for the federal government to
invest in bypass capacity. Comparing (19) with (20) should tell us whether region A has the
same incentives to build the bypass as a benevolent federal government. To sharpen our
intuition, consider the case where there is no local transit traffic \( y = 0 \) and there is a lot of
interregional transit traffic \( \delta \) approaching 1. Then it can be shown that the incentives to
build the bypass are only half as large for the local government as for the federal
government. The local government hence prefers a high toll solution for the city center road
compared to building a bypass only used by external transit travelers.

Consider next the case where the share of interregional transit \( \delta \) decreases, then the
incentives for the local government to build the bypass increases and becomes larger than
50%. When the total share of transit traffic is small compared to the share of local traffic, the
incentive for the regional government to construct the bypass can even in some situations
be larger than the incentive for a benevolent federal government. This implies that there
exist situations where the regional government would invest in a bypass (if able to set toll
levels unilaterally) when the federal government would not (with efficient toll levels), and
other situations where the situation is reversed. Concluding, when the share of outside
transit is largest, the underinvestment bias of the local government is largest.
4 Solutions with cooperative regions

Up to now we assumed that either the federal government or region A is in command. When region A decides, it decides in a non-cooperative way. But region B is affected by both the toll setting and the investment decisions of region A. This raises the question whether region A and B might cooperate, and how the gain from cooperation is shared between the two regions. In this section, using cooperative game theory, we look into the outcome of the negotiations and the role of the federal government therein.

Game theory is a toolbox designed to analyze the phenomena that occur when decision makers interact. Here the decision makers are the two regions in a federal setting and this allows binding contracts. Therefore the set of possible actions are the set of joint actions rather than the set of action profiles where each action is taken by the communities autonomously. A solution concept in this context is therefore not an equilibrium action-profile but a division-principle with certain desirable properties, usually properties associated with fairness, for instance limiting the possible differences in outcome, giving a dummy-player no share in the profit, Pareto-optimality, efficiency etc. In the bargaining process the two communities have to agree on what principles they view as fair, and find a solution concept that satisfies these principles.

There are three well-known solution concepts that can be applied to this situation: the Nash Bargaining solution (see Nash (1950)), the Nucleolus (see Schmeidler (1969)) and the Shapley value (see Shapley (1953)). The ideas behind these concepts are quite different. The Nash bargaining solution is the allocation that maximizes the product of the two excess utilities. The Shapley value assigns to each player the average marginal cost contribution that the player makes to each of the coalitions to which he belongs. The Nucleolus is the allocation that minimizes the maximal dissatisfaction of any coalition, i.e. the cost of the coalition acting alone minus what is allocated to this coalition. However for games with only two players, in this case the two regions, these three solution concepts coincide and suggest an equal division of the profit from cooperation.

Since this division has all the desirable properties of these three solution concepts it seems to be a likely outcome from negotiation between the two regions.

Let \( W_{A^*} \) be the highest welfare that A can achieve without cooperating with B, and let \( W_{B^*} \) be the highest welfare that B can achieve without cooperating with A. Further, let \( W_{coop} \) be the maximal total welfare of A and B that can be achieved with cooperation. In a two-player game, given that cooperation occur, the Shapley value, the Nucleolus and the Nash bargaining solution all suggests an equal split of the welfare gain from cooperation, that is:

\[
W_A = \frac{W_{coop} + W_{A^*} - W_{B^*}}{2} \tag{21}
\]

\[
W_B = \frac{W_{coop} + W_{A^*} - W_{B^*}}{2} \tag{22}
\]

However, the sharing of the gain from cooperation depends on the definition of the threat point. Consider Figure 3, where the axes represent the gains for the two regions. Assume that building the bypass is welfare improving. The origin represents the equilibrium where
no bypass is built. The curve XY represents the possible divisions of the gain of cooperation between the two regions. Consider now two alternative threat points. When region A is allowed to decide on the bypass and to set toll levels unilaterally, one reaches the non-cooperative equilibrium. In this case one can expect a rather larger gain for region A who sets the tolls. Region B will gain too as they will make use of the bypass. The second threat point corresponds to the case where the federal government only accepts that region A builds the bypass if both regions agree. In this case the origin is the threat point. As Figure 3 shows the threat point will co-determine the sharing of the gains of cooperation.

The government can influence the situation by restricting what region A is allowed to do autonomously. In practice this means that the government can influence the outcome of the negotiations by deciding what threat point to be used in the negotiations.

4.1 **Would the cities spontaneously negotiate?**

In order to understand the incentives of the regions to cooperate we need to compare the total welfare of the two regions in the most efficient solution with the total welfare of both regions in the non-cooperative solution.

With a bypass, total welfare with efficient toll levels is:

\[ W_{TOT}^{eb} = (1 - \gamma - \delta) \frac{(a-gc-MEC)^2}{2b} + (\gamma + \delta) \frac{(a-gb)^2}{2b} - COST \]  

(23)

What is the welfare loss if region A unilaterally is allowed to set the toll levels? Total welfare can only be lower and equals (in case 1):

\[ W_{TOT}^{ab} = (1 - \gamma - \delta) \frac{(a-gc-MEC)^2}{2b} + (3\delta + \gamma) \frac{(\delta+\gamma)^2}{(2\delta+\gamma)^2} \frac{(a-gb)^2}{2b} - COST \]  

(24)

Analytical expressions for the welfare for region A and B for the different toll regimes are summarized in Appendix A.

By choosing toll levels above the globally efficient levels, region A gains\(^4\):

\[ \Delta W_A^{ab-eb} = (2\delta + \gamma) \frac{\delta^2}{(2\delta+\gamma)^2} \frac{(a-gb)^2}{2b} \]  

(25)

at the expense of region B:

\[ \Delta W_B^{ab-eb} = -(3\delta + 2\gamma) \frac{\delta^2}{(2\delta+\gamma)^2} \frac{(a-gb)^2}{2b} \]  

(26)

The total welfare loss from allowing region A to unilaterally choose the toll levels in case 1 is:

\[ \Delta W_{TOT}^{ab-eb} = -\delta^2 \frac{(\delta+\gamma)}{(2\delta+\gamma)^2} \frac{(a-gb)^2}{2b} \]  

(27)

---

\(^4\)This expression is based on the assumption that region A pays the full cost of the bypass and receives all toll revenues even in the case of efficient pricing.
As we can see, there is a potential welfare gain if regions A and B decide to cooperate since $\Delta W_{TOT}^{ab-eb} < 0$ for $\delta > 0$. If $\delta = 0$, the loss is zero since all travelers then belong to region A. A similar result is reached in case 2 although the expressions are more complex.

4.2 The negotiation between region A and region B

Using the solution concepts presented above we can find a transfer that both cities are likely to agree upon. First we study the scenario where region A unilaterally can decide about the toll levels. Region A bears the full cost of constructing the bypass and receives all the toll revenues. Region B then tries to influence region A to set efficient toll levels (from a global point of view) by offering a monetary transfer $D$. This policy is called $cab$ (cooperation where A can decide not to cooperate, with bypass).

Using the notation of the previous section, we have $W_{A*} = W_{A}^{ab}$, $W_{B*} = W_{B}^{ab}$ and $W_{coop} = W_{TOT}^{ab}$. Inserting the expressions above we get:

\[
W_{A}^{cab} = (1 - \gamma - \delta) \frac{(a - g_c - MEC)^2}{2b} + \frac{(\gamma + \delta)(5\delta^2 + 6\gamma^2) (a - g_B)^2}{2(2\delta + \gamma)^2} - COST
\]

\[
W_{B}^{cab} = \frac{(\gamma + \delta)(3\delta^2 + 2\gamma^2) (a - g_B)^2}{2(2\delta + \gamma)^2} - \frac{\delta(5\delta^2 + 3\gamma^2) (a - g_B)^2}{2(2\delta + \gamma)^2}
\]

The size of the transfer $D^{cab}$ that gives us this welfare split is:

\[
D^{cab} = W_{A}^{cab} - W_{A}^{eb} = W_{B}^{eb} - W_{B}^{cab} = \frac{\delta(5\delta^2 + 3\gamma^2) (a - g_B)^2}{2(2\delta + \gamma)^2}
\]

Comparing (30) with (25) and (26) we see that both cities benefit from the cooperation.

4.3 How the federal government restriction affects the regional negotiations

Assume now that the government only allows region A to build the bypass and impose tolls if both cities can agree on how to split the costs and the revenues. As before, we assume that region A pays for the construction of the bypass and receives all of the revenues. The two regions negotiate about the size of the monetary transfer $D$ (given efficient toll levels from a federal point of view). If the cities fail to come to an agreement, no bypass is built and no tolls are implemented. This policy is called $c0b$ (cooperation from initial situation, with bypass).

Under these conditions, we have $W_{A*} = W_{A}^{0}$, $W_{B*} = W_{B}^{0}$ and $W_{coop} = W_{TOT}^{eb}$, which give the outcome:

\[
W_{A}^{c0b} = \frac{(1 - \gamma - \delta) (a - g_c - MEC)^2}{2b} + \frac{(\gamma + \delta) (a - g_B)^2}{2b} + \frac{(1 - 2\delta) (a - g_c)^2}{2b} - \frac{MEC a - g_c}{b} - \frac{COST}{2}
\]

\[
W_{B}^{c0b} = \frac{(1 - \gamma - \delta) (a - g_c - MEC)^2}{2b} + \frac{(\gamma + \delta) (a - g_B)^2}{2b} - \frac{(1 - 2\delta) (a - g_c)^2}{2b} + \frac{MEC a - g_c}{b} - \frac{COST}{2}
\]

The size of the transfer $D^{c0b}$ that gives us this welfare split is:
Comparing the size of the transfers with and without federal restrictions we see that while $D^{cob}$ is always positive, the sign of $D^{cab}$ is ambiguous. This implies that the federal restriction can result in a situation where region A has to pay region B in order to build the bypass even though region A pays the full cost of constructing the toll-free bypass. This can happen if the share of traffic from region B is small. Then the government in region A would receive almost all of the welfare gains but region B will only agree if it receives half of these gains. Making the agreement of adjacent regions compulsory can thus be problematic.
5 Political acceptability of infrastructure investments and pricing

5.1 Introduction
In previous sections we have analyzed regional welfare at an aggregate level for infrastructure investments and user pricing policies. We have compared the solution proposed by a single region with the globally efficient solution. We have also studied how cooperation between neighboring regions improves aggregate welfare in both regions and how federal interventions can affect the sharing of the gains. In this section we will extend the analysis to also consider the political acceptability of the proposed policies within each region.

5.2 A definition of political acceptability
When analyzing the political acceptability of road pricing empirically, redistributive concerns are often found to be important for the public opinion on different road pricing policies (Verhoef, Nijkamp and Rietveld 1997). Assume that an individual accepts a policy if he or she does not lose compared to the reference situation. A measure of political acceptability is then the share of citizens within a region that accepts a given policy. A problem with this definition is that it in general requires detailed information about each individual’s preferences and how the net revenues from the policy are recycled.

A simpler approach to study political acceptability is to assume that each citizen belongs to one or more interest groups where each interest group is modeled as a representative agent. The interest groups represent different “hats” that an individual citizen can have. An interest group is assumed to accept a policy in the same way as an individual. The idea is that if an influential interest group (car drivers, environmentalist or tax payers) is worse off from a policy, they can oppose the policy and try to stop the decision. Political acceptability is then studied by analyzing which interest groups that accepts a given policy. An important assumption in the paper is therefore that the policy makers do not have access to any compensatory transfers between the interest groups. If able to fully compensate the losers, the trade-off between efficiency and acceptability would disappear since the policy maker could redistribute welfare to make every welfare increasing policy a Pareto improvement.

5.3 The acceptance of the chosen solutions among the interest groups
In the model we define a total of six interest groups in the two regions. The first three interest groups are the traveler groups described in section 2.2, local travelers from region A (LA), transit travelers from region A (TA) and transit travelers from region B (TB). The fourth interest group comprises the residents living near the city center (EA) that is affected by the negative externality from the city road. We assume that this group only consists of citizens in region A. Finally there are two interest groups for the taxpayers, one group belonging to region A (PA) and one group belonging to region B (PB). The taxpayers in region A pay for the construction of the bypass and receive the toll revenues. If the regions choose to cooperate, the monetary transfer $D$ is taken from the taxpayers in region B and given to the taxpayers in region A.
In this section we analyze the acceptance of the policies by the different interest groups described above. Does coordination of investments and user charges among different regions in a transport network leads to more acceptability within the regions or does it subverts it?

In Table 1, welfare for each interest group as a function of the toll levels $t_C$ and $t_B$ are shown under the assumption that $g_C + t_C \geq g_B + t_B$.

Since there is neither a road toll ($t_C = 0$) nor a transfer between the cities ($D = 0$) in the initial situation, the welfare for the taxpayers in both cities is normalized to zero. Comparing the two columns in Table 1, we see that the toll on the city road decreases welfare for the local travelers. Since both the bypass and the road toll $t_C$ decrease traffic on the city road, the local residents (EA) benefit from the change. The taxpayers in region A benefit if the collected toll revenues and the transfer from B cover the annualized cost of the bypass. As long as $t_B < g_C - g_B$, the transit travelers are also better off compared to the initial situation.

In Table 2 the signs of the welfare change for the six interest groups are summarized. All policies are compared to the initial situation (0).

We see that in the situation where region A unilaterally sets the toll levels, the taxpayers in B (PB) never benefit from cooperating with A. When the government restricts the negotiation this can change since, depending on the setting, the restriction on the negotiation can result in that region A has to send a transfer to region B. We also see that if $g_B + t_B^{max} < g_C$ the transit travelers from region B still benefit from the bypass compared to the initial situation even though region A controls the toll on the bypass.

If the interest groups do not strongly overlap, so that the individuals that pay the taxes in region B differ from the individuals that use the bypass, it can be difficult to motivate why region B should negotiate with region A only to increase welfare for interregional transit travelers from B even further. We also see that none of the policies described above is Pareto-improving since there always is some interest group that is worse off compared to the initial situation. We will therefore continue the analysis by examining whether there exists a policy that improves welfare for all interest groups.

### 5.4 A Pareto efficient solution

In previous sections we have analyzed a number of policies all targeted at maximizing aggregate welfare, either in region A or in both regions. Are these also the policies that politicians will propose? In general, the empirical answer to this question in Sweden is no—nearly all bypass proposals put tolls on the bypass but not the city route, and such a bypass is now under design for the city of Sundsvall. Instead of a policy that maximizes welfare, can we define a policy that maximizes political acceptability or a policy that is guaranteed to make no one worse off? And what is the cost of this acceptability policy in terms of loss in efficiency?

We denote a policy designed to make no interest group worse off (acc). Since a toll on the city road reduces welfare for the local travelers that cannot use the bypass, a Pareto-efficient policy that maximizes welfare for all interest groups is given by:

$$
\min \{ t_C : g_C + t_C \geq g_B + t_B \}.
$$
improving solution requires that \( t_c^{acc} = 0 \). From the transit travelers’ point of view, any toll level on the bypass can be accepted since they can continue to use the city road if the toll on the bypass is too high. As long as the transit travelers use the bypass, the city environment is improved and the residents living near the city center are better off even without a toll on the city road. Hence the toll on the bypass must satisfy \( t_b^{acc} \leq g_c - g_B \). For the taxpayers in region B to accept the solution we need that \( D \leq 0 \). Finally, the taxpayers in region A are better off if the collected revenues cover the cost of the bypass. Assuming that the toll on the city road is zero, the maximum toll revenue that can be collected from the bypass is:

\[
REV MAX = \begin{cases} 
(y + \delta) \left( \frac{a - g_B}{4b} \right)^2, & a \leq 2g_c - g_B \\
(y + \delta) \left( \frac{g_c - g_B(a - g_c)}{b} \right), & a > 2g_c - g_B
\end{cases}
\]  

(34)

If \( COST \leq REV MAX \), then there exists a solution that does not make any interest group worse off. Observe that if the construction cost is strictly lower than the maximal toll revenue, then neither the choice of toll level on the bypass nor the transfer from A to B is unique.

5.5 The cost of acceptability

In previous section we saw that political acceptability and economic efficiency produced very different results regarding the use of road user charges. The economically efficient solution was to put a toll on the city road to internalize the marginal external cost where we do not want people to drive and no toll on the bypass where we want people to drive. From an acceptability point of view (or the view of a local politician wanting to avoid making influential interest groups worse off), the tolls should instead be placed the other way around: no toll in the city to keep local travelers happy and a positive toll on the bypass to finance the construction of the bypass. The result is in line with the road pricing literature where a trade-off between efficiency and acceptability often is found (see for example Verhoef, Nijkamp and Rietveld 1996a).

Acceptability in this context therefore has a cost in terms of lower efficiency. The cost (or welfare loss) of full acceptance among these mutually exclusive interest groups (assuming the revenues on the bypass cover construction cost) is:

\[
\Delta W_{Accept} = -(1 - \gamma - \delta) \frac{MEC^2}{2b} - (y + \delta) \frac{(t_B^{acc})^2}{2b}
\]

(35)

where \( t_B^{acc} \leq g_c - g_B \). The loss is illustrated in Figure 4.

In Figure 4 we study efficiency and acceptability from the perspective of the federal government, hence disregarding where the transit travelers come from. The toll levels in the figure are chosen to maximize acceptability, hence \( t_c^{acc} = 0 \), \( t_B^{acc} \leq g_c - g_B \) and \( D^{acc} \leq 0 \).

The cost of acceptability in terms of lower efficiency is shown by the two triangles. That is, the welfare loss of getting all interest groups to accept the road pricing policy in terms of lower efficiency compared to efficient toll levels. Since the road toll on the city road is zero, only the negative environmental externality from the transit travelers is reduced. This means that even though the environment is improved compared to the initial situation, the welfare
gain is not as large as it could have been. Since a toll on the bypass is needed to finance the
construction cost in order not to hurt the taxpayers, this creates an additional efficiency loss
among the transit travelers.

We can see this the other way around as well: the cost of efficiency in terms of lower
acceptability. First, without compensation, the efficient toll on the city road makes the local
travelers worse off compared to the initial no-toll situation. Since both the citizens living
near the city center and the transit travelers’ benefit from the bypass, these groups will
accept the efficient solution. The acceptability for the taxpayers depends on whether the toll
revenues cover the cost of the bypass or not. This can be problematic especially in situations
where MEC is low or the number of local travelers is low compared to the cost of building
the bypass.

6 Numerical illustration

To illustrate the theoretical results we use a numerical example using a stylized model of the
traffic situation in Örnsköldsvik, a small city of 55000 people located along the Gulf of
Bothnia in northern Sweden. Örnsköldvik is 110 km south of the somewhat larger city of
Umeå, which has a population of 115000, and it is 530 km north of Stockholm. The purpose
of the example is to illustrate both the theoretical results and the effect of cooperation
between different regions on the acceptability of the policy. We choose Örnsköldsvik
because it encompasses the essential topology of interest here: a linear series of population
centers served today by only a single highway, E4, through the city center; and where a
parallel bypass has been proposed around the city center for the purpose of alleviating the
external effects of transit traffic in the city center—in particular, accidents and vehicle
emissions—but also for the purpose of reducing travel times for transit traffic.

6.1 Approach

For our numerical illustration, we test a series of scenarios that mirror the theoretical
illustrations above. The background assumptions we use are drawn mostly from a benefit-
cost analysis that was performed on the E4 bypass proposal in 2002, which forms the basis
for most many assumptions (Swedish Road Administration 2002).

We make the following additional assumptions, based on the benefit-cost analysis by the
Swedish Road Administration (2002):

- The existing local road has a distance of 2.3 km which, at 40 km/hour, takes 3.45
  minutes.
- The proposed bypass is 1.3 km which, at 50 km/hour, takes 1.56 minutes, a savings of
  1.89 minutes.
- The value of time for all travelers is 164 SEK/hour (16.4 €/hour), suggesting that the
  travel time savings are 0.52 € per trip.
- When building the bypass, 6700 daily trips are diverted from the local road.
- The base demand (at 1998 levels) is 16000 vehicles per day for a generalized cost of
  0.94 €. The benefit-cost analysis assumed constant demand, but in our simulation we
  assume linear demand as a function of generalized cost, such that the total demand
  at zero generalized cost for the study segment is 22000 vehicles per day. This gives a
  point price elasticity of demand of -0.375 at the base demand level, which is
  consistent with the broader literature on travel demand. Transforming these
assumptions to the demand curve form in (4), we find the parameters $a = 3.46$ and $b = 0.0001575$. The share parameters are $\delta = 0.1$ and $\gamma = 0.3$.

- The cost of building the bypass, including tunneling costs, is estimated to be 60.6 million €, which at 4% interest rate over 60 years represents a daily cost of 10710 €, which we round off to 10000 €/day.
- External cost savings due to reduced accidents and vehicle emissions are 31.15 million €, which at 4% interest rate over 60 years represents a cost savings of 0.82 €/trip. However, since we have not included time savings for local trips anywhere else in the analysis, we increase these cost savings to 1.00 €/trip.

In the simulations that follow, we start by varying the decision-making considerations to mirror the scenarios presented in the theoretical analysis above. We also make a second set of calculations, where the cost of constructing the bypass is only one-quarter the original amount. This alternative assumption is meant to reflect cases where a proposed bypass does not require an expensive tunnel, as would be the case in Örnsköldsvik.

### 6.2 Results

Testing each of the same decision-making scenarios in the theoretical analysis above, we can compare the expected welfare levels that could be reached if, for example, tolling only is considered, or a bypass is built; depending on whether the design is chosen by the federal government, by region A, or by a negotiation between regions A and B; and for the negotiated outcomes, depending on which threat points form the basis for negotiations.

The first results of the simulation are the welfare levels that are reached when adjusting tolls on the existing road (see Figure 5, alternative 0). In the initial situation, without tolling, the two regions happen to have comparable total welfare levels: while region A enjoys a greater number of trips than travelers from region B, the benefits of these trips are largely erased by the negative externalities of all trips through the city center.

The next two scenarios consider setting a toll on the city road, without constructing a bypass. In the globally optimal solution $(enb)$, the toll is set at 1.00 € to exactly offset the environmental externalities (see Table 3). As a result, only the highest-value trips by both regions’ residents remain. If region A sets the toll to optimize its own welfare $(anb)$, the toll would be slightly higher at 1.14 €, with the increment purely an opportunity to extract taxes from region B. As shown in (10), this mark-up would be higher if region B represented a larger share of the demand. Indeed, real-world proposals for tolling on a sole center-city highway are extremely rare, probably because of the ambiguity between the two cases $(enb)$ and $(anb)$. Due to the difficulty in exactly estimating external effects of the transit traffic, it is difficult for decision-makers to know whether some portion of the toll is tax exportation.

The remaining scenarios consider the case where a bypass is built and various strategies are used to set the tolls. At optimal toll levels $(eb)$, the bypass is an improvement in overall welfare over the initial situation (0), but not as beneficial as simply tolling the existing road $(enb)$. Indeed, the maximum daily cost where $(eb)$ would be preferable to $(enb)$ is 8724 €/day. Yet, because under the optimal tolls the bypass is not tolled, this scenario still represents an improvement for region B over the scenarios with only tolling.
On the other hand, were region A to set the toll levels, it would again gain by exporting tax to region B’s transit travelers. In section 3.5 we discussed two regimes: in the first, the city toll is exactly the marginal external costs of trips through the city center, while in the second, an additional markup allows both tolls to be increased while keeping the bypass preferable for transit trips. In the simulation, we see the first of these cases, with a toll on the city road of exactly 1 €/trip, owing to the relatively small share of region B travelers and the relatively high external costs.

The next two scenarios concern negotiated outcomes with two different threat points. In the first, \((U)\), the threat point is that region A decides unilaterally on tolls, while in the second, \((c0b)\), the threat point is that no bypass is built, nor tolls set. In the Swedish context, the latter of these is closer to reality: since the main route through Örnsköldsvik is a national highway, either tolls or rerouting to a bypass would require federal approval, and it is far more likely that approval would be granted if the two regional governments could agree.

In both negotiated outcomes, the tolls are identical to the global optimal case, \((eb)\). Yet, the starkly different transfers from the two negotiated scenarios illustrate the importance of the fall-back positions: when the threat point favors region A, region B has an incentive to make a substantial transfer such that its situation is improved \((cab)\), whereas when the threat point is the initial situation, there a smaller transfer in the opposite direction is required for agreement \((c0b)\). These transfers are of substantially different character. In the former, region B compensates region A as an alternative to the elevated bypass toll in \((ab)\). In the latter, region A compensates region B as a way of sharing the huge welfare improvement it achieves from compensating for externalities, less the cost of the bypass. The cost of the bypass only affects the latter case: the transfer from A to B would be larger if the bypass was less expensive, and it would be reversed if the bypass were more expensive.

In the final simulation scenario, we see the results of the proposed Pareto-efficient bypass-and-toll scenario from section 5.4. Most striking is that a toll is now only set on the bypass, and not on the city road. The toll of 0.41 €/trip is set so that it does not exceed the benefits of time savings relative to the city road, yet that toll level generates only 2728 €/day, not nearly enough to cover the estimated cost of the tunnel bypass. For comparison, tolls that have been discussed in connection with the planned E4 bypass bridge past Sundsvall, 150 km south of Örnsköldsvik, have ranged from 10 €/crossing for goods vehicles over 3.5 tons, to 1 €/crossing for passenger vehicles. No tolls are planned in the old road through Sundsvall’s city center, but the road will be redesigned for lower speeds and traffic volumes. Discussions of a bypass in Örnsköldsvik are at a far more preliminary stage so it is difficult to say what tolling regime might be proposed. Yet, if that bypass follows Sundsvall’s example, then the toll scheme would most closely resemble scenario \((acb)\), suggesting that acceptability is worth a substantial sacrifice in total efficiency.

7 Discussion of limitations to transferability

The model used in the paper is based on several simplifying assumptions. In this section we will briefly discuss some of the limitations this imposes on the transferability of the results.

No congestion
Pricing road congestion is more attractive to travelers compared to tolls targeted at reducing environmental externalities since the reduced congestion directly benefits the travelers whereas a reduced environmental externality primarily benefits other interest groups. Unless the travel time gains are very large or the collected charges are directly returned to the travelers, the overall welfare effect on the traveler collective is still likely to be negative.

**No interaction with local road network**
The use of road user charges can also have negative spillover effects in the form of reduced safety and increased congestion in other parts of the road network if the pricing shifts traffic from the main highways onto local roads. If the effects from the shift are large, the situation needs to be analyzed in a second-best setting where the effects from the untolled alternative are included in the analysis (see Verhoef, Nijkamp, RietVeld (1996b)).

**The generalized cost of the bypass is lower than the generalized cost of the city road**
The Pareto improving strategy to place road user charges on the bypass but keep free access on the city road depends on that the generalized cost of the bypass is lower than the generalized cost of the city road. Without the initial cost differences, alternative measures such as traffic calming or local traffic regulations in the city center, are needed to make transit travelers use the tolled bypass instead of the free city road. The acceptability of the policy hence depends on the public reception of the taken measures. See Verhoef, Nijkamp and Rietveld (1996a) for a discussion about the social feasibility of road pricing compared to other regulating measures.

**Marginal cost of public funds equal to one**
Setting the marginal cost of public funds to one implies that we assume that it is more efficient to let the taxpayers finance the bypass with other taxes, than to let the travelers finance it through road user charges. If $MCPF > 1$, the expression for the optimal toll level without a bypass becomes:

$$t^{MCPF}_C = \frac{MEC}{2MCPF-1} + MCPF \frac{a-\delta_C}{2MCPF-1} - \frac{a-\delta_C}{2MCPF-1}$$

The optimal toll level consists of three terms: the first term is proportional to the marginal external cost, the second term is related to the value of the collected toll revenues, and the third term corresponds to the negative effect that the toll has on the traveler’s social surplus. All terms also have a markup related to the value of the collected revenues. If MCPF is equal to one, the last two terms cancel out and the optimal toll level on the city road is equal to the marginal external cost of the environmental externality. For large values of MCPF, the optimal toll level approaches the monopoly toll level that maximizes the total collected revenues. Increasing MCPF hence make the taxpayers better off. Unless the marginal external cost is very high, the optimal toll level also increases with MCPF which makes the travelers worse off.

**Rural residents**
The model assumes that there is no environmental externality on the bypass. Adding a marginal external cost of bypass traffic by including rural citizens in the model would motivate a toll on the bypass to internalize the negative externality. Political acceptability can also motivate the construction of a more expensive bypass (longer distance or
underground) to minimize the negative impact on rural citizens living near the bypass who might oppose the project.

8 Conclusions and implications for policy

In this paper we have studied the pricing and investment of a bypass road in different institutional settings and compared their relative efficiency and their interregional and intraregional acceptability. It is instructive to arrange the different settings in order of their overall efficiency.

Leaving all the decisions to the region where the bypass is located leads in general to excessive tolls on the city road and insufficient incentives to invest in the bypass. A cooperative agreement with the neighboring regions where these regions share in the investment cost in return for more efficient tolls is clearly a better solution from a welfare perspective. How both regions share in the gains and cooperation will depend on the federal regulations that may make these projects depend on interregional agreements. Making cooperation mandatory can also be problematic since it may lead to situations where a region is extorted by neighboring regions in order to be able to invest in new infrastructure.

Although regional cooperation can increase welfare, it may not necessarily increase acceptability since the negotiation involves monetary transfers between taxpayers from different regions. Solutions where the taxpayers of both regions pay part of the investment cost of the bypass may hence limit the political acceptability. It is the political acceptability that may lead to the absence of implemented tolls on city center roads, as well as the use of tolls on bypasses, which is a second best solution.

To summarize: to maximize efficiency the toll should be put on the city road where we want to reduce traffic, to maximize acceptability the toll should instead be placed on the bypass where we want people to drive in order to finance the construction without making the local travelers unhappy. When we introduce congestion on the city road and bypass, the taxpayers’ contribution will be lower than in the uncongested case. This is because the efficient toll will now be higher, as it also has to cover the marginal external cost related to congested travel times. Congestion on the city road can also increase acceptability among local travelers, since the reduced travel time from the diverted transit traffic creates a direct welfare gain for the remaining travelers on the city road.

Our analysis is one of the first attempts to integrate the pricing and investment problem of regional infrastructure in a context where intraregional and interregional decision rules both affect the outcome. There are many more dimensions to be explored. We mention four. First, one could add a parallel region offering an alternative route, this would decrease the monopoly power of the through traffic region and increase the bargaining power of the region where the transit traffic originates. A second fruitful dimension is to consider more explicitly the asymmetries in information between the building region and the neighboring region. The building region has an incentive to overstate the external costs that are caused by the neighboring regions. A third extension is to consider not a bypass road but to consider an investment in a second mode (rail) that would be an imperfect substitute for the existing road through the city center. A fourth extension is to consider price discrimination where for
example the regions negotiate about whether to allow price discrimination between its citizens or not.

9 Acknowledgements

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Tables and Figures

Table 1. Expressions for the welfare for the six interest groups in the initial situation and as a function of the toll levels $t_c$ and $t_B$ with a bypass.

<table>
<thead>
<tr>
<th>Interest group</th>
<th>Welfare in initial situation (0)</th>
<th>Welfare with bypass as a function of the toll levels $t_c$ and $t_B$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local travelers from A</td>
<td>$W_{LA}^0 = (1 - \gamma - \delta) \frac{(a-gc)^2}{2b}$</td>
<td>$W_{LA}(t_c, t_B) = (1 - \gamma - \delta) \frac{(a-gc-t_c)^2}{2b}$</td>
</tr>
<tr>
<td>Transit travelers from A</td>
<td>$W_{TA}^0 = \gamma \frac{(a-gc)^2}{2b}$</td>
<td>$W_{TA}(t_c, t_B) = \gamma \frac{(a-gc-t_c)^2}{2b}$</td>
</tr>
<tr>
<td>Residents living near city center in A</td>
<td>$W_{EA}^0 = -MEC \frac{a-gc}{b}$</td>
<td>$W_{EA}(t_c, t_B) = -MEC \cdot (1 - \gamma - \delta) \frac{a-gc-t_c}{b}$</td>
</tr>
<tr>
<td>Taxpayers from A</td>
<td>$W_{PA}^0 = 0$</td>
<td>$W_{PA}(t_c, t_B) = t_c \cdot (1 - \gamma - \delta) \frac{a-gc-t_c}{b}$ $+ t_B \cdot (\gamma + \delta) \frac{a-gc-t_c}{b} + D - COST$</td>
</tr>
<tr>
<td>Transit travelers from B</td>
<td>$W_{TB}^0 = \delta \frac{(a-gc)^2}{2b}$</td>
<td>$W_{TB}(t_c, t_B) = \delta \frac{(a-gb-t_b)^2}{2b}$</td>
</tr>
<tr>
<td>Taxpayers from B</td>
<td>$W_{PB}^0 = 0$</td>
<td>$W_{PB}(t_c, t_B) = D$</td>
</tr>
</tbody>
</table>

Table 2. Change in welfare for the six interest groups compared to the initial situation for all of the analyzed polices.

<table>
<thead>
<tr>
<th>Interest Group</th>
<th>Comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td>$W_{LA}$</td>
<td>enb - 0</td>
</tr>
<tr>
<td>$W_{TA}$</td>
<td>-</td>
</tr>
<tr>
<td>$W_{EA}$</td>
<td>+</td>
</tr>
<tr>
<td>$W_{PA}$</td>
<td>+</td>
</tr>
<tr>
<td>$W_{TB}$</td>
<td>-</td>
</tr>
<tr>
<td>$W_{PB}$</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 3. Numerical Illustration Results: Toll Levels and Transfers

<table>
<thead>
<tr>
<th>Toll; No Bypass</th>
<th>Toll with Bypass</th>
<th>From Maximal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No Negotiation</td>
<td>Negotiation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Toll on City road (€/trip)</td>
<td>0.00</td>
<td>1.14</td>
</tr>
<tr>
<td>Toll on Bypass (€/trip)</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Daily Transfer from A to B (€/day)</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Daily Transfer from B to A (€/day)</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>

*Assuming 100% bypass costs; \(^b\) assuming 25% bypass costs.
Figure 1 Illustration of the city road, the proposed bypass and the three categories of trips (LA, TA, and TB)
Figure 2. Optimal city road toll and bypass toll for the regional government
Figure 3. Comparison of cooperative solutions for two different threat points

Figure 4. The Cost of Acceptability measured as efficiency loss compared to efficient toll levels
Figure 5. Numerical Illustration Results: Welfare by Region

<table>
<thead>
<tr>
<th>Situation</th>
<th>Toll; No bypass</th>
<th>Toll with Bypass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Optimal for A (anb)</td>
<td>Global optimum (enb)</td>
<td>Optimal for A (ab)</td>
</tr>
<tr>
<td>From A's optimum (cab)</td>
<td>From initial situation (c0b)</td>
<td>Maximal acceptability (acc)</td>
</tr>
</tbody>
</table>

Region A | Region B | Total
## Appendix A. Comparison of optimal tolls and welfares by scenario

<table>
<thead>
<tr>
<th>Scenario Options</th>
<th>Scenario Optimization</th>
<th>Toll levels and transfers, $t_c$, $t_b$, and $D$</th>
<th>Welfare for Region A, $W_A$</th>
<th>Welfare for Region B, $W_B$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Initial</strong></td>
<td>None, 0</td>
<td>(no tolls or transfers)</td>
<td>$W_A^0 = (1 - \delta) \frac{(a-g_b)^2}{2b} - MEC : \frac{a-g_c}{b}$</td>
<td>$W_B^0 = \delta \frac{(a-g_b)^2}{2b}$</td>
</tr>
<tr>
<td><strong>Toll Only</strong></td>
<td>Efficient, $enb$</td>
<td>$t_c^{enb} = MEC$, $t_b^{enb} = 0$</td>
<td>$W_A^{enb} = (1 - \delta) \frac{(a-g_c-MEC)^2}{2b}$</td>
<td>$W_B^{enb} = \delta \frac{(a-g_b-MEC)^2}{2b}$</td>
</tr>
<tr>
<td></td>
<td>Optimal for A, $anb$</td>
<td>$t_c^{anb} = \frac{MEC+\delta(a-g_b)}{1+\delta} &gt; MEC$</td>
<td>$W_A^{anb} = \frac{1+\delta}{(1+\delta)^2} (a-g_c-MEC)^2$</td>
<td>$W_B^{anb} = \delta \frac{(a-g_b-MEC)^2}{2b}$</td>
</tr>
<tr>
<td><strong>Bypass and Tolls</strong></td>
<td>Efficient, $eb$</td>
<td>$t_c^{eb} = MEC$, $t_b^{eb} = 0$</td>
<td>$W_A^{eb} = (1 - \gamma - \delta) \frac{(a-g_c-MEC)^2}{2b} \frac{(a-g_b)^2}{2b} - COST$</td>
<td>$W_B^{eb} = \delta \frac{(a-g_b)^2}{2b}$</td>
</tr>
<tr>
<td></td>
<td>Optimal for A (case I), $ab$</td>
<td>$t_c^{ab} = MEC$, $t_b^{ab} = \frac{\delta}{2(\delta+y)}(a-g_b)$</td>
<td>$W_A^{ab} = (1 - \gamma - (\delta+y)^2 (a-g_c)^2 (a-g_b)^2 - COST$</td>
<td>$W_B^{ab} = \delta \frac{(a-g_b)^2}{2b}$</td>
</tr>
<tr>
<td></td>
<td>Optimal for A (case II), $\bar{ab}$</td>
<td>$t_{\bar{a}}^{\bar{b}} = 1 - \gamma - \delta \frac{MEC}{1+\delta}$</td>
<td>$W_A^{\bar{a}}^{\bar{b}} &lt; W_A^{ab}$</td>
<td>$W_B^{\bar{a}}^{\bar{b}} &gt; W_B^{ab}$</td>
</tr>
<tr>
<td><strong>Negotiate from Optimal for A, $cab$</strong></td>
<td>$t_c^{cb} = MEC$, $t_b^{cb} = 0$, $D = \frac{\delta(5\delta^2+6\delta y)(a-g_b)^2}{2(2\delta+y)^2}$</td>
<td>$W_A^{cab} = (1 - \gamma - \delta) \frac{(a-g_c-MEC)^2}{2b} \frac{(y+\delta)(5\delta^2+6\delta y)(a-g_b)^2}{2(2\delta+y)^2} - COST$</td>
<td>$W_B^{cab} = \delta \frac{(a-g_b)^2}{2b}$</td>
<td></td>
</tr>
<tr>
<td><strong>Negotiate from Efficient, $cbb$</strong></td>
<td>$t_c^{cb} = MEC$, $t_b^{cb} = 0$, $D = \frac{(\delta-y)(a-g_b)^2}{2b} \frac{1-\gamma-\delta}{2} \frac{(a-g_c-MEC)^2}{2b} \frac{(a-g_b)^2}{2b} + \frac{MEC-a-g_c}{2b} + \frac{COST}{2}$</td>
<td>$W_A^{cbb} = \frac{(1-\gamma-\delta)(a-g_c-MEC)^2}{2b} \frac{(y+\delta)(a-g_b)^2}{2b} + \frac{MEC-a-g_c}{2b} + \frac{COST}{2}$</td>
<td>$W_B^{cbb} = \frac{(1-\gamma-\delta)(a-g_b)^2}{2b} \frac{(y+\delta)(a-g_b)^2}{2b} + \frac{MEC-a-g_c}{2b} + \frac{COST}{2}$</td>
<td></td>
</tr>
</tbody>
</table>