Transport Infrastructure Provision and Road-Pricing: The Sax-Wicksell Concept in the Light of Today's Policies

by

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Abstract: This paper re-introduces the Sax-Wicksell concept of transport infrastructure provision and financing in a club fashion. Against this background, the EU proposal for a common transport infrastructure charging framework and the recent introduction of a new road use charging system in Germany are discussed. Among other things, it is argued that the proceeds of charges that are supposed to internalize negative external effects of traffic, such as congestion and environmental damage, should be spent on reducing the underlying causes of these effects in order to avoid rent seeking incentives and to boost trade and economic growth.

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1 Introduction

Optimal provision of transport infrastructure ensures minimal transport costs and, therefore, guarantees full benefits from free trade. For this reason, optimal provision of transport infrastructure has always been a policy issue in the European Union (EU) and its Member States, but over the last decade this debate has gained considerable drive (see Button 2005, for an overview). Essentially, financing through vehicle or fuel taxes versus direct charging for the use of transport infrastructure has been the focus of the debate. For example, in the late 1990s the EU Commission (1998, p. 3) found that of the then 15 Member States five levied road tolls, six others used the Eurovignette scheme for heavy commercial vehicles, one other applied a different form of user charge and the remaining three did not charge for road use at all. In addition, all Member States levied annual vehicle taxes, but these varied by up to 3000 ECU, and diesel fuel excise duties varied by up to 330 ECU per 1000 liters.[1] The Commission (1998, p. 5) concluded that these differences and any further drifting apart in this policy area would have negative effects for the efficient allocation of transport infrastructure and traffic within the EU, with an ultimately negative impact on internal and external EU trade. Consequently, the Commission sought to initiate a process towards a harmonized transport infrastructure charging framework in the EU. This initiative has so far led to some reports on transport related costs and various Directives or proposals for Directives on transport infrastructure charging.

Against this background, the purpose of this paper is twofold. First, to draw attention to some concepts and views on transport infrastructure charging that seem to have been

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[1] Note that the ECU (European Currency Unit) was the forerunner of the Euro and was replaced by the Euro on January 1, 1999.

overlooked in modern transport economics and the EU debate. Second, to discuss a few problems that may complicate the optimal provision of transport infrastructure. Yet, although the analysis could be applied to transport infrastructure in general, this paper is predominantly confined to road infrastructure and road transport, which is the dominant mode in the EU.

The paper proceeds as follows. Next, the views of Sax and Wicksell on transport infrastructure provision and financing are re-introduced. In section three, these views will be compared and contrasted with recent EU proposals. Section four is devoted to some additional aspects that might be relevant with respect to the optimal provision of transport infrastructures. Section five concludes.

2 The Sax-Wicksell concept of transport infrastructure provision and financing

The Austrian economist Emil Sax (1845–1927) published the first edition of his treatise on transport economics, *Die Verkehrsmittel in Volks- und Staatswirthschaft*, in two volumes in 1878 and 1879. This extensive work may well represent the first analysis of the transport sector that gives special attention to all modes of transport known at the time. Pickhardt (2005a) provides an overview regarding Sax's work on transport economics, Schmidt (1987) and Neck (1989) offer an analysis of Sax's contribution to public economics.

Regarding the provision and financing of transport infrastructure,[2] Sax (1878, pp. 62–86) considers a multiple stage system. At the first stage, only private firms provide the transport infrastructure and the financing is entirely based on market prices. The remaining three stages all fall into the public domain, but to different degrees and this is fully reflected in the provision and financing of the relevant infrastructure. For example, at the second stage Sax places public or publicly regulated firms. At this stage so called 'tax prices' are charged, where the term 'tax price' refers to a price that may only in the long run lead to cost coverage or profits, while in the short run a 'tax price' would typically be below the total production

[2] Sax does not use the term „infrastructure", but speaks of "standing capital" (*stehendes Capital*).

costs per relevant unit of usage (Sax 1878, p. 81). It is for the latter reason that a private firm cannot offer such 'tax prices'. Thus, the essentially longer time horizon of the public firm, reflected in aiming at cost coverage and profit only in the long run, allows for charging of prices below the short run market prices which a private firm would have to charge *ceteris paribus*. Moreover, according to Sax (1878, p. 71), prices below the short run market level would induce a higher demand for transportation, which in turn would enhance trade and induce more competition in goods markets and would therefore be beneficial for the economy as a whole. In other words, 'tax prices' would induce a welfare enhancing dynamic process. Two things should be emphasized, however. First, public firms, just like private firms, do seek a surplus or profit, but they do so in the long run rather than in the short run. Second, Sax's term 'tax price' is a somewhat misleading expression as it refers to a 'taxed' or assessed 'cost price' and is not at all related to levying a tax. At the third stage, Sax places the so called public institutions. At this stage, price exclusion is still a guiding principle with respect to the use of transport infrastructure. Yet, only a 'fee' is charged. In Sax's system a 'fee' differs from a market price or a 'tax price' insofar as a 'fee' is neither related to the reservation price of the user (market price) nor to the underlying costs of the relevant unit ('tax price'). Rather, a 'fee' is calculated in such a way that total costs of providing the infrastructure are covered by the total proceeds from the 'fee' and neither a surplus nor a deficit is envisaged *a priori* by the public institution. Finally, at the fourth stage, Sax analyses the provision of transport infrastructure by the government. The price exclusion principle no longer applies at this stage and all economic agents are free to use the transport infrastructure as they see fit. There are no direct charges whatsoever and the infrastructure is entirely financed through the general budget, i.e. by taxes. Table 1 summarizes the four provision stages in Sax's system.

Yet, four aspects must be stressed with respect to Sax's stage system. First, the system is mode and not time related. Therefore, the four stages do not reflect a necessary development over time. Rather, all four stages might be found simultaneously in a transport system, with certain infrastructures provided by private firms and certain other infrastructures by public firms, public institutions or the government. The criterion for applying one or another stage to a certain mode is the extent of usage. For example, if only a few use a certain mode of transport then market provision and market prices should apply, but if the entire population uses a mode by and large to the same extent then government provision and a general tax would be appropriate.

Table 1: Sax's Stage System

Stage	Providing Institution	Charging Scheme	Price Exclusion	Stage Application
1	Private Firm	Market Price	Yes	Exceptional
2	Public Firm	'Tax Price'	Yes	Rule
3	Public Institution	Fee	Yes	Rule
4	Government	General Tax	No	Exceptional

Second, in modern terms, the stage system reflects different degrees of positive external effects of the transport system on trade and growth and the different pricing methods essentially are supposed to internalize these effects (Sax 1878, pp. 71–77 and 82–86). Third, Sax views provision through private firms (stage 1) and the government (stage 4) as exceptional cases (Sax 1878, pp. 63–77 and 83–84). Provision through public firms (stage 2) and public institutions (stage 3) would be the rule. Fourth, Sax's stage system is only part of a wider theoretical background that includes, among other things, four laws of transportation (Sax 1878, pp. 16–86). Yet, with respect to the purpose of this paper it suffices to concentrate on Sax's stage system.

The Swedish economist Knut Wicksell (1851–1926), in his dissertation *Finanztheoretische Untersuchungen* ... (1896, pp. 125–138), discusses Sax's stage system.[3] In this context, Wicksell (1896, p. 130) argues that, in principle, it would not matter for the users of a certain infrastructure[4] whether they pay for the benefit they receive through 'tax prices' charged per use or through contributions in the sense of a membership fee, either at once or in monthly, quarterly or annual installments over a longer period. Wicksell continues that the latter case would allow for an immediate reduction of the 'tax prices' to the actual costs per unit of use. Also, Wicksell distinguishes two cases with respect to his further analysis. In the first one, the costs per unit of use are either close to zero or the costs of charging would exceed the proceeds, whereas in the second one the costs per unit of use are significant.

In the first case, price exclusion could be removed entirely so that every economic agent would be free to use the relevant infrastructure. According to Wicksell (1896, p. 130) both the removal of the price exclusion principle and the immediate reduction of the 'tax price' to the actual costs per unit of use would lead to a large increase in use and would therefore be beneficial not only for the economy as a whole, but also for each individual entity. Next, Wicksell points out that private firms will usually not be able to choose this procedure, unless the consumers have formed an association or 'club' and provide themselves with the relevant infrastructure. But according to Wicksell (1896, p. 130), the state and the public institutions or associations are already constituted as 'clubs' and, because of their power to tax, already possess the means to collect such contributions or 'membership fees'. This constitutes, according to Wicksell, an important argument for the provision of transport and other infrastructures by the state or the government and Wicksell (1896, pp. 130–132) presents a numerical example to further substantiate this point. However, he also concedes

[3] Note that Wicksell (1896, pp. 125–138) does not refer to Sax (1878), but to Sax (1890, p. 571), Sax (1887, p. 461) and Sax (1885, p. 533). However, Sax (1890, 1885) represent a contribution on the nature of transportation and communication in Schönberg's handbook. This paper is a condensed version of Sax (1878, 1879) and Sax's (1887, p. 461) note on value and differential tariffs is also related to his treatise on transport economics, in particular, to public firms (stage 2). For details on all references see Pickhardt (2005a).

[4] Wicksell does not use the term „infrastructure", but the term „undertaking" *(Unternehmung)*.

that it would be difficult, if not impossible, to calculate the relevant tax in such a way that it truly reflects the degree to which an individual has actually used the infrastructure or the subjective benefit the individual derives or may derive from using the infrastructure. Yet, despite this 'unevenness' of taxation, Wicksell (1896, p. 132) argues that the resulting gain in utility would still generate a larger or smaller surplus for each and every individual.

In the second case, where the costs per unit of use are significant, the price exclusion principle should continue to apply and open access would not be a welfare enhancing option (Wicksell 1896, p. 133). In these cases, the reduction of the 'tax price' should not go beyond the true costs per unit of use. The latter, however, would usually decrease with an increasing frequency of usage. For this reason, Wicksell (1896, p. 133) formulates the general rule that the reduction of the 'tax price' should go only so far that the resulting 'new price' would still cover the additional (marginal) infrastructure costs caused by the increase in the usage frequency that results from the price reduction. Wicksell (1896, pp. 133–134) restates this general rule in mathematical terms in the following way.

Suppose that the costs per unit are constant and equal to k for each utilization act. Then the appropriate 'tax price' p would be given by: $p = k$, (1). Alternatively, if the costs per unit are not constant, the annual total costs of the infrastructure [C] must be expressed as a function of the annual usage frequency x, that is, $C = f(x)$, (2), where the actual functional form f should be determined empirically, according to Wicksell. Also, note that the term in square brackets has been added here to comply with contemporary representations of the issue. Then, a small increase in the annual usage frequency, dx, will cause a corresponding increase in the annual total costs, $dC = f'(x)\ dx$, (3), and this corresponding increase in the annual total cost must be covered by the additional revenue raised by the increase in the annual usage frequency, dx, which yields the following rule, $f'(x)\ dx = p\ dx$, or [$C' = p$], (4). In addition, in must be taken into account that *ceteris paribus* the usage frequency x is also a function of the 'tax price' p, which can be expressed as, $x = \varphi(p)$, (5), again the actual functional form of φ should be determined empirically. Substituting (5) into (4) yields, $f'(\varphi(p)) = p$, (6), which allows for calculating the optimal 'tax price', p^*.

Wicksell (1896, p. 134) continues his analysis by stressing two important implications of his pricing rule. First, charging p^* means that only variable costs are fully recovered by the charge and that a deficit emerges that is equal to the fixed costs of providing the transport infrastructure.[5] At the same time, however, charging p^* guarantees allocative efficiency because the optimal frequency of use, x^*, emerges. Second, no revenue in excess of the (variable) costs is tolerable. In the event that such excess revenue occurs it would only call for a further reduction of the 'tax price' p. As described above, the dynamic process would then induce more demand and, according to Wicksell (1896, p. 134) "all would benefit, nobody lose, provided that the reduction in profit would be covered in an appropriate manner by taxes". Of course, in Wicksell's view the notion of an "appropriate manner" refers to a tax scheme that is (almost) unanimously adopted (1896, p. 135). Also, it must be stressed again that the tax is not a general tax, but rather a specific tax levied on those who benefit from transportation infrastructure and all tax revenue would be earmarked exclusively for coverage of the fixed costs of the relevant transport infrastructure. This highlights the club fee character of the tax. In this context it is worth noting that Wicksell (1896, p. 135, fn. 1) makes the rather remarkable statement that in cases in which a national transport infrastructure is frequently used by foreigners, who cannot be taxed, cost compensation could be either achieved through special tariffs or international compensation agreements. Again, this remark highlights the club character of Wicksell's approach. Finally, Wicksell (1896, p. 136) rejects Sax's analysis with respect to the fourth stage on the grounds that the "tax price" p should, in general, not be reduced below the cost of an additional (marginal) user act.

[5] Note, however, that Wicksell is not necessarily right here. Rather, with marginal cost pricing, his results essentially depends on the underlying scale effects in providing the infrastructure. For further details see Button (2004, p. 16) and others.

To summarize, Wicksell (1896) takes up the basic idea of providing transport infrastructure in a club fashion from Sax (1878) and on this basis develops a concept of optimal transport infrastructure provision. Hence, both Sax and Wicksell advocate a system in which transport infrastructure is in general provided in a club fashion, that is, only users and beneficiaries pay for the transport infrastructure and prices depend negatively on the frequency of use as all revenue is exclusively used for cost coverage. Throughout this paper, this is referred to as the Sax-Wicksell concept of transport infrastructure provision and financing. There are, however, also some fundamental differences between Sax and Wicksell. They include: (i) that Sax does not consider marginal cost pricing, (ii) that the two exceptional stages in Sax's system, i.e. stages one and four, may not really represent a club provision, and (iii) that Wicksell does not consider different stages. Rather, except for the qualifications mentioned, Wicksell's pricing rule applies in general. Thus, direct user charges in Sax's entire stage system may differ from those resulting from Wicksell's pricing rule, except perhaps in cases where specific cost structures prevail. To this extent, the usage frequency x may be non-optimal in all four stages of Sax's system. Yet, as Wicksell's pricing scheme always includes tax financing of the fixed costs, Sax and Wicksell effectively propose different institutional settings and these institutional settings may have adverse effects on welfare. Therefore, *a priori* it may be difficult to tell which pricing system would be more welfare enhancing.

Finally, the views of Sax and Wicksell on transport infrastructure provision and financing must be put in their historical context. To keep things brief, however, I shall confine myself to just a few comments. First, the introduction of marginal cost pricing with respect to the provision of transport infrastructures goes back to Dupuit (1844, 1849) and Launhardt (1872), rather than to Wicksell (1896). But Wicksell seems to have developed his concept independently from both Dupuit and Launhardt. This conjecture is substantiated by the fact that Wicksell (1896, p. 136) himself wonders why the rather plausible results of his analysis on infrastructure financing have not been observed in relevant literature, except by Marshall in his *Principles of Economics* (Book V, Ch. VIII, § 8). In addition, neither Dupuit's nor Launhardt's writings were particular popular at the time. Second, just like Sax and Wicksell, both Dupuit and Launhardt rejected, in general, the provision of transport infrastructures by private firms on the grounds that they would charge too high a price and would therefore not maximize societal welfare. Third, neither Dupuit nor Launhardt discuss the idea of providing transport infrastructure in a club fashion. Moreover, as Sax (1878) does not reference Dupuit at all and references Launhardt only once with respect to the economics of establishing a transportation network (Sax 1878, p. 148), it seems that the idea of providing transport infrastructure in a club fashion essentially goes back to Wicksell (1896) and to some extent to Sax (1878).

Overviews regarding Dupuit's and Launhardt's contributions to economics are provided by Ekelund (1987), Johansson and Mattsson (1995), or Niehans (1987), Backhaus (2000), respectively.

3 The EU proposals on direct charging for the use of transport infrastructure

In the preceding section some 19th century views on transport infrastructure financing have been revisited. Upon reflection, and with bearing in mind the findings mentioned in the introduction, it should now be apparent that Sax's stage system still represents an accurate description of almost the entire transport systems of the present 25 Member States of the EU. But the link to Sax's stage system has so far not been noticed. Yet, the proposals put forward by the Commission with respect to a common transport infrastructure charging framework imply a fundamental change and, in essence, abandoning of the Sax styled stage system. Therefore, this section now compares and contrasts the views of Sax and Wicksell with the proposals put forward by the Commission and, where appropriate, with transport infrastructure financing schemes applied in EU member states. As noted, the Commission's 1998 White Paper "Fair Payment for Infrastructure Use" is the basis for all recent EU

Directives and proposals for Directives on the issue. For this reason, the following brief sketch of the Commission's view bears heavily on the White Paper.

3.1 A common transport infrastructure charging framework in the EU

According to the White Paper (Commission 1998, p. 2), the provision of transport infrastructure is efficient if all private and broader public benefits and costs are taken into account. Efficient use of existing transport infrastructure is promoted when the variable costs are reflected in the final prices faced by users. In this context, it is argued that different current charging principles distort competition, and therefore have a negative impact on trade and, ultimately, on welfare, whereas "common charging principles would create a level playing field and correct intra and intermodal imbalances" (Commission 1998, p. 4). In particular, it is estimated that overall welfare benefits in the range of at least 30-80 billion ECU per year would result (Commission 1998, pp. 12 and 30). This conclusion is substantiated with a few observations and arguments, including that:

(i) Member States have charged or taxed transport with a view to raise government revenues rather than to cover variable or total costs of transportation (1998, p. 3),

(ii) distortions such as modal imbalance, congestion and pollution are often considered as specific and isolated problems rather than interrelated problems (1998, p. 3).

Therefore, the Commission's (1998, pp. 5–12) new approach to transport infrastructure pricing consists of developing a framework based on common principles for charging commercial vehicles in all modes of transport and with the option of extending the scheme to passenger vehicles (see also European Parliament 1999 and Commission 2003). These principles include: *Marginal Social Cost Pricing, Adequate Incentives, Cost Coverage, and Subsidiarity*. There can be no doubt, however, that the introduction of marginal social cost pricing is the cornerstone of the Commission's approach, as virtually everything else follows from that.[6] In particular, the introduction of marginal social cost pricing is expected to induce economic agents on both the demand (vehicle drivers and owners) and the supply side (infrastructure provision) to adjust their individual plans in an efficiency enhancing way. Moreover, for the transport system as a whole, the Commission expects that total cost coverage for the provision of transport infrastructure would become possible, eliminating or at least reducing the need for government subsidies or government provision of transport infrastructure.

To assess these essential elements of the Commission's proposal, the next subsection compares and contrasts them with the views of Sax and Wicksell.

3.2 The Commission's view: Anything new?

To begin with, it is worth noting that the Commission follows Wicksell and others by proposing marginal cost charging. However, there is no mentioning that this principle goes back to 19th century authors such as Dupuit, Launhardt and Wicksell. Yet, regarding the concepts of Wicksell (and Sax) this may well be explained by the fact that these writings have only recently been translated into English language (see Sandelin (1997) and Pickhardt (2005a), respectively). This may also explain why even in contemporary contributions, where due credit is given to some 19th century writers, neither Sax nor Wicksell are mentioned (e.g. see Button 2004, pp. 8–9, Johnansson and Mattsson 1995, pp. 10–13).

A striking difference between the writings of both Sax and Wicksell on the one hand and the Commission's proposal on the other hand is related to the treatment of positive and negative external effects caused by road users, either to third parties (e.g., enhanced economic

[6] Marginal social costs are defined as those variable costs that reflect the cost of an additional vehicle or transport unit using the infrastructures. They may include operating costs (e.g., energy and labor), infrastructure damage costs (e.g., resurfacing of roads), congestion costs (e.g., costs of time delays to other users or non-users, or costs of being physically excluded), environmental costs (e.g., air, water and noise pollution), and accident costs.

growth, environmental costs) or to those who use the relevant road infrastructures at more or less the same time (e.g. accident costs and time losses due to congestion). Sax and Wicksell both consider and emphasis only positive effects of transportation. In particular, the interdependence of the price per user act with the number of user acts and the positive impact on a spatial spreading of competition which would enhance trade, regional economic growth and, ultimately, welfare. In contrast, the Commission seems to focus predominantly on negative external effects of traffic. To a large extent, of course, this difference reflects the development over time, in particular, the sharp increase in transport related negative environmental externalities. Yet, following Aschauer (1989) many empirical studies have identified positive effects of investments in public infrastructure on economic growth (e.g. see Ott 2001, p. 58).[7] More recently, for example, Colombier (2004, p. 57) identified a stable positive correlation between government expenditure on transport and communication infrastructures and economic growth in 21 OECD-countries. Therefore, the Commission should have considered appropriate growth models to assess the impact of transport infrastructures on economic growth and to study the impact of alternative consumption or usage properties on financing schemes or the growth rate. To this extent, the Commission's (1998, pp. 29–32) assertion that the introduction of the proposed charging framework would have "little or no direct effect on GDP growth, but it permits secondary benefit through the recycling of revenues" seems to be rather questionable regarding the first part. This observation is reinforced by the fact that the Commission (1998, p. 7), on the contrary, claims that subsidies should be paid by Member States to infrastructure managers "to compensate for wider social benefits to non-transport users".

Another important difference is related to the covering of capital costs or fixed costs of transport infrastructures. The Commission (1998, pp. 7, 9 and 45–46) proposes to cover these

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[7] According to Ott (2001, p. 58), out of 39 studies, 72 percent found a positive relation between investments in public infrastructure and economic growth, 20 percent a negative relation and in 8 percent of the cases the relation was ambiguous.

costs through congestion charges and, where necessary, through additional flat rate charges. In contrast, Wicksell seeks to cover these costs by an earmarked tax and Sax considers either coverage by a tax (stage 4) or by a certain kind of user charge (stages 1 to 3). But with marginal cost pricing, a case for financing fixed costs through congestion charges would arise only if provision of the relevant infrastructure is associated with economies of scale. In this case unit costs of providing capacity decrease the more capacity is provided, so that average costs may exceed marginal costs, and marginal cost pricing may not make up for fixed infrastructure costs.[8] However, there seems to be at least one reason why a congestion charge should never be spent on fixed cost coverage.

To see why, note that congestion is usually a temporarily phenomenon that occurs either due to an accident, poor coordination capacities of individual vehicle drivers or because peak demand cannot be accommodated by a transportation network or certain parts of it. In the latter case, congestion signals some capacity scarcity.[9] But, according to the Commission (1998, p. 45), it is "seldom justified to build capacity to provide free flow conditions also during peak-hours", rather "capacity should be geared towards normal demand levels". To be sure, provided that the congestion charge is set optimally it will induce a sufficient number of users to change their demand patterns and, therefore, solves the congestion problem.[10] In addition, it is worth noting that with respect to internalizing congestion it does not matter, in principle, how the proceeds from the congestion charge are spend.[11]

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[8] In all other cases, i.e. constant returns to scale or decreasing returns to scale, marginal cost pricing would either cover or exceed total costs so that there would be no need to use congestion charges for fixed cost coverage. For further details see, for example, Button (2004, p. 16). Note, however, that the concept of scale effects is essentially a quantity concept that relates input changes to output changes. Yet, costs may also depend on the underlying market conditions.

[9] In fact, the signaling of capacity scarcity is duly acknowledged by the Commission (1998, p. 9, fn. 8).

[10] An optimal congestion charge would result at the point where the social marginal cost curve intersects the demand curve, with the optimal congestion charge measured as the distance between the marginal private cost curve and the marginal social cost curve at this particular point. For a graphical illustration see Button (2004, p. 7, Fig. 3).

[11] Note, however, if the government decides on spending the proceeds and if they are spend in a welfare enhancing way, a double dividend would result. This issue is addressed by the Commission's mentioning of "secondary benefits through the recycling of revenues" (see above).

But if the proceeds of a congestion charge are not spend on reducing the underlying scarcity problem and with a view of making the congestion charge obsolete, self-interested public and private agents have an incentive to set congestion charges with a view to maximize revenue rather than to optimally internalize the congestion effect. As a consequence, congestion charges would be set in a non-optimal, monopolistic manner, and would therefore tend to be too high and may prevail for too long. In practice, this rent extraction incentive may be even stronger if private firms are involved because private agents can benefit directly from the extracted rents, whereas public agents can benefit only indirectly, for example, through higher budgets or a larger number of employees. In any case, too many users may be either price-excluded or charged too high a price, which may cause negative effects on competition, trade and growth. For example, industries that trade low value-added goods may be sensitive to even small price changes and therefore particularly affected (e.g. see Martinez-Zarzoso *et*. *al*. 2005). In addition, expanding the transport infrastructure may be just one option for solving the underlying scarcity problem. Button (1998), for example, discusses a whole set of alternatives to congestion charges and these alternatives may also represent an option for spending the proceeds of a congestion charge with a view of solving the underlying scarcity problem. Hence, to avoid the rent extraction incentive problem, the proceeds from charges that are supposed to internalize a negative external effect should always be spent with a view to avoid the external effect. Under such circumstances congestion charges would represent a short- or medium-term instrument for solving capacity scarcity problems. Thus, the proposal of the Commission to cross-finance the provision of transport infrastructure through the scarcity component of marginal social cost pricing seems to ignore the rent extraction incentive it may generate, or implicitly assumes that a non-selfishly acting altruist sets the congestion charge always at the truly optimal level.

Finally, there seems to be an important common element in the Commission's proposal and the writings of Sax and Wicksell. In fact, to a certain extent, the Commission seems to advocate the provision of transport infrastructures in a club fashion and, therefore, implicitly adopts the Sax-Wicksell concept of transport infrastructure provision and financing. Primarily, this is because the Commission recommends that public or private infrastructure managers should keep those parts of the charges which are related to the costs of providing the infrastructure, and that those parts related to external costs should be given to the government and should be spend on reducing the external damage caused or on compensating those affected (Commission 1998, pp. 9–10). Note, however, that the Commission recommends spending revenue from social cost charges (environmental damage and accident costs) on reducing the damage or on compensating those affected, but it does not recommend this same procedure, i.e. the reducing of capacity scarcity, with respect to congestion charges. This discrepancy may reinforce the argument put forward above in favor of spending congestion charge proceeds exclusively on solving the underlying capacity problem. In addition, the Commission notes that in the past Member States have charged or taxed transport with a view to raise government revenues rather than to cover variable or total costs of transportation. In other words, Member States have extracted a surplus or a rent form transport infrastructure provision. The case of Germany can be used to substantiate this point.

Table 2 provides some data concerning transport related expenditures and revenues in Germany for the year 2003, i.e. the latest year for which such data is currently available. In Germany, the federal government is responsible for motorways and federal highways, whereas the federal states and the municipalities care for the remaining roads. At the end of 2003, the federal road system comprised 12,044 km of motorways and 41,139 km of federal highways. According to Table 2, in 2003 the federal government's revenue from traffic related taxes was more than seven times higher than its spending on federal road infrastructure. Moreover, even the earmarked infrastructure share of the fuel tax, together with the share of the revenue from VAT charged on the fuel tax, alone would have more than covered the federal government's spending on federal roads. This illustrates the size of the rent which the federal government extracts from the provision of transport infrastructures. Yet this is only the lower bound of the rent, because neither VAT on the net value of the fuels nor VAT on other transport related goods and services are included.

Table 2: German Federal Road System – Expenditure and Revenue in 2003

	Expenditure (Million Euro)			**Revenue** (Million Euro)	
	Federal Motorways	Federal Highways		Total	Federal Government
Operation	420.0	405.4	Fuel Tax	38,148.8	38,148.8
Maintenance	754.9	657.8	Vehicles Tax	7,335.6	-
Expansion	561.2	-	VAT	>6,103.8	>3,137.96
New Construction	1,057.6	791.3			
Interest and Land Purchases	128.8	106.3			
Purchases of Privately Build Roads	166.0	55.5			
Sub-Sum	*3,088.5*	*2,016.3*			
Miscellaneous and Common Items	476.1				
Sum	*5,580.9*		*Sum*	*>51,588.2*	*>41,286.76*

*Notes: Maintenance refers to resurfacing and some reconstruction and expansion; Expansion refers to adding lanes; New Construction refers to newly build motorways and rebuilding of existing highways; Maintenance, Expansion and New Construction includes spending on reducing noise pollution; Miscellaneous and Common Items includes research, publications, planning, cycling paths, etc.; Fuel Tax excludes tax on fuels used for space heating (oil and natural gas); Vehicles Tax accrues to the federal states only; VAT refers exclusively to the 16 percent VAT charged on the Fuel Tax, and the federal governments share of VAT in 2003 was 51.41 percent. The market price of fuel is calculated in the following way: ((net market value of fuel per liter + fuel tax per liter)*1.16(VAT)= market price of fuel per liter). Sources: Bundesverkehrsministerium (2004, p. 31); Statistisches Bundesamt(2004, Fachserie 14, Reihe 4).*

Also, the additional revenue from other direct and indirect taxes that accrues due to an enhanced economic activity, induced by the provision of transport infrastructure, is not included.[12] Moreover, it would be interesting to see how much the federal government spent in 2003 on "reducing the external damage caused or on compensating those affected", that is, e.g. on the reduction of transport related emissions of carbon dioxide and polluting agents. Although exact figures were not available, it seems to be doubtful that this spending was in the range of 30 to 35 billion Euros.

To be sure, in a club setting it would be assumed that all road-users form a virtual club and share the costs for providing the club good, i.e. road infrastructure. The club fee would then be calculated by dividing total costs of providing the infrastructure through a certain number that reflects club membership. For example, club membership in 2003 could have been indicated by the number of registered vehicles (54,082,200), the average annual number of vehicles on the road(s) (21,159,050), the annual number of driven vehicle-km (322,500,000,000) or a combination of these and other measures. In the case of the federal road network in Germany, the 2003 club fees would have been either: 103.19 Euro per registered vehicle, or 263.76 Euro per vehicle on the road, or 0.0173 Euro per driven vehicle-Km. Of course, each of these measures has its pros and cons, but due to a lack of space I shall not discuss them here. Rather, it is important to emphasize that the "road infrastructure club" should be compensated for the positive external effects it generates to non-users and the economy as a whole in terms of enhanced competition, trade and growth. Also, for reasons explained above, this compensation should be spent exclusively on the road infrastructure and with a view to lower the club fee. Likewise, vehicle operators should compensate third parties for the environmental damage they may cause. Again, it is important to spend these proceeds exclusively on reducing the environmental damage that is caused, for example, on research and development of less pollutant fuels such as BioDiesel or Hydrogen, fuel efficient engines, and so on. However, such a set of different fees and charges requires some formal modeling to get a clear image of the interdependencies and the optimality conditions. Buchanan (1965)

[12] Note, however, that the figures in Table 2 may include taxes on fuels used in rail road (excluding electricity) and inland waterway transport.

offered the first formal model of an economic club and Cornes and Sandler (1996, pp. 347–480) and Galzer et. al. (1997) provide an overview concerning club theory.[13] A club model that explicitly models rival and non-rival consumption acts within a club is provided by Pickhardt (2003, pp. 146–171; 2005b). With a few modifications the latter model would allow for modeling the rival consumption of the road infrastructure, non-rival negative effects such as congestion and environmental damage, as well as non-rival positive effects on non-users and the economy as a whole.

To summarize, central aspects of the Commission's White Paper are convincing but not new as they were already proposed by 19th century authors such as Sax and Wicksell. In particular, this includes marginal cost pricing and the provision of transport infrastructures in a club fashion. In addition, several new aspects such as marginal *social* cost charging for transport related pollution and congestion either represent an extension of the marginal cost charging principle or are not entirely convincing, e.g. spending of congestion charge revenue on cost coverage rather than on solving the underlying scarcity problem.

4 Further issues in road use charging

The preceding sections have dealt with various theoretical concepts for the optimal provision of transport infrastructure. In practice, however, there may be various obstacles that further complicate the optimal provision of transport infrastructures. This section illustrates a few such obstacles using experience from the introduction of a direct charging system in Germany.

Based on EU-Directive 1999/62/EC, Germany recently introduced a fundamental change in its road infrastructure use. Until the end of 2004 all roads were free to use for every agent, but since January 1, 2005 the use of the entire German motorway system by heavy commercial vehicles is subject to a direct charge. This charge comprises the following three

[13] Note that Buchanan translated parts of Wicksell (1896) in 1958, but not chapter V where Wicksell advocates the provision and financing of transport infrastructures in a club fashion.

elements: (i) distance traveled in km, (ii) number of axles of the vehicle, (iii) emission class of the vehicle, but it does not have a congestion component. Currently the charge ranges from 0.09 Euro per km to 0.14 Euro per km (MautHV 2003, §1). Total revenue in the first half of 2005 amounted to 1.4 billion Euro (Bundesverkehrsministerium 2005) and on an annual basis a revenue of 3.0 to 3.4 billion Euro is expected. This revenue accrues to the federal budget, but is earmarked exclusively for the operating costs of the charging system, and for covering the costs of operating, maintaining and improving the federal transport infrastructure, predominantly the federal motorways and highways but also the rail road system and inland waterways (ABMG 2004, §11).

A comparison with the figures of Table 2 shows that the expected annual revenue for 2005 would basically make up for the entire costs of the federal motorway system in 2003. Despite the environmental cost component and the fact that heavy trucks cause a several thousand times higher damage to roads than passenger cars, these figures clearly indicate that heavy commercial vehicles are overcharged. Or, in other words, that the charge is not set optimally. Moreover, if it is assumed that the expenditure and revenue patterns in 2005 are roughly similar to those in 2003, the revenue from the charge simply increases the rent of the federal government. Hence, despite the associated gains in efficiency, rent seeking intentions may have played a role as well. For example, the scheme allows the government to charge foreign transit vehicles that would otherwise make only a minor contribution through fuel taxes and VAT, if at all. In addition, the private firm that invented, produced and now monopolistically operates the charging system not only receives a virtually risk free profit stream, but it also gets an ideal demonstration case that will help selling the product elsewhere. Again, the case highlights the relevance of rent extraction incentives leading to non-optimal charges, as mentioned in the preceding section.

Another problem that emerged after the introduction is related to the behavior patterns of vehicle drivers. It turned out that far more drivers than expected did not pay the stipulated charge and that an unexpectedly larger number of drivers legally bypassed the charge either by switching to lighter trucks or by using the federal highways system instead of the motorway system.[14] In certain areas the latter behavior pattern is causing substantial increases in noise and other pollution as well as congestion. In transport economics such problems are sometimes analyzed with Braess's paradox (e.g. see Johansson and Mattson 1995, p. 24). Figure 1 shows a slightly amended version of Braess's (1968, p. 263) original example. Hagstrom and Abrams (2001) develop a generalized Braess paradox.

Figure 1: Braess's Paradox

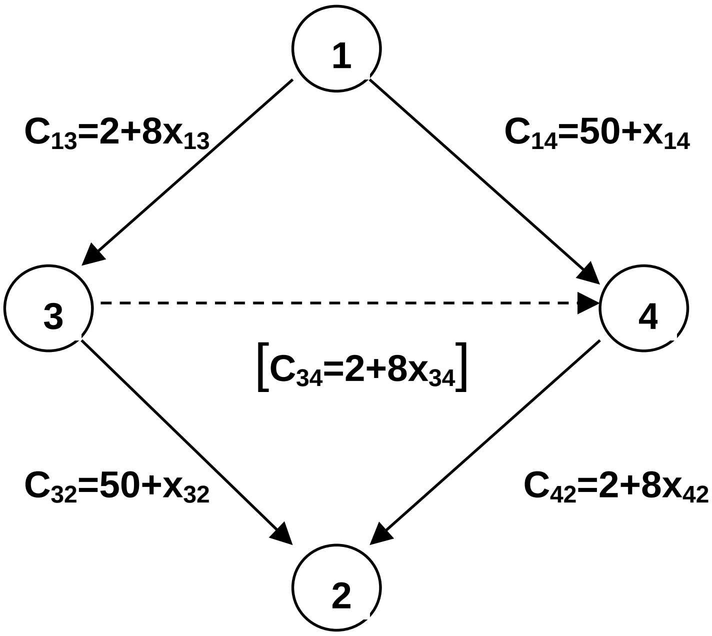

Figure 1 represents a simple transport network with four nodes numbered 1 to 4, where C_{ij} represents the costs of traveling from node i to j in terms of units of time, x_{ij} is the frequency of usage in terms of homogenous vehicle-driver units traveling from node i to j, and the arrows indicate the permitted direction of travel. Now suppose that traffic occurs from supply

[14] According to figures from the Kraftfahrtbundesamt (2005), the number of newly registered trucks with a total maximum weight of 7.5 to 12 metric tons, i.e. trucks which are not subject to the charge, has increased in the first half of 2005 by 36.9 percent compared to the same period in 2004. However, the total number of newly registered trucks increased only by 4.7 percent and in the weight class of 12 to 18 metric tons this number even decreased by 5.2 percent during the same period.

node 1 to demand node 2, that demand at node 2 is constant and equal to x=6, and that the link between nodes 3 and 4 does not exist. In this case the equilibrium flow distribution over the two possible routes [1-3-2] and [1-4-2], is: $x_{13} = x_{32} = x_{14} = x_{42} = 3$, which yields costs of [(C_{13}=)26 + (C_{32}=)53] = [(C_{14}=)53 + (C_{42}=)26] = 79 per unit of vehicle-driver and total costs of (79*6) = 474. Now suppose the link between nodes 3 and 4 is added to the network. The first vehicle-driver unit that changes *ceteris paribus* to the new route [1-3-4-2] incurs costs of [(C_{13}=)26 + (C_{34}=)10 + (C_{42}=)34)] = 70 and, therefore, makes a profit of 9 units. But total costs have now increased to (78*2+70*1+87*3) = 487. Moreover, because of 79<87 the other three vehicle-driver units on route [1-4-2] have an incentive to search for an alternative route. Search continues until the new equilibrium flow over the three possible routes is found at [1-3-2] = [1-3-4-2] = [1-4-2] = 2, which yields costs of 86 for each vehicle-driver unit and total costs of (86*6) = 516. Hence, because of 79<86 and 474<516, the paradox emerges that adding new infrastructure to an existing transportation network may increase individual and total costs of traveling. Looking at the paradox the other way round, blocking some parts of an existing transportation network may improve the costs of traveling. In fact, blocking certain parts of the federal highway system for heavy commercial vehicles is currently debated as a solution to the problem of bypassing the motorway charge in Germany.

Moreover, Figure 1 can be used to illustrate the provision of transport infrastructure in a club fashion. Suppose that only route [1-3-2] exists and that the total non-variable costs, *T*, of operating and maintenance, including interest payments, amount to *T*=156 monetary units per annum. Also, demand depends negatively on the individual club fee, c_i, with, $x=\varphi(c_i)$, (5), e.g. …, $\varphi(80)=6$, $\varphi(75)=8$, $\varphi(70)=11$, …, where the numerical example mimics Wicksell's (1896, p. 131). *Case A (No Congestion Costs*): The individual club fee, c_i, is then calculated from: $c_i = T/x$, (7), where *x* is again the usage frequency. In this case, the optimal club size in terms of *x* would approach infinity, $x \rightarrow \infty$, so that in principle the entire demand should be accommodated. *Case B (Congestion Costs)*: Now suppose that there are also variable costs, say 9 monetary units per unit of usage, *x*, which may represent congestion costs. Then, with x=6 as in Brass's paradox, the club fee amounts to c_i=80, which is now calculated from: $c_i = T/x + 9x$, (8). With the given cost structure, however, the optimal club size would be x^*=4, which yields c_i^*=75.[15] Hence, the representative club member would not admit a fifth or sixth club member. But, if constant returns to scale in the production of the infrastructure prevail, the club could be replicated at the same costs (i.e. route [1-3-2] plus route [1-4-2], as in Figure 1), and the entire demand of $\varphi(75)=8$ could be accommodated in two separate clubs. This allocation would then represent a Pareto-optimal flow equilibrium, with marginal social cost pricing and an optimal provision of transport infrastructure. Now assume that the proceeds of the congestion charge component, i.e. ((9*4)*4=) 144, are spent on reducing the total non-variable costs T (156-144=12), as proposed by the Commission. Within the club, the club fee should then be reduced to c_i=[(12/4)+(9*4)]= 39. But because of $c_i=[T-(9x)x]/x + 9x$, equation (8) is simply reduced to (7) within the club, and only club members would benefit. In contrast, if the proceeds are spent on reducing or eliminating congestion in the long run, so that the congestion function would change over time from 9x to, say 3x, the optimal club size would increase *ceteris paribus* to x^*=7, which yields c_i^*=43. Hence, in this case, both the original club members and some new club members in existing or newly created clubs benefit directly through the reduced club fee, and the economy as a whole may benefit indirectly through the enhanced transport activity. In fact, this constitutes another reason for spending the proceeds of a congestion charge on reducing the underlying scarcity problem rather than on covering fixed costs.

Finally, Braess's paradox may have some implications for the modeling of transport infrastructure. Infrastructure is usually modeled as a public input and, depending on whether rival or non-rival consumption is prevailing, various specifications of public inputs can be

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[15] Note that because of $dci/dx = -(T/x^2) + 9$, (9), the optimal club size condition is: $9 = T/x^2$, (10), which yields x^*=4.163… and ci^*=74.939…, rather than x^*=4 and ci^*=75. But because of the discrete nature of x, I prefer the latter approximation. An analogous reasoning applies to the figures x^*=7 and ci^*=43, a few lines below.

distinguished (Colombier and Pickhardt 2002, 2005). Also, Ott (2001) and Ott and Turnovsky (2005) have recently demonstrated that the prevailing consumption properties rivalness and nonrivalness determine the choice of the optimal financing instrument(s) for the provision of infrastructure in an endogenous growth model. For example, if both rival and non-rival consumption acts prevail and price exclusion is possible, the optimal set of financing instruments includes a user fee, an income tax and a tax on consumption (Ott 2001, pp. 119–137). However, as Ott (2001, p. 173) herself notes, infrastructure is specified as a pure flow variable in her model, which may not be an adequate specification for a transport infrastructure network. Also, Brass's paradox would call for incorporating stochastic variables that capture route-choice behavior of drivers. Smith *et. al.* (1995), for example, develop such a stochastic user-equilibrium model.

5 Concluding remarks

The writings of Sax and Wicksell on transportation have so far not been taken into account in modern transport economics. However, the analysis in this paper indicates that the Sax-Wicksell concept of providing and financing transport infrastructure in a club fashion may have several advantages over alternative institutional settings and may therefore be most suitable for an optimal provision of transport infrastructure. In this context, it has been argued that the proceeds of charges that are supposed to internalize negative external effects of traffic, such as congestion and environmental damage, should be spent on reducing the underlying causes of these effects in order to avoid rent seeking incentives and to boost trade and economic growth. Of course, this conjecture calls for an appropriate modeling along the lines indicated above. But these modeling tasks go beyond the scope of the present paper and rather delineate a future research agenda.

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